Mathematical Statistician and Engineering Applications
ISSN: 2094-0343
2326-9865

# A Study of the World's Minimum Energy Performance Standard for Electric Motors and Drives

**S.Manoharan[1], P.Palpandian[1], B.Mahalakshmi[2], N.Divya[3]**

[1]Dept. of Electronics and Instrumentation Engineering, Karpagam College of Engineering, India

[2]Dept. of Physics, Hindustan College of Engineering and Technology, India

[3]Dept. of EEE, Sri Ramakrishna Engineering College, India

manoish07@gmail.com

**Article Info**
**Page Number: 658 – 674**
**Publication Issue:**
**Vol. 71 No. 3s (2022)**

**Abstract**

It has been proven that industrial electric motors consume 30-40% of all electricity generated worldwide. The electric motor system consumes roughly 70% of the electrical power spent by industrial segment in which induction motors play a significant role. Nowadays, we prefer energy-efficient electric motors, which not only save money on power but also minimize greenhouse gas emissions. As a result, regulatory plans are in place in the EU, as well as the USA, China, and other countries, requiring new installations to comply with gradually increasing efficiency requirements. This study examines the IEC/EN 60034-30-1: 2014 Standard, which aims to standardize efficiency classes all around the world. This paper also discusses International norms and domestic legislation for the high efficiency electric motors and the systems that power them, as well as the universal trend of electrical motors meeting minimum energy performance standards (MEPS), with a focus on the new EU 2019/1781, amendment (EU) 2021/341 for electrical motors and drives with varying speeds.

**Keywords:** Minimum Energy Performance Standards (MEPS), Energy efficient Motor, Efficiency, IE1, IE2, IE3, IE4

**Article History**
**Article Received:** 22 April 2022
**Revised:** 10 May 2022
**Accepted:** 15 June 2022
**Publication:** 19 July 2022

## 1. Introduction:

Despite massive investments in the energy sector since independence, the gap between supply and demand for electrical energy continues to widen. Energy conservation, which is considered a new source of energy and environmentally beneficial, can assist bridge the gap between supply and demand for energy. With a quick payback period and a low initial investment, energy conservation is financially advantageous. To meet the growing demand for electrical energy, large expenditures in power generation must be made on a constant basis. These investments, on the other hand, depend on external resources that are depleting

due to ongoing environmental constraints, as well as sophisticated medium and long-term planning. To preserve energy supply in the short run, the best solution is to reduce waste and improve energy efficiency. Around 53% of worldwide industrial power usage [1] and close to 65% of industrial electricity demand is accounted for by electric-motor-driven system [2-4]. According to some estimates, systems that are powered by electric motors consume over 70 percent of total industrial electrical power, though this ratio varies by country and depends on the amount of industrialization [5]. The energy consumed by all electric motors is 68% by mid-size (0.75-375kW) and general-purpose 3ϕasynchronous motors, as well as the systems controlled by these motors. It is predicted that the energy savings in poor countries could reach 300 TWh per year by 2030, saving 200 million tonnes of $CO_2$ [6]. A shift to high-efficiency motor (HEM) systems could reduce global electricity needs by 20 to 30 percent by 2030, based on the current creation and delivery of energy security and environmental legislation on a global scale.Many governments throughout the world have adopted state ordinances, sometimes referred to as MEPS, for a variety of equipment, including electric motors, as a result that the need to cut energy bills and $CO_2$ emission [7].In today's world, there are a variety of energy efficiency levels/classes in use, which can lead to confusion and market barriers. Because motors are designed for a global market, this is a major issue for manufacturers. As a result, the International Electro technical Commission (IEC) created a categorization norm (IEC 60034-30) to regulate classes on worldwide energy efficiency for 3ϕ asynchronous motors [8].

Table.1 Differences in motor efficiency classes according to the IEC

| PARAMETERS | LEVELS OF EFFICIENCY | | | |
|---|---|---|---|---|
| | IE1 | IE2 | IE3 | IE4 |
| Name of efficiency | Standard | High | Premium | Super Premium |
| International standard | IEC 60034-30 and IEC 60034-2-1 | | IEC 60034-1-30 | IEC 60034-30-1 |
| Output (kW) | 0.75 to 355 | | | 2.2 to 230 |
| Poles | 2, 4, 6, 8, 10 and 12 | 2, 4, 6 | 2, 4, 6, 8 | |
| Speed | 500 to 3600 rpm | 1000 to 3600 rpm | 750 to 3600 rpm | |
| Frequency | 50 or 60 Hz | | | |
| Aluminum Frame Size/Cast Iron Frame Size | 56-200/80-400 | 80-160/80-400 | | 100-160/100-315 |
| Temperature Class | B | | | |

| | | | |
|---|---|---|---|
| Cooling Method | IC411 | IC411 and IC416 | |
| Insulation Class | Class F | | |
| Duty Type | S | S1, S2, and S3 | S1. |
| Motor Protection | IP55, IP56, IP65, IP66 | | IP55, IP56, IP65 |

## 2. Efficiency of Electrical Motors

The IEC is a global standard body that sets and releases standards for the use of electrical apparatus. Electric motors are classified as IE1 (lowest efficiency), IE2, IE3, IE4, or IE5 (highest efficiency) in accordance with IEC Standard 60034-30-1 [9- 10]. One of these levels is typically chosen as the minimal performance criterion by policymakers. Table.1 indicates the differences between the least efficiency IE1, IE2, IE3, and highest efficiency IE4. IE1 is not even met by a huge number of motors around the world. This is due to the fact that the government does not regulate and enforce motor standards, as well as the fact that the motor is outdated. IE5 is not yet fully defined, but it would be incorporated into a fictional update of IEC 60034-30-1, with the goal of achieving a 20% decrease in energy loss over IE4 [11]. It should be emphasized, however, that the IE5 is still being drafted; therefore it is not yet accessible on the commercial market.

The minimum energy efficiency requirements for IE Efficiency Classes with level fluctuates with motor sizing are presented in Figure 1. Kirloskar Electric (India), Honeywell International Inc, Rockwell (US), Johnson Controls Inc, ABB (Switzerland), Nidec (Japan), Microchip Technology, Inc, MagneteckInc, WEG (Brazil), Emerson Electric Company (USA), Marathon Electric (India), Siemens (Germany), Bosch Rexroth AG (Germany), CG (India), Schneider Electric (France), Regal Beloit Corporation (USA) and GE (US) are some of the major competitors in the HEM industry.

## 3. Review of the International Minimum Energy PerformanceStandards:

In general, energy efficiency standards are a set of rules and regulations that govern the energy performance of produced goods, sometimes prohibiting the sale of goods that are less energy efficient than the minimum requirement. Energy efficiency is a critical strategy in Canada's, México's, and the United States' energy strategies. Test processes, standards, labeling, and associated compliance programmes are significant programme endeavors to accomplish energy security, environmental, and diverse economic policy objectives under the three countries' energy efficiency mandates [12].The MEPS are extending beyond Low-Voltage (LV) motors as well. China has taken the lead in high voltage (HV) motor energy efficiency, establishing the first mandatory MEPS for HV motors in late 2014. A voluntary HV motor efficiency standard exists in the United States. The fact that these forerunners have already entered the implementation phase sends a strong message to other markets that they should follow suit. Europe must be in the forefront of efforts to conserve energy and cut $CO_2$

emissions.

In the following paragraphs, the world's minimum energy performance standards for electrical motors will be described.

### 3.1 USA and CANADA:

The USA and Canada took the lead in implementing MEPS at the IE2 level in 1997 and upgraded to the IE3 level in 2010 [13]. The National Electrical Manufacturers Organization (NEMA), the trade association for motor producers in the United States, initiated a programme in 2001 to promote even better efficiency motors (NEMA Premium). The MEPS had been restructured to the analogue of the IE3 level (NEMA Premium) in 2007 (Energy Independence and Security Act), and the scope was then expanded in 2015 to accommodate small motors with multiple phases ranging from 0.18 kW to 2.2 kW with IE3 and 1ϕwith IE2 [14]. In the United States, the national IEEE 112B test standard and the Canadian CSA390 test standard are currently accepted in line with law, whereas IEC 60034-2-1 test standard is not (the difference is small).The requirements are being reviewed to see if they should be changed to allow testing in order to comply with the IEC standard. The Department of Energy (DOE) has the authority to develop and modify saving energy guidelines as well as procedures for testing small electric motors and electric motors. The current DOE test procedures for small electric motors are contained in Appendix B to subpart B of 10 CFR part 431[15]. The current DOE test protocols for electric motors are found in Subpart X, part 431 of Title 10 of the Code of Federal Regulations. The Minimum Energy Performance Standard used in the USA, Canada, and Mexico is shown in Table 3. We concluded from the table that, with the exception of Regulation, the remaining parameters are the same in the United States and Canada.

### 3.2 MEXICO:

The NOM-016-ENER-2016 standard stipulates the minimum level of energy efficiency that must be met by ac, 3ϕ, cage- asynchronous motors with the nominal power rating ranging of 0.746 kW - 373 kW and a rated voltage of up to 600 V, It hasa single frequency of rotation, horizontal or vertical installation position, air cooling and continuous state. The NOM-016-ENER- 2016 standard replaces the NOM-016-ENER-2010 standard. The MEP levels of motors with 8 poles have been increased in the 2016 edition. Minor adjustments have been made to other levels of efficiency. All motors placed on the market must meet NEMA Premium efficiency standards [16].

The standard NOM-014-ENER-2004 specifies the minimum energy efficiency levels for ac, 1ϕ, cage, air- cooled motors with nominal power of 0.180 - 1.5 kW, 2, 4 or 6 poles, split-phase or starting capacitors, open or closed. [17]. Mexico accepted the IE3 level of motor efficiency MEPS, which are the same as those in the rest of North America. Furthermore, while Mexico does not require industry to increase its efficiency in terms of energy, it has established a model for industry to enter into mutual transactions for accepted increases in efficiency [18].

**Table: 3 Minimum Energy Performance Standard followed in USA, Canada and Mexico.**

| **Country** | | | | |
|---|---|---|---|---|
| **Parameters** | **United States of America/ Canada** | | **Mexico** | |
| Regulation | **USA:** Subpart X - Small Electric Motors, Department of Energy's 10 CFR Part 431 | Subpart B - Electric Motors of the Department of Energy's 10 CFR Part 431 | NOM-014-ENER-2004 | NOM-016-ENER-2004 |
| | **Canada:** Small Electric Motors Amendment 14 to Energy Efficiency Regulations | Electric Motors Amendment 13 to the Energy Efficiency Regulations | | |
| Standard | IEEE Std 114-2010, IEEE Std 112-2004, CSA C390-10, CSA C747-09 | IEEE Std 112-2004, CSA C390-10 | NOM-014-ENER-2004 | NOM-016-ENER-2004 |
| Power Supply | 1ϕ or 3ϕ | 3ϕ | 1ϕ | 3ϕ |
| Minimum energy performance (MEP) | Premium | NEMA Premium | - | NEMA Premium |
| When MEP is able to operate at inverter frequency | Not applicable | NEMA Premium | - | NEMA Premium |
| Output | 0.25 up to 3 HP (0,18 up to 2.2 kW) * | 1 up to 500 HP (0.75 up to 375 kW)** | 0.18 up to 1.5 kW | 1 up to 500 HP ( 0.75 up to 375 kW) |
| Number of poles | Two, Four and Six | Two, Four, Six and Eight | Two, Four and Six | Two, Four, Six and Eight |
| Voltage | All | up to 600 V | All | up to 600 V |
| Frequency (Hz) | 60 or 50/60 | | 60 or 50/60 | |
| Duty cycle | S1 | | S1 | |
| Cooling method | Open Drip Proof | TEFC, ODP, TENV, TEBC | All | |
| Degree of protection | All | | All | |
| Area classification | safety area | safety and hazardous area | safety area | safety and hazardous area |
| Altitude (m) | All | | All | |
| Ambient temperature (°C) | All | | All | |

| | | |
|---|---|---|
| Required documentation | Certificate | Certificate |

Note:

*Applicable to frame sizes NEMA 42, 48 and 56 (IEC 63 and 71).

**Applicable to frame sizes from NEMA 143 (IEC 90 and above).

***NEMA motors up to 5 kV can bear the NEMA Premium Mark, as long as they meet the minimum estimated values, even ifthey are out of DOE scope without CC029A

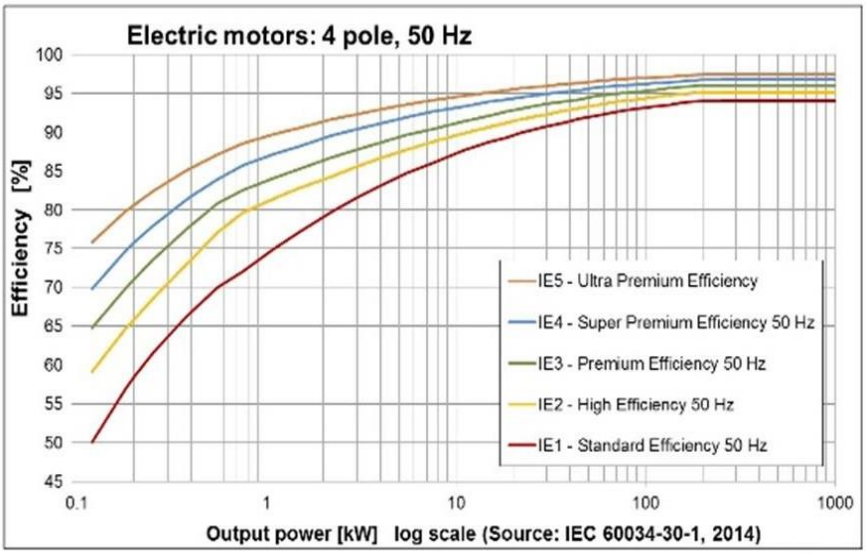


Fig.1: IE classes of Efficiency for four-pole motors

### 3.3 AUSTRALIA and NEW ZEALAND

The Australian and New Zealand governments have adopted MEPS for low-voltage, 3ϕ-cage asynchronous motors supplied domestically to encourage the development and adoption of HEM. The MEPS regulatory standards described in the Standard AS/NZS 1359.5:2004 [19-20] applied to motors with outputs ranging from 0.73 kW to 185 kW that were made in or imported into Australia or New Zealand.

Table 4 shows the MEPS that Australia and New Zealand adhere to.

**Table 4: Minimum Energy Performance Standard that Australia and New Zealand**

| **Australia and New Zealand** | |
|---|---|
| Regulation | GEMS Act of 2019 |
| Standard | IEC 60034-30-1 |
| Power supply | 3ϕ |
| MEP | IE2 |
| When MEP is able to operate at | IE2 |

| | |
|---|---|
| inverter frequency | |
| Output (kW) | 0.73 up to <185 |
| Number of poles | Two, Four, Six and Eight |
| Voltage (V) | up to 1100 |
| Frequency (Hz) | 50 or 60 |
| Duty cycle | All (other than S2) |
| Cooling method | Totally Enclosed, Fan-Cooled, Open Drip Proof, Totally Enclosed Air Over/Airtight |
| Degree of protection | IP 00 up to IP 66 |
| Area classification | Safety and hazardous |
| Altitude (m) | All |
| Ambient temperature (°C) | All |
| Required documentation | Register by model |

MEPS levels in both countries were tightened in 2006 to roughly align with IE2 levels prescribed in the International Electro technical Commission's (IEC's) framework. Minor changes were made to Australia's MEPS levels in 2019 to align them with IE2 levels. Australia and New Zealand's high efficiency levels were aligned to IE3 (Premium Efficiency) levels as part of this update.

The first stage of the Australian MEPS programme was launched by the Australian Greenhouse Office (AGO) in October 2001 for 3ϕ asynchronous motors, which required compliance from both motor manufacturers and importers. The Equipment Energy Efficiency (E3) programme was established by the Commonwealth Greenhouse and Energy Minimum Standards (GEMS) Act 2012, which contains a number of energy labeling and MEPS measures. Many of the policies were put in place decades before the GEMS Act was enacted.

The MEPS programme for electric motors is part of the E3 Plan, which is managed by the Department of the Environment and Energy with input from state / territory governments as well as the New Zealand government. The GEMS Act for 3ϕ Cage asynchronous motors was published on November 14, 2018. As stated in the document, providers must register motors in line with the revised Determination beginning May 14, 2019.

The Determination 2018 defines minimum energy efficiency standards for 3ϕ−cage asynchronous motors, as well asassociated test requirements. It applies to 2, 4, 6, or 8 poles, voltages up to 1,100 V. 3ϕ cage asynchronous motors with rated outputs from 0.73 kW to lesser than185 kW. For the purposes of the Act, this group of products is considered a single product class. The main difference in the new Determination is the test procedure that is mentioned. [21-26].

3.4 CHINA:

A new norm for energy efficiency in electrical motors has been introduced by China's State Administration for Market Regulation (SAMR). Standard GB 18613-2020 defines Energy Efficiency Minimum Allowable Values and Energy Grade Values for motors. The CN MEPS standard GB18613-2020, which replaced GB18613-2012 and GB 25958-2010, was released on May 29, 2020. The CN MEPS standard GB18613-2020, which will replace GB18613-2012, was released on May 29, 2020. The implementation will begin on June 1, 2021, taking into account the CEL007-2021 registration requirements, which will be published by the China Energy Efficiency Center [27]. Table 5 shows the minimum Energy Performance Standard used in China.

**Table.5: Minimum Energy Performance Standard followed in China**

| **CHINA** | | | |
|---|---|---|---|
| Regulation | Decree nº 35 (CEL 007:2006) | Draft (CEL 007:202) | CEL 038:2020 Three-phase Permanent Magnet |
| Standard | GB 18613-2012 | GB 18613-2020 | GB 30253-2013 |
| Power supply | 3ϕ | 1ϕ & 3ϕ | 3ϕ |
| MEPS | GB3 (IE2) | GB3 (IE3) | GB3 |
| When MEP is able to operate at inverter frequency | GB3 (IE2) | GB3 (IE3) | GB3 |
| Output (kW) | 0.75 up to 375 | 0.12 up to 1000 | 0.55 up to 90 |
| Number of poles | Two, Four, and Six | Two, Four, Six and Eight | Six and Eight |
| Voltage (V) | up to 1000 | | |
| Frequency (Hz) | 50 or 50/60 | | |
| Duty cycle | S1 or S3 ≥ 80% | | |
| Cooling method | Totally Enclosed, Fan-Cooled (IC 411) | Totally Enclosed, Fan-Cooled (IC 411) or Totally Enclosed, Blower Cooled (IC 416) | |
| Degree of protection | IP 44 TO IP 66 | | |
| Area classification | Safe and hazardous | | |
| Altitude (m) | up to 1000 | | |
| Ambient temperature (°C) | -20 up to 40 | All | |

| | |
|---|---|
| Required documentation | Register by model |

## 3.5 EUROPEAN UNION

The European Union established Motor MEPS in 2009, and after ten years, it was updated in 2019 with regulation 2019/1781 that covered a broader range of electric motors [28]. New technical regulations became mandatory for Ukraine market access as part of a larger programme for the implementation of energy efficiency requirements in Ukraine, with a gradual implementation schedule. The regulations establish ecodesign requirements for energy-related products and are based on the relevant European Commission Regulation, as well as the implementing directives 2009/125/EC and 2005/32/EC.

Between September 2018 and January 2019, the United Kingdom voted in favor of a new package of EU eco design regulations for electric motors as an EU Member State. The EcoDesign for Energy-Related Products Regulations 2010 (as modified) [29-30] is the governing legislation in the United Kingdom and Northern Ireland.

### *3.5.1* Introduction about Eco design or ErP regulation:

The term "ecodesign" refers to the energy and environmental requirements that the EU imposes on products in order to remove the least energy-efficient products from the market. In practice, this means that the ecodesign requirements are not visible to consumers because they are a requirement for manufacturers rather than a brand. Eco design contributes to the reduction of energy consumption at the industrial level in the EU. All EU and EEA countries must meet the same standards. Products that do not meet the requirements may not be used in new applications on the markets of the countries in question. Similarly, older motors must be replaced to meet the new standards. [31]. Electric drives consume roughly half of the electricity generated in the EU. As a consequence, they have a significant impact on reducing energy cost and resource use. Furthermore, it is worth noting that the demands placed on energy-efficient products are constantly increasing [32].

In the past, globally applicable efficiency classes and a series of energy efficiency regulations were developed to determine the energy efficiency of a motor, which are summarized under the name eco-design or ErP regulation. The efficiency classifications are based on the international standard IEC/EN 60034-30-1. An efficiency class simplifies direct energy-related comparison and certification of electric motors in terms of how much valuable resource they can save [33].

### *3.5.2* Minimum Efficiency Performance Standard under EU Ecodesign Regulation 2019/1781

The Regulation (EU) 2019/1781, which establishes new legal standards for motors and drives, as well as its modification Regulation (EU) 2021/341, which goes into effect on February 23, 2021. New standards for variable speed drives and electric motors are laid forth in Commission Regulation EU 2019/1781, amendment (EU) 2021/341. MEPS is a new

regulation (EU) 1781/2019 that establishes minimum specifications for motors (Minimum Efficiency Performance Standards). They also feature a clear ruling for converters and an IE4 efficiency class requirement for electric motors for the first time. The old "EC 640/2009" regulation will remain in effect until June 30, 2021. Individual modifications that take effect on July 1, 2021 are detailed in the following sections [34-35].

The directive will go into effect on January 1, 2021, and will be phased in over the next three years.. The EU will extend the Ecodesign guidelines on January 1, 2021, to incorporate higher and more ambitious energy standards for electric motors. The criteria will be used to phase out the least efficiency motors on the market today. Even though the criterion is IE3, motors powered by frequency converters (VFDs) only need to be IE2 today. On July 1, 2021, the VFD exception will be phased out. In 2023, no new restrictions for variable speed drives will be implemented. As a result, the EU directives will have an impact on the majority of OEMs both inside and outside of Europe. [36-37]

### *3.5.3* Changes in Stages:

The following time table, presented in Table 6, will be used to apply eco-design standards for electric motors [38- 39].

Table 7 [40-41] shows a detailed analysis of the Minimum Energy Performance Standard in the EU, the UK, and Ukraine. Table 7 indicated that, with the exception of regulation, all other parameters are the same across the EU and the UK. According to the aforementioned debates, China, the EU, the United States, Canada, Mexico, and Korea all employ IEC compatible efficiency restrictions in their MEPS. There is equivalence between the NEMA and IEC efficiency levels in the United States. For example, NEMA Premium values are similar to IEC IE3 60 Hz values.

## 3.6 INDIA

In India, the legislation is based on the Indian Standard: 12615-2018, which is an updated version of IS12615:2011. IS 12615 was first published in 1989, with further changes in 2004, 2011, and 2018 to align with global standards and international best practices and to encompass all efficiency classes currently in use. The IEC60034-30 is the foundation for IS 12615-2018. All motors that will be installed in India or that will pass through the country must be certified. Since 2009, India has had a comparative efficiency label, and since 2012, it has had a voluntary standard at the IE2 level [42]. This standard applies to the single-speed line-operated 3ϕ- cage asynchronous motor with Two, Four, Six and eight poles for continuous duty (S1) operation, at rated voltage up to 1,000V and frequency of 50 Hz from a rating from (0.12 - 1 000) kW.

**Table 6: Phased changes time line of Ecodesign requirements for Electric motors**

| From 01-07-2021 | From 01-07-2022 | From 01-07-2023 |
|---|---|---|
| All motors with a rating of 0.12 - 0.75 kW with Two, Four, Six or Eight-poles that are not Ex eb increased safety motors must meet the IE2 efficiency standard, while 0.75 kW to 1000 kW with Two, Four, Six or Eight- poles that are not Ex eb enhanced safety motors, IE3 efficiency requirements must be met. | Unlike the current scenario, when testing is done only at full speed and with varying loads, motor suppliers will be forced to test all electric motors at varied speeds. This is due to the increasing number of VFD-controlled applications on the market, which operate at a variety of speeds and loads. | Ex eb increased safety motors in the 0.12 - 1000 kW range, as well as 1ϕ motors in the 0.12 kW to 1000 kW range, meet IE2 standards. The IE4 standards must be met by all regular motors between 75 and 200 kW. |

3.7 JAPAN

TOP Runner is the name of the Japanese regulation. After April 1, 2015, all motors sold must fulfill the IE3 efficiency requirement. The motors in question are those covered by the JIS C 4034-30 standard (which is similar to CEI60034-30). The MEPS was introduced in Japan and covered single-speed, 3ϕ, 50 Hz asynchronous motors with Two, Four and six poles, output power rating ranging from 0.75 - 375 kW, voltage up to 1,000V, and rated on the basis of either duty type S1 (continuous duty) or S3 (intermittent periodic duty) with a rated cyclic duration factor of 80 percent or higher [43].

**Table: 7 Minimum Energy Performance Standard followed in European Union, Great Britain and Ukraine**

<table>
<tr><td colspan="5">Country</td></tr>
<tr><td colspan="4">EU and UK</td><td>Ukraine</td></tr>
<tr><td>Parameters</td><td></td><td colspan="2">From July 2021</td><td>From July 2023</td><td>From September 2021</td></tr>
<tr><td rowspan="2">Regulation</td><td>EU: Regulation 640-2009, Directive 2009-125-EC</td><td colspan="2">Regulation 1781/2019 of the European Union</td><td rowspan="2">Decree N° 157, Resolution N° 804 and Resolution N° 1184</td></tr>
<tr><td>Great Britain: The EU Exit (Amendment) Regulations 2019 on Ecodesign for Energy-Related Products and Energy</td><td colspan="2">The EU Exit (Amendment) Regulations 2020 on Ecodesign for Energy-Related Products and Energy Information</td></tr>
</table>

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Information | | | | | | |
| Standard | IEC 60034-30-1 | | | | | | IEC 60034-2-1 |
| Power supply | 3ϕ | | | | | 1ϕ | 3ϕ |
| MEPS | IE3 | IE3 | IE2 | IE4 | IE2 | IE2 | IE3 |
| When MEP is able to operate at inverter frequency | IE2 | IE3 | IE2 | IE4 | IE2 | Not applicable | IE2 |
| Output (kW) | 0.75 up to 375 | 0.75 up to 1000 | 0.12 up to <0.75 | 75 up to 200 | 0.12 up to 1000 | | 0.75 up to 375 |
| Number of poles | Two, Four, and Six | Two, Four, Six and Eight | | Two, Four, and Six | Two, Four, Six and Eight | | Two, Four, and Six |
| Voltage (V) | up to 1000 | | | | | | |
| Frequency (Hz) | 50 or 50/60 | 50 or 60 | | | | | 50 |
| Duty cycle | S1, S3 ≥ 80% or S6 ≥ 80% | | | | | | S1 or S3 ≥ 80% |
| Cooling method | TEFC, TEBC, ODP | TEFC, TEBC, ODP, TEAO | | | | | All |
| Degree of protection | IP 00 up to IP 66 | | | | | | All |
| Area classification | Safety area | Safety and hazardous area (Ex ec, Ex tc, Ex tb, Ex db, Ex dc, Ex dbeb) | | Safety area | Hazardous area (Ex eb) | Safety area | Safety area |
| Altitude (m) | Up to 4000 | | | | | | |
| Ambient temperature(°C) | -30 up to 60 | | | | | | Up to 60 |
| Required documentation | Self-declaration | | | | | | Self-declaration |

3.8 SOUTH KOREA

Since 2008, Korea has adopted the Minimum Energy Performance Standard. KEMCO is the name of the regulation (Korean Energy Management Corporation). Since January 2010, only high-efficiency motors that have been registered and approved by KEMCO are allowed to be sold in Korea [49]. Motors with a rating of 0.75 kW to 375 kW will be covered by the MEPS under the rule MKE-2017-206, and the IE3 efficiency standard will be necessary. The MEPS was introduced in South Korea and covered single-speed, 3ϕ, 60 Hz induction motors with Two, Four, Six or Eight poles, voltage up to 600 V, and duty type S1 (continuous duty) or S3 (intermittent periodic duty) with a rated cyclic duration factor of 80 percent or greater [44].

### 3.9 SINGAPORE

From October 1, 2018, the National Environment Agency (NEA) issued new criteria to match with worldwide standards to boost the energy efficiency of electric motors and manufacturing facilities in Singapore. Single-speed, 3ϕ, induction motors sold in Singapore must be registered with the National Environment Agency (NEA) and meet the IE3 minimum energy level. The MEPS, which was first introduced in Singapore, covered single-speed, 3ϕ, 50 Hz asynchronous motors with output power rating from 0.75 - 375 kW, voltage up to 1,000V, Two, Four or Six poles and continuous duty operation [45].

**Table 10: Minimum Energy Performance Standard followed in Brazil, Chile and Asian Countries**

| **Country** | | | | |
|---|---|---|---|---|
| **Parameters** | **India** | **Japan** | **South Korea** | **Singapore** |
| Regulation | The Gazette of India S.O.178 | Energy Saving Act / Top Runner Program | MKE 2017-206 | Energy Conservation Act (Cap. 92C) |
| Standard | IS 12615:2018 | JIS C 4034-30 | KS C IEC 60034 | IEC 60034-2-1 |
| Power supply | 3ϕ | 3ϕ | 3ϕ | 3ϕ |
| MEPS | IE2 | IE3 | IE3 | IE3 |
| When MEP is able to operate at inverter frequency | IE2 | - | - | IE3 |
| Output (kW) | 0.12 up to 1000 | 0.75 up to 375 | 0.75 up to 375 | 0.75 up to 375 |
| Number of poles | Two, Four, Six and Eight | Two, Four and Six | Two, Four, Six and Eight | Two, Four and Six |
| Voltage (V) | up to 1000 | up to 1000 V | up to 600 | up to 1000 |
| Frequency (Hz) | 50 or 50/60 | 50, 60 Or 50/60 | 60 | 50 or 50/60 |
| Service Duty | S1 | S1, S3 ≥80% | S1, S3 > 80% | S1, S3 ≥ 80%, S6 or S9 |

| | | | | |
|---|---|---|---|---|
| Cooling method | IC411(TEFC), IC416, IC417, IC418(TEAO) | All | TEFC, ODP | TEFC, ODP, TEAO |
| Degree of protection | IP 23 up to IP66 | All | All | All |
| Area classification | safety area | safety area | safety and hazardous area | safety area |
| Altitude (m) | Up to 4000 | All | All | up to 1000 |
| Ambient temperature (°C) | -20 up to 60 | From -20 °C and above | -15 up to 40 | -30 up to 60 |
| Required documentation | Certificate | Self-declaration | Register by model | Certificate |

## 4. Conclusion:

This paper discusses an in-depth investigation of electric motors in the IE1, IE2, IE3, and IE4 efficiency classes, as defined by the IEC 60034-30-1 standard, which aims to standardize efficiency classes globally. The mandatory minimum efficiency levels for electric motors set by the European Union and Minimum efficiency performance standards (MEPS) followed by the countries around the world are also discussed. The Ecodesign Regulation (EU) 2019/1781 for Electric Motors and variable speed drives also been reported. According to EU estimates, nearly 8 billion electric motors are in use across the continent. By enhancing the efficiency of these motors and the drives that control them, the EU hopes to save 110 Terawatt hours of energy by 2030, providing an excellent opportunity to meet $CO_2$ emission reduction goals for asynchronous motors.

## References:

1. International Energy Agency, IEA. World Energy Outlook. Typeset in France by IEA and Printed in France by DESK,. URL: https://www.iea.org/topics/world-energy-outlook, November 2016
2. Jibran, M.; Tijdink, A.; Patel, M.K. Techno-economic analysis of energy efficiency improvement in electric motor driven systems in Swiss industry. Appl. Energy 2017, 205, 85–104.
3. De Almeida, A.; Fong, J.; Brunner, C.U.; Werle, R.; Van Werkhoven, M. New technology trends and policy needs in energy efficient motor systems—A major opportunity for energy and carbon savings. Renew. Sustain. Energy Rev. 2019, 115, 109384.
4. Fong, J.; Ferreira, F.J.T.E.; Silva, A.M.; De Almeida, A.T. IEC61800-9 System Standards as a Tool to Boost the Efficiency of Electric Motor Driven Systems Worldwide. Inventions 2020, 5, 20.
5. Saidur, R. A review on electrical motors energy use and energy use and energy Savings. Renew. Sustain. Energy Rev. 2020, 14, 877–898.
6. UN Environment—Global Environment Facility, United for Efficiency (U4E).

Accelerating the Global Adoption of Energy-Efficient Electric Motors and Motor Systems, U4E Policy Guide Series; UN Enviroment: Paris, France; URL: http://www.united4efficiency.org , 2017.

7. N. Janjamraj and P. Thongchai, "Development of Energy Efficiency Standard and Regulation for Electric Motors in Thailand," 2020 17th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), pp. 255-258, doi: 10.1109/ECTI-CON49241.2020.9158119, 2020.
8. Manoharan Subramanian, Ananthi Kaliyamoorthy. A Review on Efficiency of Energy Efficient Motor Standards, Journal of Electrical Engineering 2014 14 (4), 191-204
9. H Gavrila, V Manescu, G Paltanea, G Scutaru, I Peter New Trends in Energy Efficient Electrical Machines,Procedia Engineering 2017,181, 568-574
10. Elect Go, Difference between ie1, ie2, ie3, and ie4, URL: https://www.electgo.com/difference-between-ie1-ie2-ie3-and-ie4/, 2019.
11. IEC 60034-30-1:2014-Rotating Electrical Machines-Part 30-1: Efficiency Classes of Line Operated AC Motors (IE Code); International Electrotechnical Commission: Geneva, Switzerland, .https://www.menzel-motors.com/iec-motors/, 2014
12. [12] Stephen Wiel, James E. McMahon "Energyefficiency Labels and Standards: A Guidebook For Appliances, Equipment, and Lighting" Collaborative Labeling and Appliance Standards Program (CLASP), 2001.
13. F. J. T. E. Ferreira and A. T. de Almeida, "Overview on energy saving opportunities in electric motor driven systems - Part 1: System efficiency improvement," 2016 IEEE/IAS 52nd Industrial and Commercial Power Systems Technical Conference (I&CPS), 2016, pp. 1-8, doi: 10.1109/ICPS.2016.7490219.
14. USA Department of Energy. 10 CFR Part 431 Energy Conservation Program: Energy Conservation Standards for SmallElectric Motors - Final Rule; Code of Federal Regulations: Washington, DC, USA, 2010.
15. Premium Efficiency Motor Selection and Application Guide, Available at: https://www.energy.gov/sites/prod /files/2014/04/f15/amo_motors_handbook_web.pdf, 2014
16. USA Department of Energy. 10 CFR Part 431 Energy Conservation Program: Energy Conservation Standards for SmallElectric Motors - Final Rule; Code of Federal Regulations: Washington, DC, USA, 2010.
17. Federal Register-Energy Conservation Program: Test Procedures for Small Electric Motors and Electric Motors-A Rule by the Energy Department on 01/04/2021, URL: https://www.federalregister.gov/d/2020-27662/page-6. 2021.
18. IEC-Electric motors-Increasing the Efficiency of Electric motors-One of the biggest energy efficiency opportunities, URL: https://www.iec.ch/government-regulators/electric-motors, 2021.
19. IEA-NOM-014-ENER-2004,18, URL: https://www.iea.org/policies/7835-nom-010-ener2004-energy- efficiency-of-the-motor-pump-submersible-assembly-for-deep-well-pump-type-limits-and-testing-method., July 2019.
20. E4 Country Profile: Energy Efficiency in Mexico-Article —, URL: https://www.iea.org /articles/e4 - country-profile-energy-efficiency-in-mexico, 9 February 2021.
21. http://www.suiquanhua.com/-/media/APEC/Publications/2020/4/Aligning-Conformity-

Assessment-Efforts-for-Energy- Efficiency-Regulations-of-Motors/220_EWG_Aligning-Conformity-Assessment-Efforts-for-Energy-Efficiency- Regulations.pdf, 2020.

22. Issues Paper-Energy Efficiency Regulation of Electric Motors, URL: https://www.energyrating.gov .au/sites/default/files/2020-01/motors_issues_paper_-_january_2020_0.pdf, 2020.

23. Energy Rating-Electric Motors- Greenhouse and Energy Minimum Standards (Three Phase Cage Induction Motors) Determination, URL: https://www.energyrating.gov.au/products/electric-motors.,2019.

24. Federal Register of Legislation Greenhouse and Energy Minimum Standards (Three Phase Cage Induction Motors) Determination, URL: https://www.legislation.gov.au/Details /F2018L01572/Explanatory%20Statement/Text., 2018

25. https://steptoworld.com/06182019.html, 2019

26. MEPS scheme for low-voltage motors in Australia and New Zealand, https://search.abb.com /library/Download.aspx?DocumentID=PM326&LanguageCode=en&DocumentPartId=&Action=Launch, 2020.

27. Three-phase Cage Induction Motors, https://genless.govt.nz/assets/Business-Resources/Information-sheet-2019-Three-phase-electric-motors-v2.pdf, 2019.

28. Electricity Demand Forecasting Methodology Information Paperhttps://www.aemo.com.au/media/Files /Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Strategy PolicyResearch_ 2019_ Energy_ Efficiency_Forecasts_Final_Report.pdf, 2020.

29. GB 18613-2020, URL: https://www.chinesestandard.net/PDF.aspx/GB18613-2020., 2020.

30. EU introduces new motor and converter MEPS from 2021, https://www.iea-4e.org/emsa/news/eu-introduces-new-motor-and-converter-meps-from-2021/, November 2019.

31. COMMISSION REGULATION (EU) 2019/1781, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?ur i=CELEX:32019R1781&rid=10, 2019.

32. de Almeida, Anibal T. & Fong, Joao & Falkner, Hugh &Bertoldi, Paolo, 2017. "Policy options to promote energy efficient electric motors and drives in the EU," Renewable and Sustainable Energy Reviews, Elsevier, vol. 74(C), pages 1275-1286.

33. IEC 61800-9-2:2017-Adjustable Speed Electrical Power Drive Systems-Part 9-2: Ecodesign for Power Drive Systems, Motor Starters, Power Electronics and Their Driven Applications-Energy Efficiency Indicators for Power Drive Systems and Motor Starters; International Electro technical Commission: Geneva, Switzerland, 2017.

34. Higher cost efficiency less Co2, https://new.siemens.com/global/en/products/drives/topic-areas/energy-efficiency .html, 2018.

35. Electric Motors, https://ec.europa.eu/energy/sites/ener/files/documents/20141211_GuidelinesElectricMotors%20 cover.pdf, 2014

36. Get ready for updated energy requirements in EU, URL: https://hoyermotors.com/wp-content/uploads/2020/07/ Whitepaper-Ecodesign.pdf., 2020.

37. Information about the Ecodesign Regulation(EU) 2019/1781 for Motors and Drives from CAPIEL and CEMEP, https://cemep.eu/assets/files/Information-Ecodesign-Regulation-2019-1781-CEMEP-CAPIEL-1st-Edition-final.pdf, 2020.
38. European Parliament-The Ecodesign Directive (2009/125/EC) URL:https://www.europarl.europa.eu/RegData/etudes/ STUD/2017/611015/EPRS_STU(2017)611015_EN.pdf , 2017.
39. Commission Regulation (EU) 2019/1781 of 1 October 2019 Official Journal of the European Union URL : https://eur- lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1781&rid=10, 2019.
40. ABB, https://new.abb.com/motors-generators/ecodesign-motors-drives., 2017.
41. New European Efficiency Regulations, https://static.weg.net/medias/downloadcenter/h92/h3f/WEG-new-european efficiency-regulations-50103352-guide- english-web.pdf
42. Energy Efficiency Motor Standard, https://docplayer.net/119085071-Energy-efficient-motor-standard-is-12615-2018.html, 2018
43. Efficiency Regulations for Motors and Motor Systems, https://autodocbox.com/Electric _Vehicle/ 96608829-Efficiency-regulations-for-motors-and-motor-systems.html, 2021
44. Sew Euro Drive, https://download.seweurodrive.com/download/pdf/22134204_G02.pdf, 2018.
45. Sew Euro Drive, https://download.seweurodrive.com/download/pdf/21274592.pdf, 2017
46. Global MEPS Guide For Low Voltage Motors, URL:https://static.weg.net/medias/downloadcenter/h68/h3c/WEG-global- meps-guide-for-low-voltage-motors-50060049-brochure-english-web.pdf, 2021.