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Standards of Energy Efficiency of Induction Motors: Latin American Context

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***Abstract*—In this paper a comparison between the energetic efficiency of induction machines in Latin America and the so called Developed Countries is presented. The comparison reveals that Latin America presents a considerable delay in the implementation of classification standards and methods for testing the efficiency of electric motors more widely used worldwide: IEC 60034-30:2008, IEC 60034-2-1: 2007, IEEE 112:2004 and EPAct'92, compared with the countries of the European Union, the United States, China, Australia, and other developed countries where these standards have been adopted. In addition, the comparison reflects the absence of programs in the region focused on improving the energy efficiency of electric motors. Moreover, there are a limited number of laboratories accredited under an international standard for testing the efficiency of induction motors, so most Latin American countries are obliged to establish recognition agreements with other countries in order to validate the results of this test.**

***Index Terms*—Electric motor system, Energy efficiency standards, Mutual recognition agreements, Test laboratories**

I. Introduction

THE energy crisis of the 1970's, the progression of weather changes, and the increasing of greenhouse effect motivate to the governments to define policies and regulations to encourage improvements in the quality and efficiency of energy supply.

In the energetic context, the electric energy prevails over other forms of energy, becoming an essential mean for industrial progress and society welfare. The electric energy involves very wide application areas where electric machines play a key role (electric machines have been cataloged as a fundamental element in the productive chains) [1].

In particular, it is estimates that the induction motors consume about 70% of the total electric energy in industrial applications, mainly in devices such as compressors, pumps, fans and mechanic traction [2], [3], [4], [5].

In order to analyze the energy efficiency of electric motors different authors have proposed involve the efficiency of others devices associated to their performance [2], [6]. Often, this concept is defined as Electric Motor System (EMS). EMS establishes a relationship between the efficiency of the own motor and the efficiencies of the control system, the power source, the speed driver, the transformer, and the mechanical transmission system (gear, brake, clutch, transmission, etc.) [7], [8]. In this sense, it is evident that an inefficient component will produce a negative effect on the global performance of the EMS [3].

Several studies published between years 2006 and 2011 [2], [9], [10], [11], [12], [13], [14], [15], [16], [17], coincide in that EMS demands between 43% and 46% of total consumption of worldwide electricity (Fig. 1). This consumption was estimated in about 6000 TWh in 2005 and its contribution to CO_2 emission was near to 4400 Mt (approximately 16% of total emission related with energy) [16].

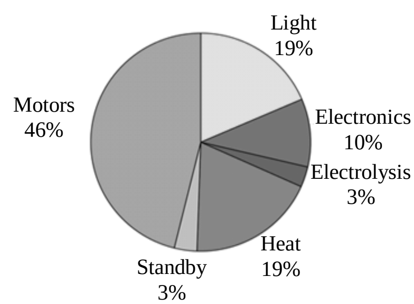

Fig. 1. Estimated electric energy consumption for each utilization sector [12].

In 2010, electricity sector accounted 41% of CO_2 emission [18]. Although the grams emission of CO_2 per kWh of produced electricity varies between countries, and depend of the combination of the used energy sources, it is expected that between 2010-2030 electricity energy demanded by EMS will increase from 8360 TWh/year to 13360 TWh/year (about 63%), with the consequent increasing in CO_2 emissions from 6040 Mt to 8570 Mt (approximately 75%) [2], [16], [6].

The global demand of electric energy consumed for EMS in 2009 was estimated at 6919 TWh/year, classified by motor size, as presented in Table I, medium-sized motors (powers between 0.75kW and 375kW), with about 230 millions of installed units, consumed about 68% (4776 TWh/año) [19]. These values reveal that medium-sized motors produce the major electric energy consumption and therefore constitute a key target for most accepted international standards of the electric motor efficiency.

To aim to improving productivity and sustainability of

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industrial enterprises and contribute to the reducing of the greenhouse effect, it is essential that all participants of motorized systems join efforts to get potential energy savings. In this sector, savings are estimated close to 20% to 30%, which account a reduction of total global electricity consumption near to 10% [2], [6], [20], [21], [22] [23].

TABLE I
ELECTRIC POWER DEMANDED BY INDUCTION MOTORS [16]

All kinds of electric motors	Output size Pm (kW)			Number running stock	Electricity demand	
	Min	Max	Total GW	Million	TWh/a	fraction
Small	0.001	0.75	316	2000	632	9.1%
Medium	0.75	375	2182	230	4676	67.6%
Large	375	100000	450	0.60	1611	23.3%
Total			**2948**	**2230**	**6919**	**100.0%**

In order to evaluate different required strategies and policies to improve energy efficiency of electric motor is essential to have specialized laboratories and systematic processes to properly calculate such efficiency. In this sense, international standardization organizations have established several regulations to define the conditions to determine the efficiency of an electric motor.

This research shows that in Latin America and Caribbean (LA&C) there is a significant delay in the implementation of standards related to the efficiency of electric motor and there are very few accredited testing laboratories to apply the necessary tests to certificate the efficiency of this type of machines.

This paper is divided in two main sections which present a state of the art on efficiency standards and mutual recognition agreements and support programs to efficiency of electric motor system in LA&C.

II. EFFICIENCY STANDARDS AND MUTUAL RECOGNITION AGREEMENTS

International standards provide to countries a common language to facilitate trade by classification, specification and labeled of products, in order to establish quality level of processes and services, to regulate test procedures and certification of products, to offer a mechanism to join efforts to fight against weather changes, to secure interchangeability of products and interoperability of processes, and to serve as support to governments to legislate about health, security, environment and energy efficiency [24]. Thereby, international standards create global confidence.

A. *Energy losses in electric motors*

From [25], [26], efficiency of an electric induction motor (η) is defined as the relationship between the produced mechanical power and consumed electrical power, i.e.

$$\eta = \frac{P_o}{P_i} = \frac{P_i - \sum P_l}{P_i}$$

where $\sum P_l$ correspond to power losses.

The electric motor presents five kind of losses: at the core, at the stator copper, at the rotor copper, by friction and cooling, and load-dependent additional losses [27], [28]. Therefore, efficiency is determined if it is known a power (output or input) and the losses.

The main difference between international standards used to measure induction motor efficiency is the method to calculate the load-dependent additional losses. These losses are more complex to determine that the others, so the process to calculate them has generated an intense debate along decades [5], [41], [42], [43], [44], [45], [46]. Moreover, the simple approach to determine efficiency directly by measure of the input electric power with a wattmeter and output mechanical power using a torque sensor, and speed with a tachometer, could lead to big mistakes. Even, this estimation is more complicated in high efficiency motors where both powers are bigger than the motor losses [13].

B. *Energy efficiency standards in LA&C*

Studies on energy efficiency carried out in LA&C between 2004 and 2011 analyzed the situation and prospects of the implemented actions and instruments used to improve energy efficiency. Such studies have been mainly focused in five aspects: advances in political, normative and institutional framework; participants; resources and financial mechanisms of energy efficiency programs; the results of these programs; and learned lessons [29], [30], [31], [32], [33], [34], [35], [36].

An evaluation of the reports presented in these studies shown that most countries over this region have started individual programs, projects and national initiatives, and have implemented laws to improve energy efficiency. Some of these programs are: PUREE and PAyEE in Argentina, PROCEL in Brazil, PROURE and CONOCE in Colombia, PRONACE in Costa Rica, CUREN in Chile, PAE in Ecuador, CONAE and FIDE in Mexico, PREE in Peru, PAEC in Cuba, PESIC in Honduras, and PEE in Uruguay. These programs present several approaches in aspects such as size and economic conformation of countries, population distribution, technology and information access, financing possibilities, development of regulating instruments, and environmental, cultural and social aspects [30].

However, in these reports appeared in a similar way some problems: insufficient regulations; lack of institutional control and coordination, with respect to accomplishment of existing regulations; few financial sources oriented to energy efficiency programs; low stimulus level in order to incorporate technologies and projects to favor a rational and efficient energy use; and absence of indicators on achievements of national programs of energy efficiency. Despite of the availability of data bases in the region related to energy programs, most countries do not have reliable and systematic information in order to monitor the results of these energy efficiency programs. For this reason, the *Comisión Económica para América Latina y el Caribe* (CEPAL) has proposed to create indicators to evaluate energy efficiency activities in the region [36], [37].

Latin America has followed suggestions from Collaborative

Labeling and Appliance Standards Program (CLASP) [34]. From such suggestions, it has been possible to identify seven sectors where are centralized the politics and programs on efficiency applied to final use of electric energy. These sectors are: illumination, buildings, cogeneration, transport, electrical appliances, pumping systems, and electric motors. In the first six categories, most countries of the region present important advances, but excepting Brazil, Mexico and Chile, the rest of countries do not have shown enough interest to improve electric motor efficiency [15], [38].

C. Mutual Recognition Agreements and Multilateral Agreements

The determination of the efficiency of an electric motor implies two important concepts: i) a test procedure to calculate energy performance of the motor, developed in an accredited test laboratory, and ii) an established limit over energy consumption, globally known as Minimum Energy Performance Standards (MEPS). Fig. 2 shows a simplified procedure to certificate electric motor efficiency. The use of this scheme allows assuring the accomplishment of procedure technical standards and test methods for evaluating electric motor efficiency. Moreover, following the procedure presented in Fig. 2 is possible to satisfy and/or achieve Mutual Recognition Agreements (MRAs) or Multilateral Agreements (MLAs) approved by accreditation organisms. Notice that MRAs and MLAs required the acceptance of the technical competence of the laboratory responsible for emitting the certificate. In any case, the tests to determine motor efficiency should be done by an accredited test laboratory.

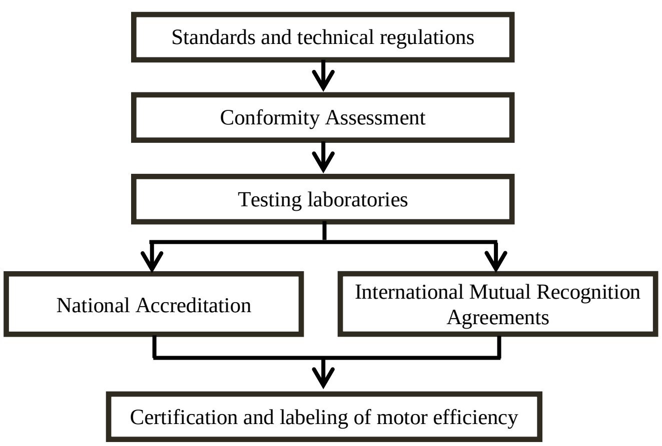

Fig. 2. Electric motors efficiency certification process

Fig. 3 shows some of most important international, regional and national technical standards on classification, test procedures and labeled of induction motor energy efficiencies. On the other hand, the Table II presents a summary of the most widely used classes for the efficiency of electric motor.

Nowadays there are many international mutual recognition agreements to evaluate the acceptance and certification of laboratories that satisfy the requirements of the standard ISO/IEC17025:2005. Those agreements are validated and accepted depending upon the technical competency and the management system used for the testing procedures [13], [39], [40]. This quantity of diverse electric motor efficiency standards complicates direct comparison of efficiency indicators and obstructs trade of efficient motors.

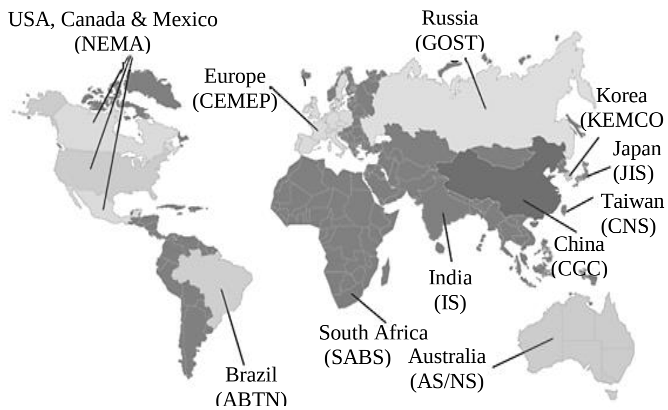

Fig. 3. Significant agreements and energy efficiency standards for electric motors worldwide [57].

In this sense, IEC has worked joined to NEMA, CEMEP, JEMA, IEEE, and other international organizations in order to harmonize the procedure standards and the test methods; the efficiency classes; and the subsequent process of motor labeling, with the purpose of recognizing high efficiency motors in the market. As a result of this work, many countries have adopted an efficiency classification scheme (IEC 60034-30:2008) and test methods (IEC 60034-2-1:2007) applied to electric motors [13].

TABLE II
MEPS, CLASSIFICATION STANDARDS AND TEST METHODS FOR ELECTRIC MOTORS [17]

Efficiency Levels	Efficiency Classes	Testing Standard	Performance Standard
3-phase induction motors	IEC 60034-30	IEC 60034-2-1	Mandatory MEPS***
	Global classes IE-Code	incl. stray load losses	National Policy Goal
	2008; rev. 2012 *	2007; rev. 2012 **	
Super Premium Efficiency	IE4	Preferred Method	- - -
			- - -
Premium Efficiency	IE3		Canada
			Mexico
			USA
			Europe**** 2015/2017
High Efficiency	IE2	Summation of losses with load test: P_{LL} determined from residual loss	Australia
			Brazil
			China
			Europe
			South Korea
			New Zealand
			Switzerland
Standard Efficiency	IE1		Costa Rica
			Israel
			Taiwan
*) Sizes 0.12 kW- 800kW, 50 and 60 Hz	**) for three-phase machines, rated output power < 1 MW	***) Minimum Energy Performance Standard	****) Europe 2015 (below 7.5 kW), 2017, IE3 or IE2 + Variable Speed Drive

The IEC 60034-30:2008 standard defines the classes IE1 (Standard Efficiency), IE2 (High Efficiency), and IE3 (Premium Efficiency), for three-phase induction motors from 0.75 kW to 375 kW, 50/60 Hz, 1000 V, of 2, 4 and 6 poles. There is a calendar to apply these efficiency classes as Table II shows: IE3 is obligatory in USA (2010), Canada (2010), Mexico (2010), EU (2015-2017), and voluntary in Japan (2015); IE2 is obligatory in Australia (2006), Korea (2008), Brazil (2009), China (2011), EU (2011), Taiwan (2013), and voluntary in India (2011); IE1 currently is applied in many countries of Latin America, Asia and Africa.

The IEC standards do not yet have into account EMS concept, however the publication of revised standard, programmed to 2012, will probably include all motor classes (from 0.12kW to 800kW; 2, 4, 6, 8 poles; and permanent magnet motors). In addition, it is probable that efficiency classification be extended to IE4, and it is possible that it includes IE5 class (Ultra-Premium Efficiency), which at present is not available [14], [28], [1], [41]. In Table III others updated and supplementary standards are presented. In those standards, characteristics such as total energy efficiency are accounted. In this sense, motor, frequency drive, and operated equipment (pump, fan, compressor, transporter, etc.) were recognized as a unified system.

Unfortunately, whereas many countries progressively are using High Efficiency and Premium Efficiency motors, the advances in electric motor energy efficiency is an important pendent issue in most LA&C countries. The main regional initiative on this aspect corresponds to CT 52-005 technical committee of the *Comisión Panamericana de Normas Técnicas* (COPANT). This committee has proposed a new standard titled "Energy efficiency. Three-phase induction motors. Efficiency and power factor determination". This standard is in voting process, so has not been yet accepted by any National Standard Body (NSB) of the region [42], [43].

Table IV shows the energy efficiency standards for three-phase induction motors in LA&C. Most of them have a similar title ("Energy Efficiency. AC motors, three-phase induction squirrel-cage type, rated output of 0746-373 kW. Limits, test

TABLE III
CURRENT OVERVIEW OF STANDARD IEC [17]

Description	Standard	Title	Publication	Related Motors
Evaluation and performance	IEC 60034-1	Rating and performance	2010	
Efficiency test	IEC 60034-2-1	Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)	2007 (in review)	Standard Motors (AC, DC and synchronous)
	IEC 60034-2-2	Specific methods for determining separate losses of large machines from tests- supplement to IEC 60034-2-1	2010	Special motors and high power motors
	IEC 60034-2-3	Specific test methods for determining losses and efficiency of converter-fed AC motors	2011 (draft)	Drive motors
Efficiency classes	IEC 60034-30	Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code)	2008 (in review)	Induction motors of 0.75 kW to 375 kW, 2-pole 4.6; of 50/60Hz
Application Guide	IEC 60034-31	Selection of energy-efficient motors including variable speed applications - Application guide	2010	Motors and inverters

TABLE IV
ENERGY EFFICIENCY STANDARDS FOR INDUCTION MOTORS IN LA&C.
SOURCE: NATIONAL STANDARDS BODIES OF EACH COUNTRY, 2011.

Country	Standard	Current	Reference Standard
Argentina	IRAM 62405	Emitted, validity: 15/7/2010	IEC 60034-2-1; IEC 60034-30
Brazil	ABNT NBR 17094-1:2008	Published: 12/12/2002 in force	IEC 60034-1
	NBR 5383-1:1999 (ABNT 1999)	in force	IEC 60034-1
Chile	NCh3086.Of2008	Published:2009 Effective:2011	IEC 60034-1; IEC 60034-2-1; IEC 60034-5
Colombia	NTC 3477	Ratified: 2008-12-10	IEC 60034-2-1:2007
	RETIQ, Annex E	Draft Technical Regulation July 8, 2010	NTC 3477; IEC 60034-2-1
Costa Rica	INTE 28-01-10-08	Approved and published October 2008	COPANT 152-005: Efficiency classes
	INTE 28-01-11-08	Approved and published October 2008	COPANT 152-005: Labeling
	INTE 28-01-12-08	Approved and published October 2008	COPANT 152-005: Test Methods
Cuba	NC 719	Effective since 2009	ISO 15550: 2006
Ecuador	NTE 2498:2009	Released: 2009-06-16 Approved: 2009-02-27	NTC 5105; NTP 399.450; IRAM 62405
Honduras	NHN 5:2008	Published on December 17, 2009	Not available
Mexico	NOM-016-ENER-2010	2010-10-20	CAN/CSA C390 IEEE 112
Nicaragua	NTON 10 007-08	Published on March 10, 2010	NOM-016: 2002; CSA C390; IEEE 112; NEMA MG 1
Peru	NTP 399.450:2008	Published: 2008-12-17	IEC 60034-2-1:2007
	NTP IEC 60034-2-1:2010	Published : 2010-03-2	IEC 60034-2-1:2007
Salvador	NSO 29.47.02:08	Published, January 22, 2009. Effective August, 2009. Under Consideration	NOM-016: 2002; CSA C390; IEEE 112; NEMA MG 1
Uruguay	UNIT 1192:2010	Approved November 2010 by the General Committee of Standards on December 15, 2010	IEC 60034-1: 2010 IEC 60034-2-1: 2007
Venezuela	COVENIN 862:1976	In Review	---

methods and labeling"), and refer or literally quote the content of an international standard or part of the technical data of this standard. These standards comply with the precepts specified in Annex 3 of the Agreement on Technical Barriers to Trade (Code of practice for the preparation, adoption and application of technical standards - ISO, 2010); therefore its application in each country is recognized internationally.

Before update of the standards IEC in 2007 (test methods) and 2008 (efficiency classification), Colombia was recognized in region because applied standards on efficiency motor using the methods IEEE 112 (NTC 5111: 2002) and IEC 61972 (NTC 5293: 2004). In addition, this country currently has a project of Technical Regulation of Labeled (RETIQ), which takes into account a method to determine energy efficiency of three-phase induction motors. It is expected this standard is applied from 2012.

D. *Accredited test laboratories in LA&C*

Agencies of normalization and national accreditation, researchers and industrial sector recognize the importance of accreditation of the test laboratories. Some LA&C governments have shown important advances in legislation and/or have training programs related with energy efficiency of electric motors. Nevertheless, LA&C is not prepared properly to face the challenge to locally certify the energy efficiency of induction motors. This problem remains because there are not an adequate number of accredited test laboratories. Therefore, most countries in region are obligated to trust in nameplate data of motors and its available technical documentation. Moreover, most these countries are obligated to establish multilateral agreements of mutual recognition with foreign accredited motor test laboratories.

As shown in the Table V, few countries in LA&C have accredited test laboratories: there are two in Argentina, three in Brazil, five in Mexico, and one in Peru.

III. Support Programs for Efficiency of Electric Motor System

The European Union, the United States, Canada, China and Australia have wide experience implementing national and regional programs and projects to improve efficiency of EMS. Some examples of this initiative are specialized conferences such as EEMODS (International Conference on Energy Efficiency in Motor Driven Systems) and MDS (Motor Driven Systems Conference) celebrated for first time in 2012. In particular, EEMODS has had great success congregating international experts and interested public, including politicians, motors manufacturers, academics and final users of EMS [12].

In last fifteen years, it have been established several regional negotiated agreements related with efficiency classes of three-phase induction motors of squirrel-cage, some of most important are described below:

A. *EU CEMEP agreement*

This voluntary agreement began in 2000 and had validity

TABLE V
TESTING LABORATORIES OF MOTOR EFFICIENCY ACCREDITED IN LA&C
SOURCE: NATIONAL ACCREDITATION BODIES OF EACH COUNTRY, 2011.

Country	Laboratory/ Institution	Specifications/ Tests	Standard
Argentina*	Instituto Argentino de Ensayos de Verificación S.A. IADEV	Efficiency Labeled Tests. IEC 60034-2-1: 2007 Sólo cláusulas 5.7, 6.4.2, 6.4.4.1, 6.4.4.2, 6.4.5.3, 8.2.2.1, 8.2.2.2, 8.2.2.3, 8.2.2.4 y 8.2.2.5.1	IEC 60034-2-1: 2007
	Lenor SRL		IEC 60034-2-1: 2007
Brazil	Instituto de Eletrotécnica e Energia da Universidade de São Paulo - IEE/USP	ABNT NBR 17094-1:2008 Rotating electrical machines – Three-phase induction motors. Part 1: establishes the minimum requirements for induction motors. ABNT NBR 5383-1:2002 applicable tests to determine the performance characteristics of three-phase induction motors and verification	ABNT NBR 17094-1;
	CEPEL Centro de Pesquisas de Energia Electrica		ABNT NBR 5383-1;
	Labelo Pontifícia Universidade Católica do Rio Grande do Sul		ABNT NBR 5110
Mexico	Laboratorio de Pruebas ANCE, A.C. México	NOM-016-ENER Energetic Efficiency in Three-phase motors up to 5 hp	NOM-014-ENER-2004
	GEIMM Ultra Test Lab., Monterrey García, NL 66000, México	IEEE 112, Method B Electric Motor Efficiency - Input-Output with Loss Segregation (for accreditation purposes, equivalent to CSA C390, Method 1)	IEEE 112-B; CSA C390, Method 1
	Siemens, S.A. de C.V. Laboratorio de Pruebas PEM-LAB	1) Tests for determining energy efficiency to product certification ANCE under NOM-014 and NOM-016. 2) Determination of energy efficiency for squirrel-cage induction motors, Canadian standard (C390 of CSA), Mexican Official Standard NOM-014 (single) and NOM-016 (three-phase), IEEE-112 method B, valid.	NOM-014-ENER-2004; NOM-016-ENER-2010; IEEE-112 método B
	USEM de México, S.A. de C.V., Apodaca NL 66600, MEXICO	Test efficiency of electric motors according to the scope and procedures given in Method B of Institute Standard 112 (IEEE) Test Method for induction motors and polyphase generators, and Method 1 of the Canadian Standards Association (CSA) standard C390	NOM-016-ENER-2010; IEEE 112-B; CSA C390, Method 1
	WEG de México, S.A. de C.V. Laboratorio de Pruebas de Media Tensión	Determining the efficiency by methods A, B, E1, F1	NOM-016-ENER-2010; NMX-J-075/3-1994-ANCE; IEE112-2004
Peru	FIEE: Facultad de Ingeniería Eléctrica y Electrónica. Universidad Nacional de Ingeniería de Lima	Motors. Generators. Motors AC / DC. No load test; Load test; Speed torque test; Efficiency test; Insulation test; winding resistance test; Applied voltage test; and Induced voltage testing (2 VN, 2 FN).	NOM-016-ENER-2010

* Lenor SRL has subsidiaries with certification scope in China: Lenor Asia Ltd., Chile: Lenor Chile Ltda., and Colombia: Lenor Colombia SAS.

until 2010. This agreement took into account normalized motors IEC 60034 with powers of 1.1 to 90 kW, 2 and 4 poles, and 400V-50 Hz, according to IEC 60034-2:1996. This agreement classified to motors in three efficiency categories. These categories indicated the rating efficiency values like a function of poles number and IEC size that a motor must comply. In 2009, European Commission published 640/2009 regulation to apply 2009/125/CE directive, which includes electric motors in Eco-Design program, and establishes a calendar to start a new agreement EU MEPS.

B. EU MEPS agreement

The European Minimum Efficiency Performance Standards (EU MEPS) is recognized as the most important agreement about energy efficiency of low voltage motors. This agreement specifies the minimum limit of efficiency that a three-phase motor should to meet to be included in European market. Manufacturers are obligated to mark in a permanent form the International Efficiency (IE) in nameplate of motor and report it on its respective technical documentation. MEPS is based in new standards IEC 60034-2-1:2007 and IEC 60034-30:2008 and will develop in three phases from 2011. This standard classified the motors in four categories as shown in Table II.

C. TOPMOTORS program

This is a program of Federal Energy Office of Switzerland (S.A.F.E.) focused to improving of EMS efficiency. Their main objectives are dissemination of information, consultancy services, good training practices, and audits. TOPMOTORS coordinates every two years the international conference “Motor Summit” which emphasizes in aspects related with test laboratories of electric motors [6].

D. 4E-EMSA program

The Electric Motor Systems Annex (EMSA) program was established in 2008 as a part of the Efficient Electrical End-Use Equipment agreement (4E) of the International Agency of Energy. EMSA is centered in improvement of the efficiency of electric motor considering it as a complete system, including coupled equipment. Its objective is increasing energy efficiency of EMS in about 20% or 30% in next 20 years. The EMSA C task, titled The Task Testing Center, began early 2009 and currently it has more than 70 members in about 25 countries in five continents. The goal of this job is to increase quality of test laboratories of electric motors worldwide by implementing networks between laboratories in different countries [44]. It is expected that achievements of this program facilitate a dialog between experimental laboratories in order to develop better practices and procedures of the new standard IEC 60034-2-1. Australia is the leader on this job and other participants are Denmark, Switzerland and South Africa [45].

E. Round Robin test

IEC promotes this project in order to determine variations of electric motor efficiency reported by different test laboratories worldwide. It is expected the results help to estimate more accurately the level of uncertainty in testing methods for electric motors in order to evaluate the deviation of the test measurements and to define the precision of the instrumentation. In this project participated 13 laboratories in 12 countries and they were done 68 tests. The results of this job will be considered to improve and optimize test procedures of IEC 60034-2-1 and to revise the tolerance limit of IEC 60034-1 standard [46], [47].

F. European Motor Challenge Programme

The European Commission promotes this voluntary program from 2003. This program help to enterprises to enhancing energy efficiency of systems driven for electric motors. Essentially, it is a program oriented to loads with high potential energy savings such as air compressor, fans and pumping systems [6].

G. NEMA premium

The Energy Policy Act of 1992 (EPAct92) imposed the MEPS for motors of 1-200 hp, 60 Hz, 2, 4 and 6 poles (IE2 class). EPAct92 began in 1997 and became a world leader of MEPS for electric motors. EPAct92 identified seven common steps to all MEPS implementations: i) definitions and covered products (MG1); ii) efficiency rate levels; iii) the procedures standards and the test methods (IEE112 standard); iv) label standards; v) process of test laboratories accreditation; vi) compliance, observance and execution of reports (DOE and NEMA); and vii) execution calendars and revision of standard [48], [49]. In 1993 NEMA incorporated motors of 201-500 hp. In 2001, EPAct92 adopted the NEMA premium efficiency levels for motors of 1-500 hp, 60 Hz, 2, 4 and 6 poles. The B Method of IEEE 112 standard is widely recognized for its precision in determining motor efficiency, mainly because it determine load dependent losses in indirect form [50].

Others international programs that promote EMS development are presented in Table VI.

H. LA&C case

In LA&C there are general programs of regional character focused to the improvements of energy efficiency, such as: Caribbean Sustainable Energy Program (CSEP), Caribbean Renewable Energy Development Program (CREDP), LA&C Energy Efficiency Program (PALCEE), and Latin America Network for Energy Efficiency (RED-LAC-EE). Also, there are politic conversations and seminars about energy efficiency. In addition, some countries like Mexico, Brazil and Chile have promoted programs to achieve a market transformation toward the use of more efficient equipment. However, despite of these initiatives it is difficult to find an important program or a relevant activity specifically dedicated to the induction motor and much less to EMS.

TABLE VI
SUPPORT PROGRAMS TO EMS EFFICIENCY [12]

Country	Program Name	Description
Australia	Equipment Energy Efficiency (E3) Program	MEPS; test compliance in accredited laboratories
Austria	KLIMA:AKTIV Energy Efficient Companies Program	Energy auditor training, audit guidelines motor systems (compressed air systems, fans, pumps), the template for audit reports, awards, workshops, conferences
China	China Energy Label; China Energy Savings Program; China Motor System Market Transformation Program; Motor Systems Challenge	MEPS; labeled, accredited laboratories program
Sweden	Program for Improving Energy Efficiency in Energy Intensive Industries	Energy audit, purchase recommendation (cost of engine life cycle); reports on energy management
USA	Motor Systems Initiative; Motor Decisions Matter (MDM); Compressed Air Challenge; Green Motor Initiative	Forum to members, practices awareness campaigns, training
	Motor Challenge Program; Save Energy Now, LEADER	Information, training, conferences, best practices, free software tools, support to public sector documents and technical guides, assessments

IV. CONCLUSION

The EMS consumes the most part of global electric energy with its consequent contribution to CO_2 emission. Within this consumption, the electric motor constitutes the biggest part. In addition, the quantity of electric motors in all sizes is constantly increasing. So, to have a great potential of energy savings on this field, all countries should adopt serious measurements leading to improve the efficiency indicators of these machines and promote the use of electric motors of High Efficiency and Premium Efficiency. Moreover, these activities will contribute to the weather change mitigation and to the generation of relevant economical-environmental changes to the region.

It is evident that most LA&C countries present a significant delay in harmonization of minimum energy performance standards with respect to the classification international standards of electric motor efficiency IEC 60034-30:2008 (IE1, IE2, IE3) and EPAct92 MG-1 (High Efficiency and Premium Efficiency), which have currently been implemented or have defined a schedule for use in the European Union, the United States, China, Australia, among others.

In LA&C there are programs that promote rational and efficient use of electric energy in countries of the region. Each country has begun programs, projects and initiatives such as PUREE, PAyEE, PROCEL, PROURE, CONOCE, PRONACE, CUREN, CONAE, among others. However, most of these programs are applied in a general way to electric energy final use devices, as illumination, buildings, co-generation, transport, electric appliances, pump systems and electric motors. In this region practically there are not especially dedicated programs to fomenting improvements in electric motor efficiency.

It is possible that the most serious difficulties that LA&C countries face to locally evaluate electric motor efficiency are lack in accredited test laboratories under an international standard as ISO/IEC 17025, and incapacity to do tests according to the reach and procedures defined in IEC60034-2-1:2007 or NEMA, IEEE 112B standards. This research shows that LA&C only has 11 laboratories: 8 in Mexico and Brazil, and 3 in Argentina and Peru. Therefore in order to determine electric motor efficiency either to new machines or after maintenance or a reparation operation is imperative to increase the quantity of certified testing laboratories in this region.

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