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Energy Efficiency in Motor Driven Systems

EEMODS'07 Conference Proceedings

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Volume I

Victor Zhou Paolo Bertoldi Ed.

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Preface

Motor driven systems account for about 40% of global electricity demand, i.e. 7400TWh per year, and about 70% of the demand for industrial electricity. This is the single largest end-use of electricity. Not only this, but motor systems offer still today large efficiency improvement potential, calculated between 20% to 30%. This would significantly reduce greenhouse gas emissions at zero or even negative costs, as improvement measures in motor driven systems are generally economical.

Motor driven systems will therefore play a key role in bringing many countries on the road to meeting the Kyoto targets. If all the motor systems would be optimised energy cost savings would be US$100–146 billion per year. Yet energy efficiency investments are not yet priority in new plants or during refurbishments.

The fifth international conference on Energy Efficiency in Motor Driven Systems (EEMODS) was organised in Beijing (China) from 10 to 13 June 2007, to discuss the newest developments in this field of energy efficiency in motor driven systems.

This major international conference, which was previously been staged in Lisbon (1996), London (1999), Treviso (2002), and Heidelberg (2005) has been very successful in attracting an international and distinguished audience, representing a wide variety of stakeholders in the development, manufacturing and promotion of energy-efficient motor systems, including key policy makers, equipment manufacturers, academia, and end-users.

The EEMODS conferences have been very successful in attracting an international audience, representing a wide variety of stakeholders involved in policy implementation and development, and manufacturing and promotion of energy efficient motor systems.

The EEMODS conference has established itself as an influential and recognised international event where participants can discuss the latest developments and build international partnerships among stakeholders.

EEMODS'07 provided a forum to discuss and debate the latest developments in the impacts of electrical motor systems on energy and the environment, the policies and programmes adopted and planned, and the technical and commercial advances made in the dissemination and penetration of energy-efficient motor systems.

During the conference numerous studies on individual component (motors, pumps, compressors, fans) and on the consumption characterisation and the potential for improvement of energy efficiency of these systems have presented. Also policy actions in a variety of regions and countries have been presented. For motors, most of the OECD countries have adopted mandatory or voluntary efficiency requirements, classification systems and motor selection database. Other policy initiatives cover end-use equipment such as pumps, compressors, and fans. These initiatives tend to be of a voluntary nature and they include: information dissemination, best practice, voluntary agreement, audit schemes, and financial and fiscal incentives. More recently the attention of policy makers and programme designers has moved to the "systems" and to the numerous possibilities for improving efficiency and save energy in the systems design, operation and maintenance. Examples are the US Best Practice Programme and the European motor Challenge Programme.

In the opening plenary sessions representatives of policy making bodies in China, the US and the EU, as well of international organizations such as the International Energy Agency, the UNDP, and others gave an overview of the recent developments in the policy area.

96 papers were presented in the 3 concurrent sessions covering the following topics:
Compressed Air
Electrical Motors (technologies, policies, and test methods)
Fans and Fan Systems
Management Issues
Motor System Audit and Programs
Policies and International Issues
Power Electronics and Electrical Drives
Pumps and Pump Systems

This book contains the papers presented in the parallel sessions. It is hoped that its availability will enable a large audience to benefits from the presentations made in EEMODS'07. Potential readers who may benefit from this book include researchers, engineers, policymakers, energy agencies, electric utilities, and all those who can influence the design, selection, application and operation of electrical motor driven systems.

EEMODS'07 has been organised by the International Copper Association and hosted by the Energy Research Institute National Development and Reform Commission, with the scientific support of European Commission, DG Joint Research Centre.

Victor Zhou
Paolo Bertoldi

2007.10.1, Beijing

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Policies & Standards

Strategy and Status of IEC Project 60034-30 Efficiency Classes of Cage Induction Motors

Martin Doppelbauer, SEW-EURODRIVE GmbH&Co.

Abstract

In 2006 a new work project was started in IEC TC2 in order to harmonize energy efficiency classes. Currently many countries have local standards (either already in effect or announced), which are for the most part not compatible to each other. The situation is complicated even further as most non-European 50Hz countries have created regulations which are more or less related to the CEMEP-EU-Agreement while most 60Hz countries are mostly related to North-American regulations. However differences exist not only in the levels themselves but also in the test procedure, tolerances etc. This diversed situation creates many problems both for international manufacturers and for large OEMs and end users of such motors. This paper gives insight in the strategies of the new project and reports the current status.

1 History

Energy efficiency of industrial motor driven systems has been an important topic for more than a decade. It is well known that motors consume between 30% and 40% of the total generated electricity worldwide. Assuming that losses inside the motor make up between 5% and 30% of the input power (depending on motor size and design) the benefit of improved motor efficiency becomes obvious.

The US American Energy Policy and Conservation Act (EPAct) (published in 1992 and in effect since 1997) was probably the first major step of a leading industrial country towards mandatory electrical energy savings within the industrial market. However it was not before the end of 1999 that the Department of Energy (DOE) published the final application rules for industrial motors [1]. In 2001 the National Electrical Manufacturers Association (NEMA), the US motor manufacturer's association, launched an initiative for even higher efficiency motors (NEMA Premium®). Today high-efficiency motors sales have a market share of more than 50% and premium motors more than 15% in Canada and the USA [2].

Around 1996 the European Commission started discussions with the European manufacturers (CEMEP). The first conference on Energy Efficiency of Motor Driven Systems (EEMODS) took place in October that year in Lisbon. It was felt necessary to improve the rather inaccurate efficiency test standard IEC 60034-2 and a mandate was given to the European Committee for Electrotechnical Standardization CENELEC (M/244 from 1997). The mandate was passed to working group 2 of SC2G of IEC but an agreement on a new procedure could not be reached until just recently. In the meantime a new standard was created (IEC 61972) but never adopted in Europe. The next edition of IEC 60034-2, which includes two improved test procedures for additional load losses, is finally expected for 2007.

In parallel the European Commission and the motor manufacturers negotiated a voluntary agreement on the reduction of low-efficiency (eff3) and support of high-efficiency (eff1) motors. The agreement was implemented in 1998. Seven years later the market share of eff3 motors has fallen below 5% but high-efficiency motors have not even exceeded 10% (figures of 2005). The reasons are manifold, not the least being increased investment costs for producing eff1-motors.

Many other countries have implemented voluntary or mandatory energy efficiency standards for electrical industrial motors in recent years.

In Australia and New Zealand mandatory standards for high-efficiency and voluntary standards for premium are in effect since 2006. Today the market share of high-efficiency motors in these countries is about 32% and premium-efficiency about 10% [2]. Both are increasing rapidly.

Brazil has voluntary standards (NBR/Procel) since several years. High-efficiency motors have a market share of 15% [2]. Mandatory standards are announced for 2009. Other South American countries (Argentina, Chile, Mexico and Uruguay) are following a similar path (COPANT Bs As 152).

Several Asian countries (China, Japan, South Korea, Thailand) and India currently have voluntary standards with market shares of high-efficiency motors around 10% [2].

Due to its energy problems, China is working intensely on new mandatory standards for high and premium efficiency and has announced implementation for 2010.

2 Motivation

When comparing the many local standards on energy efficient motors, two major influences can be found. On one hand there is the US American NEMA philosophy with tests according to IEEE 112B and CSA 390 (including additional load losses) and distinct stepped values for efficiency ratings. These provisions were exemplary for several 60Hz countries.

On the other hand, there are the 50Hz countries, which more or less follow the European CEMEP-EU agreement and test according to IEC 60034-2 (without additional load losses). Unfortunately a European table for Premium-Efficiency has not been published yet, so some countries were forced to create their own values for premium.

Today with the energy efficiency debate gaining a lot of interest, many countries have announced the preparation of new regulations. The foreseeable lack of harmonization is likely to create severe problems both for international manufacturers as well as for large end users and OEMs.

The fourth EEMODS conference in Heidelberg in 2005 finally gave the direction for an initiative to harmonize efficiency classes of three phase cage induction motors by an IEC standard. The project was initially developed by the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) and supported by the German National Committee DKE K311. A first draft was released as IEC 2/1392/NP in April 2006. The voting result was very positive with just one negative vote out of 26 participating countries. The newly formed IEC working group 31 is now striving for an international standard which will hopefully be adopted by many countries and reduce the diversity in this field.

3 The challenge to create a global standard — 50Hz versus 60Hz

One of the very basic technical problems for motor manufacturers is the development of a motor design that is suited for both 50Hz and 60Hz power supply.

Motor torque is based on internal motor parameters like flux density, rotor surface etc. It will not change much with supply frequency (at the most, torque can be increased somewhat at 60Hz due to better cooling). Since motor speed increases linear with the frequency so does output power. In other words: A typical induction motors develops at least 20% more output power when operated on 60Hz compared to 50Hz.

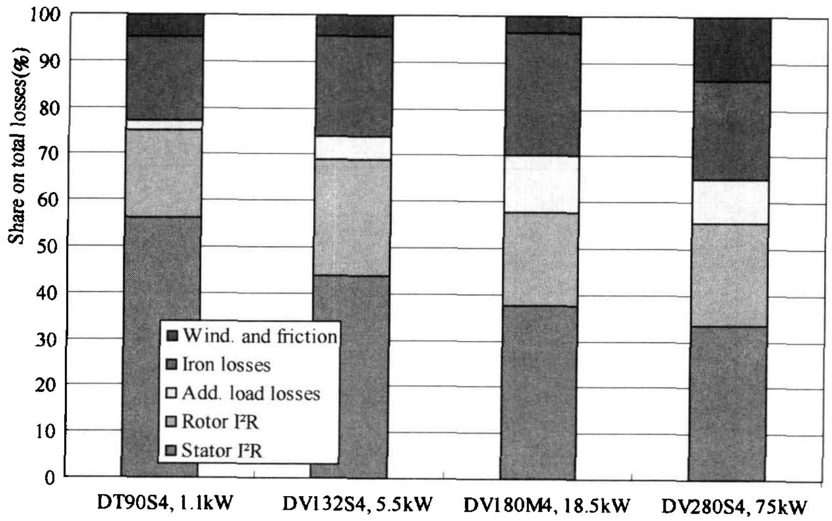

Figure 1 *Typical distribution of losses in 4-pole induction motors*

When examining the losses (see figure 1) one finds the most important part are I^2R losses in rotor and stator windings. As 400V/50Hz motors can be operated on 480V/60Hz with the same flux there is no need to change the winding design (at least not considerably). Hence winding resistance is basically identical for 50Hz and 60Hz operation. And since winding current is mainly depending on torque it will also remain constant and not change much with frequency.

Also the additional load losses are for the most part depending on torque or current and will consequently not change considerably between 50Hz and 60Hz.

Windage and friction losses naturally depend on rotor speed. They vary by the third order and linear with frequency, respectively. Also iron losses, which can be further subdivided into hysteresis losses (linear) and eddy current losses (second order), increase for 60Hz.

However when all losses are added up it can easily be seen that for most motors on 60Hz power supply the losses increase much less than the 20% output power. Hence the efficiency of these motors is better at 60Hz compared to 50Hz operation.

The following figure 2 illustrates the typical efficiency penalty for standard-efficiency (eff2) 4-pole 50Hz motors. Details will vary depending on the actual motors design, of course.