Coordination of IEC & ISO standards for energy efficient Electric Motor Driven Systems

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Abstract

Electric Motor Driven Systems (EMDS) are currently responsible for some 53 % of global electricity consumption (IEA 2017) [1]. Optimizing the selection of the respective components (motor control, motor, mechanical equipment and application) is a strategic prerequisite to realize the energy savings potential at system level; moving the optimization from component level to system level can realize extra energy savings with a factor 2 to 5 [9]. The design of the components, their sizing and selection, their combination to form an optimal motor system, together with a well-controlled operation needs a system approach to optimize EMDS energy performance. Such system approach is not only needed at design level but also when it comes to standardization.

The IEC Advisory Committee on Energy Efficiency (ACEE) has launched with its Task Group 6 a project to promote the system approach for energy efficiency standardization outlined in IEC Guides 118 and 119, published in 2017 [2]. ACEE has the powerful instrument of Basic and Group Standards to coordinate activities of Technical Committees (TC) and to ensure coherence of their publications to contribute to the improvement of EMDS energy performance. Currently, some 10 different IEC and ISO TCs (see also Figure 3) are engaged in different elements of EMDS, including control and switchgear, converters, motors, belts and pulleys, gears, pumps, fans and compressors.

A holistic approach to EMDS energy performance standardization requires a clear strategy of which energy aspects are to be considered, such as aligned operating points for efficiency tests, standard performance cycles for economic analysis, interpolation methods for the correct sizing of components and system design, etc. In order to avoid both dual and triple testing and multiple certification efforts for the manufacturer a system approach with an integrated methodology for the alignment and coordination of each EMDS' component relevant characteristics is needed. This will benefit the system integrator, the industrial user, government regulators and provide a means for effective market surveillance.

A workshop at the invitation of IEC ACEE TG6 of all the above-mentioned stake-holders will be held as a side event of EEMODS'19. The goal of this project shall be discussed with all TCs involved to eventually reach consensus on the strategy and define a roadmap to allow mutual benefits. The overall plan on how to proceed and who will participate and lead the activities will also be part of the workshop. The IEC ACEE is an ideal platform to organize efforts among some three IEC TCs and some seven ISO TCs under a workshop format with the goal of eventually shifting from vertically oriented standardization to a horizontal approach to EMDS energy performance standardization.

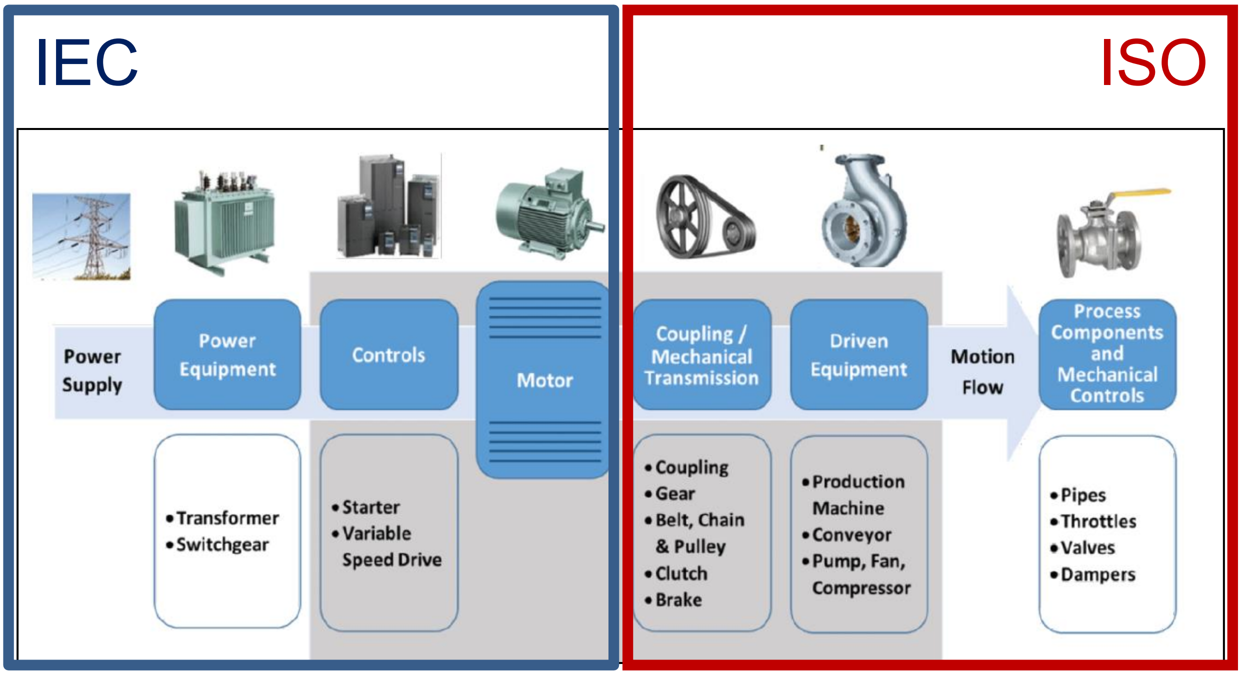

Figure 1: The electric motor driven system and its major components

Electric Motor Driven Systems (EMDS)

An EDMS is a complex composite of several sequentially electrically and mechanically linked components (see Figure 1). EMDS also represent the largest group of electric energy consumers. IEA has published in 2016 a new analysis in its World Energy Outlook [1] showing that electric motors driving pumps, fans, compressors, transport and industrial process machines are responsible for 53 % of global electricity use. For many decades, the often-repeated tune for maximizing electric energy savings in a cost-effective manner was, and still is, the coordination of the components involved in an EMDS into a well-matched system, both at the design level, the manufacturing stage, as well as in the programming, controls and operation cycles. The matching of the many components, often manufactured by several diverse specialized manufacturers, requires complex engineering expertise and good understanding of how each component and operating characteristic affects the overall system.

Of course, this coordination is easier for small integrated EMDS like circulator pumps, exhaust fans and cooling compressors in refrigerators (typically below 2 kW) that are designed and manufactured by one producer who tries to make them small, light, efficient and cost effective. There are some outstanding success stories of an integration success like the circulator pumps where, by employing advanced motors, such as new permanent magnet motor technology, the introduction of a variable frequency converter (VFC) together with better sized high efficiency pumps, have transformed the market in less than a decade. The European Ecodesign requirements quickly adopted this newly available technology in the regulation number 641 in 2009 [3] so that in Tier 2 from 1 August 2015 all circulators had to have an energy efficiency index (EEI) of not more than 0.23. This EEI of 0.23 was only possible to achieve by using this new technology with an integrated highly efficient circulator pump. According to the recent Topmotors Market Report 2018 [4] from 187 000 circulators sold in Switzerland in 2017, 96.8 % now comply with this minimum requirement.

The energy performance of an EMDS has been highly advanced since the wide spread market introduction of VFC. While only 20 % of installed EMDS already use VFC [5] the market potential in closed loop pumps, fans and many other applications with variable load and speed will eventually grow to approximately 50 %. This means that the EMDS evolves to a more complex machine where not only good nominal speed/torque performance is required but also a high efficiency over a wide band of operating points has to be secured.

The integration of several components into an EMDS becomes much more difficult and complex in larger systems where the components are typically manufactured by 2, 3 or 4 different companies. The components are designed and manufactured by specialist industries with multiple applications in mind. The industrial user selects and sizes the necessary components and has them shipped to its point of use. Only then and there, when these components are assembled on the factory floor, the system comes to life. Only now its performance can be checked and - under certain circumstances - measured in situ. The electric input is relatively easy to measure with 3-phase precision electric instruments while the EMDS is on standby and in operation, following a standard daily or weekly load profile. The accurate measurement of the mechanical output of the EMDS at the end of the pump or fan is much more complex. To measure the flow and head of the transported liquid of a pump or the flow and pressure of the transported gas of a fan requires previously installed measuring points and the availability of either permanently installed or mobile measurement equipment. It also requires detailed documentation of all the components with their nominal load points and the planned eventual field of required operating points.

Partial load

While operating systems efficiently, partial load performance becomes much more important. Most components of an EMDS (VFC, motors, belts, pumps, fans, compressors, etc.) operate at partial load with considerably lower efficiencies. To secure energy efficiency at partial load is a challenge for all products and the entire EMDS. Also, the standardization of typical operating points at partial load for efficiency measurements are more complex because they involve several components with up to four power conversion steps with different quantities of performance indicators (see Table 1).

Conversion step	Source	Input /output	Quantity	Units
1	From grid or mains	Electric input to VFC (AC)	Fundamental voltage, current and frequency, cos φ Electric power	V, A, Hz W
2	From VFC	Electric input to motor (AC)	Voltage, current, frequency, total harmonic distortion, cos φ Electric power	V, A, Hz, THD% W
3	From motor shaft (or gear, belt, etc.)	Mechanical input to pump/fan/compressor or mechanical hoist/lift/conveyor, etc.	Torque, rotational speed Mechanical power	N m, rpm W
4	From pump/fan/compressor, etc.	Mechanical output of fluid or gas of pump/fan/compressor, etc. to ducts or pipes; mechanical lift or rotation	Pressure difference (head), flow; weight, friction, acceleration Mechanical power	Pa (m), m^3/s kg, m/s^2 W

Table 1 Quantity and units of four steps of conversion in EMDS

Product standards

Most of the international product standards published by IEC and ISO deal with energy performance still focus on efficiency of single components. ACEE case study no 2 on Electric Motors [6] illustrates the number of product standards involved. Many of these components have subsequently been regulated through a national mandatory Minimum Energy Performance Standards (MEPS) based on the relevant IEC standards. One example of such interaction between Regulation and Standardization is the European Ecodesign regulation no. 640/2009 [7] for motor efficiency that has adopted the energy efficiency classification system from IEC 60034-30-1 [8] with its IE code.

Very rarely, standard makers and regulators have so far touched the complexity of publishing standards and MEPS for integrated systems (see [8]). This has a practical reason: a component can be relatively easy described in geometric terms and its performance can be measured in a testing lab based on output/input measurements. Subsequently, energy efficiency classes can be defined and given to the components.

There is also an historical reason: standardization activity has been mostly organized vertically (product oriented); one of the challenges energy efficiency poses to Standardization Organizations is therefore organizational and requires a coherent and effective framework to ensure the development of system-oriented standards.

The goal of the ACEE is to try and address this by creating guides that simplify the process while ensuring the committees consider all best practices, thereby improving the potential for commercially feasible market transformation and true energy savings.

System standards

Top down approach to standardization, starting at system level rather than at the product level is not a new concept for IEC; system standards ("horizontal" standards) are increasingly required in sectors such as environment and energy efficiency.

IEC ACEE has proposed a structured approach in order to promote a systems approach for standardization in the field of energy efficiency and to ensure the consistency of standards relating to energy efficiency aspects common to several technical committees by avoiding duplication of work and contradictory requirements.

Certainly, horizontal standardization adds complexity to the consensus reaching process typical of Standardization Organizations. Industry has long ago claimed that their preference are standards and a MEPS for systems, several coordinated components, that allow to integrate and optimize components thus saving weight, volume and cost. Industry is of course very interested in securing performance and compliance tests in one step (wire-to water or wire to air) instead of a multitude of repeated testing requirements.

Systems are not always composed of the same components: the minimum configuration is an electric motor and one type of application. Figure 2 tries to estimate the market share of the various configurations of an EMDS. Components for motor control and mechanical equipment are not always present in an EMDS.

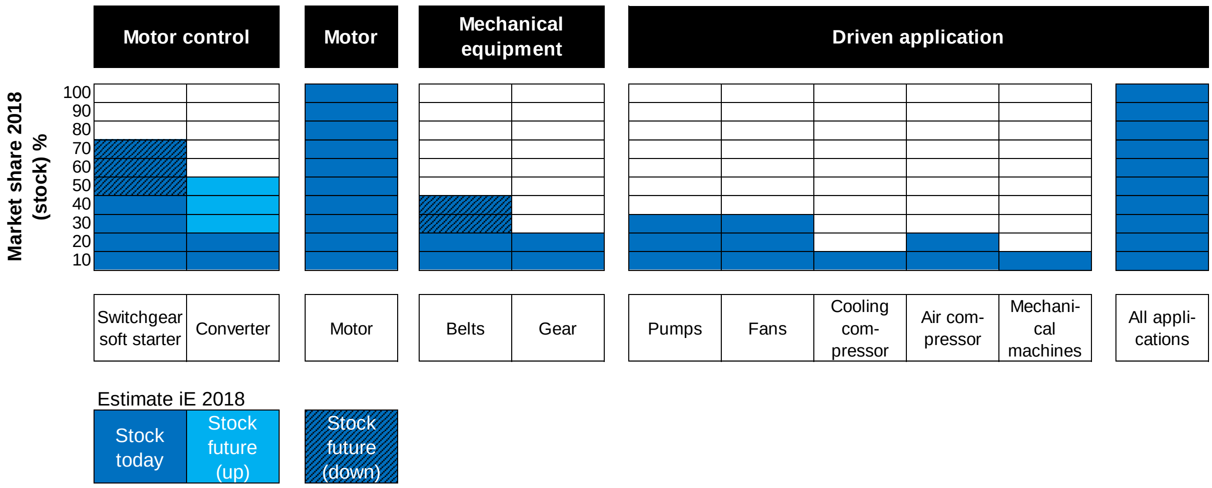

Figure 2 **Estimate of market share of the components of the various types of EMDS**

IEC has setup with its ACEE the responsible body to deal with energy efficiency matters which are not specific to one single technical committee of the IEC. ACEE coordinates IEC activities related to energy efficiency IEC Guide 119 [2], defines the formal procedure and requests from the applicants a definition of the boundary, its scope of a horizontal energy efficiency aspect and its eventual benefit. IEC ACEE receives the requests and after approval gives it to the IEC Standard Management Board (SMB) for confirmation.

A horizontal standard has (compared to a product standard) an additional pre-phase: two or more TCs together have to agree to apply to IEC ACEE in a formalized checklist to become a horizontal standard. IEC ACEE provides guidance for two different forms of horizontal standards:

- Basic energy efficiency standard (BEES):
  Publication covering energy efficiency aspects (EEA), applicable to products within the scope of two or more TCs. The focus of basic energy efficiency (EE) publications is the general tools and agreed methods for describing or achieving EE improvement in a defined boundary. These publications shall therefore describe EEA like measurement, calculation and further methods like benchmarking, Key Performance Indicators (KPI) calculation for EE as described in IEC Guide 118.

- Group energy efficiency standard (GEES):
  Publication covering energy efficiency aspects (EEA), applicable to a specific boundary including products within the scope of two or more TCs. Group EE publications may be primarily intended as EE publications, but shall also be used by other TCs in applying their provisions. In addition, guidance shall be given to TCs on how to apply information from a group EE publication, for example, how to define boundaries for a particular application (interrelation between light fixture, motion detector, outside shading, etc.).

In order to bring together several TCs to work together the need of a horizontal energy efficiency approach has to be clearly demonstrated and the TCs involved must first understand the benefits of addressing these complex questions. The TCs involved have to agree on an active collaboration that serves to better follow the needs of the stakeholders involved.

- The regulators are interested to answer industry requests to provide minimum performance requirements for systems ("wire to water", "wire to air", etc.). The regulators need energy efficiency standards for products (existing) and systems (to be established).

- The manufacturers are interested to align their products electrically and mechanically with neighboring products and to better coordinate measuring methods and performance metrics for entire systems.

- The industrial product users are interested in guidelines for better sizing, operating, optimizing and coordinating of products to evolve to energy efficient systems. A set of tools is needed to calculate the system efficiency beforehand based on component performance and guidelines to measure the performance of a completed systems in the factory.

IEC ACEE has accepted so far only two requests for a horizontal standard:

- IEC SMB has approved the request by TC 64 on the ACEE recommendation to allocate the following energy efficiency horizontal function “define energy efficiency measures in Low voltage electrical installations”, covered by IEC 60364-8-1 Edition 2 which will be give the status of Group Energy Efficiency Publication

- IEC ACEE has agreed to submit the request of IEC SC 22G to the IEC SMB for the recommendation to assign an energy efficiency horizontal function of “establishing a clear and simple system methodology for the comparison of the energy performance of motor systems to help product and system improvement” and assign the status of Group Energy Efficiency Publication to IEC 61800-9-1 in collaboration with IEC TC2 and IEC TC121.

IEC & ISO coordination

For better coordination and to ensure coherence international standards for EMDS, some three IEC TCs and six ISO TCs need to be involved (see Figure 3).

Motor control		Motor	Mechanical equipment		Driven equipment			
IEC TC 121	IEC TC 22 SC 22G	IEC TC 2	ISO TC 41	ISO TC 60	ISO TC115	ISO TC 117	ISO TC 86	ISO TC 118
Switchgear & controlgear	Adjustable speed drive	Rotating machinery	Pulleys & belts	Gears	Pumps	Fans	Cooling-Compressors	Air-Compressors
1927	1934	1911	1947	1947	1964	1964	1957	1965
Group Standard								

Figure 3: Technical Committees from IEC and ISO that are directly involved in product standards for EMDS (below: year of launch)

The goal of this coordination effort of a horizontal standard is to deal with a number of issues that are a common concern in improving the energy efficiency of EMDS, like:

- Aligned terminology, scope and boundary for EMDS
- Coordinated operating points and conditions for tests
- Typical operating characteristics and time/load profiles for economy
- Ex ante: calculation method for system energy performance
- Ex post: acceptance / testing procedure for system energy performance
- Coordinated efficiency classification methods and metrics for product and system energy performance
- Aligned interpolation method for losses and efficiency of system

A first level of improved interaction between TCs is recommended through the liaison of experts as members of two interacting committees (see Figure 4). This liaison serves to speed up the exchange of information especially with ongoing projects and helps to better understand each TCs concerns and expertise.

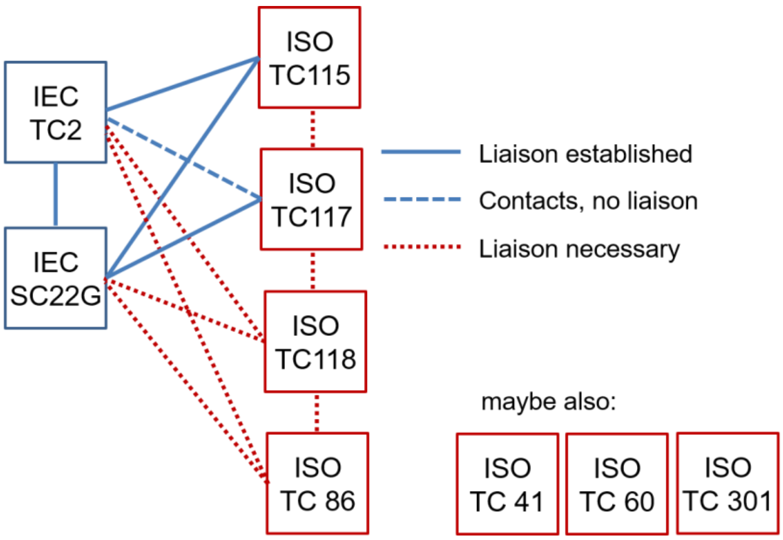

Figure 4 Liaisons (established and planned) between the IEC and ISO TCs involved

The coordination effort of EMDS involves a review of IEC and ISO standards (already published and under development) that include energy efficiency aspects, both in general terms, for energy performance testing, energy efficiency classification and for basic elements like scope, performance and tolerances (see Figure 5, draft survey, to be extended and completed).

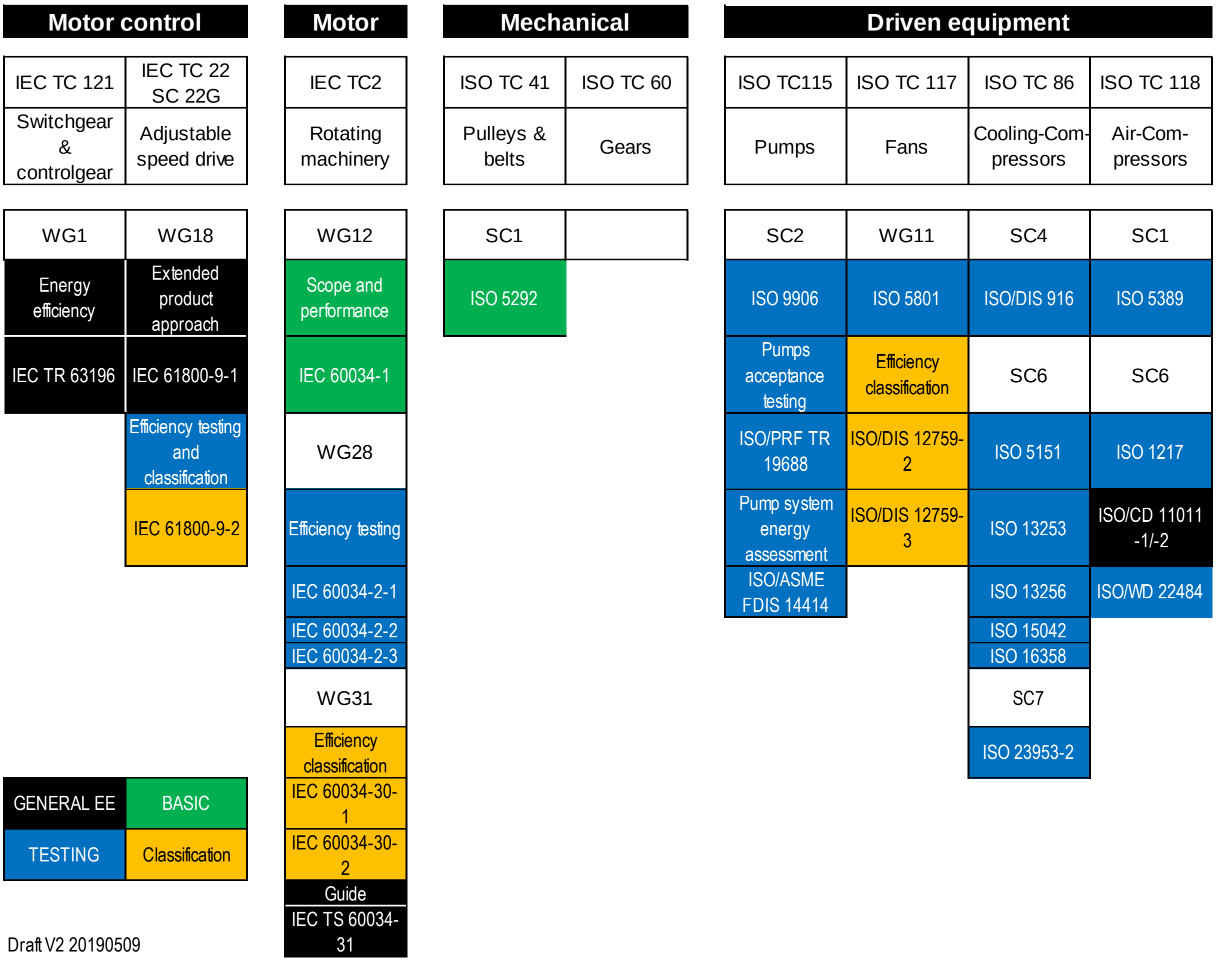

Figure 5 **Relevant energy efficiency standards for EMDS in IEC and ISO TCs (draft, to be extended and completed)**

Tools and guidance for EMDS

The assessment of the energy performance of such a system is one of the possible system attributes. System energy attributes are one of the energy efficiency aspects (EEA) addressed in IEC Guide 119.

Ex ante, a system performance calculation is required to assess the efficiency of the components involved. With the Motor Systems Tool (MST, see Figure 6, [10]) a variety of operating points of an EMDS can be defined and their combined efficiency calculated. For VFCs, electric motors, gears and belts as well as driven equipment like pumps and fans a well-documented data base of performance data from standards is underlaid so that a specific calculation can be made quickly. The MST includes the data base of motor efficiency from IEC 60034-30-1. In its latest version, the MST also includes the reference values and IE-classification for VFCs of IEC 61800-9-2, edition 1.

When used together with measured or estimated statistics of hours of load for an EMDS, the MST provides the data to calculate annual system efficiency. These results are crucial for economic decisions on the cost effectiveness of investments in components.

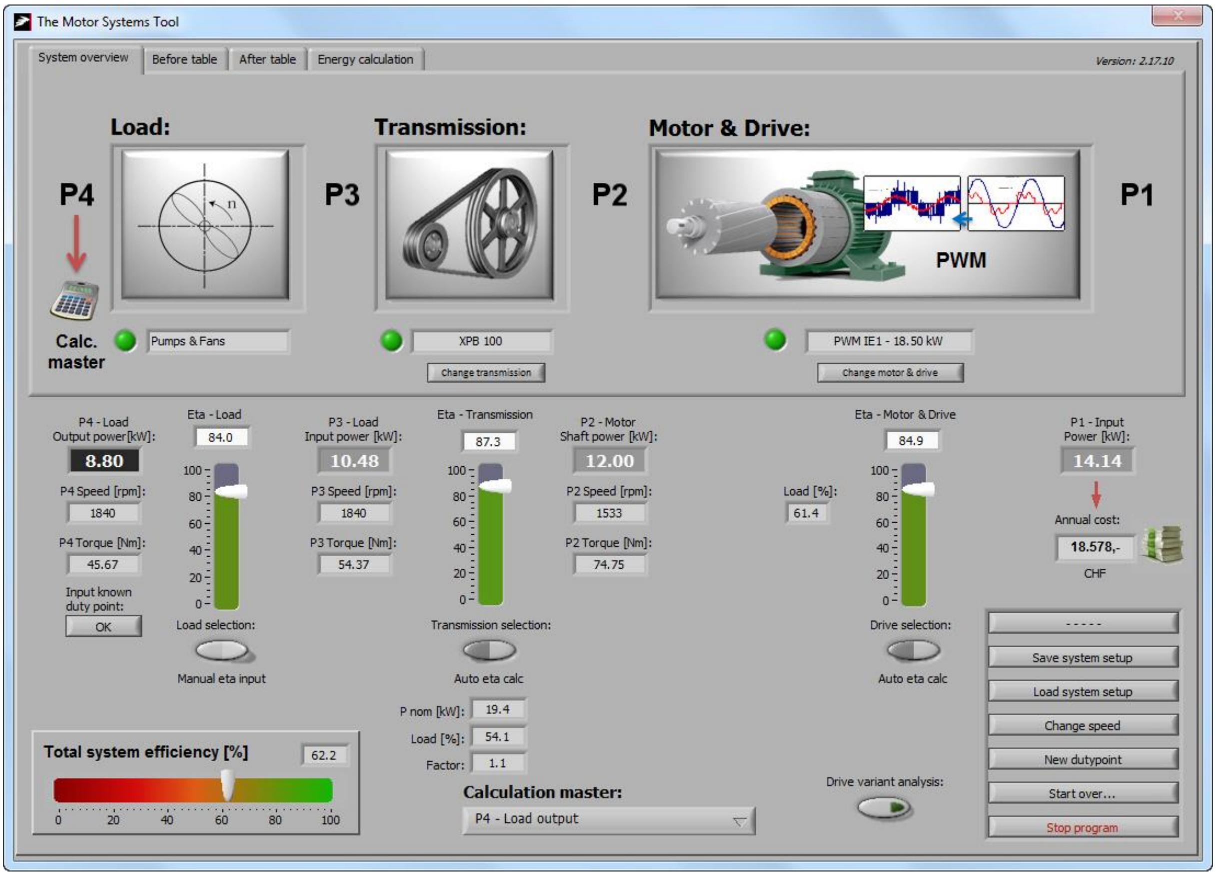

Figure 6 **The Motor Systems Tool (source: Danish Technological Institute, available at www.motorsystems.org)**

Ex post, the specific energy efficiency aspect of system performance assessment under operating conditions can be approached in different moments of the EMDS life cycle. Three examples from existing standards (even though they might not be 100% replicable) serve as guidance for EMDS (see below). A good example for on-site acceptance tests are in several existing IEC standards, typically for large machines that can only be assessed once assembled in the place of final use:

- IEC 60953-2:1990
  Rules for steam turbine thermal acceptance tests. Part 2: Method B - Wide range of accuracy for various types and sizes of turbines

- IEC 62381:2012
  Automation systems in the process industry - Factory acceptance test (FAT), site acceptance test (SAT), and site integration test (SIT)

- IEC 60193:1999
  Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests

These acceptance tests serve as models for performance tests of EMDS while assembled in the final user position in a factory. It helps to define, already in the stage of specifications and contracts of products, the measuring points, the operating conditions and the minimum requirements. It eventually serves as the base for the final acceptance protocol to check the contractual performance and efficiency data. It can also be used to check test government regulations for minimum efficiency requirements of products and systems.

Workshop in Tokyo

In order to bring stakeholders from industry, university, international standards, etc. to the table, an international workshop (by invitation only) will be staged by IEC ACEE Task Group 6 on 20 September 2019 as a side event of EEMODS'19 in Tokyo.

The goals of this workshop, as part of the project to align and coordinate IEC & ISO standards for energy efficient EMDS, are:

1. Inform participants on energy efficiency aspects in EMDS
2. Collect information from all TCs and stakeholders:
   a. existing and proposed energy efficiency standards and regulations
   b. hear needs, concerns and interests to cooperate for energy efficient EMDS
3. Explain and propagate IEC Guides 118 and 119:
   a. explain Basic and Group standards for EMDS
   b. identify Energy Efficiency Aspects for EMDS
4. Discuss possible ways forward:
   a. Liaison and Joint Working Group?
   b. Group EE Standard/Basic EE Standard?
   c. start with Project Group, cooperation with existing TCs
   d. revise existing standard or launch a New Work Item Proposal (NP)?

Agenda

Speaker	Affiliation	Topic	Country
08:30 Registration			
09:00 Workshop starts			
Conrad U. Brunner	IEC ACEE TG6, Impact Energy	Welcome and goal of the IEC & ISO Workshop on energy efficient EMDS	Switzerland
Franco Bua	IEC ACEE TG6	Basic and Group Standards according to IEC Guides 118 and 119	Italy
Maarten van Werkhoven	IEC ACEE TG6, EMSA, TPA energy advisors	Policy Guidelines for Motor Driven Units	Nether-lands
Geoff Lockwood	ISO TC 117, EVIA, ebmpapst	Energy efficiency standards for fans, focus on Europe	UK
Tim Mathson	AMCA, Greenheck Fan Corp.	Regulatory policy for fans, focus on USA	USA
Benoït Leprèttre	IEC TC 121, Schneider Electric	Energy efficiency standards for switch-gear and controlgear	France
Peter Gaydon	ISO TC 115, Hydraulic Institute	Regulations on pumps in the USA	USA
Markus Teepe	ISO TC 115, Wilo	Energy efficiency standards for pumps	Germany
Luc De Beul	ISO TC 118, Pneurop, Atlas Copco	Energy efficiency standards for air compressors	Belgium
Lunch break (60 minutes)			
Sandie B. Nielsen	IEC TC 2, IEC SC 22G, Danish Technological Institute (DTI)	System efficiency: Software Motor Systems Tool	Denmark
Martin Doppelbauer	IEC TC 2 chairman, IEC SC 22G, Karlsruhe Institute of Technology (KIT)	Interpolation methods for partial load	Germany
Benno Weis	IEC TC 22 chairman, Siemens	The Extended Product Approach according to IEC 61800-9-1	Germany
Kurt Stockman	University of Gent, IEC SC 22G WG18	Gearbox and belt drive efficiency from a EMDS perspective	Belgium
Shunsuke Matsunaga	Hitachi Industrial Equipment Systems, chairman of Inverter TC of JEMA	Impact of motor system standards on motors, inverters and application in Japan	Japan
Kirk Anderson	IEC ACEE TG6, NEMA	What the US industry (NEMA) can benefit from aligned motor system standards?	USA
Jesper Jerlang	Danfoss	What can the European Industry (CEMEP) benefit for from aligned motor standards?	Denmark
General discussion (100 minutes)			
Conrad U. Brunner	IEC ACEE TG6, Impact Energy	Conclusions, the way forward	Switzerland
17:00 Workshop ends			

Figure 7 Agenda of the IEC & ISO workshop on energy efficient EMDS in Tokyo on 20 September 2019

The speakers (see Figure 7) together with the invited guests will represent several ISO & IEC TCs involved and other stakeholders from industry associations, universities and national regulators.

The invited participants will be experts from the EMDS field who can contribute to defining a good way forward including calculation tools, interpolation methods, policy guidelines and relevance for regional markets, etc.

The outcome of the informal workshop will be a list of interested experts and TCs who are willing to go forward and cooperate with the definition of basic and/or group standard(s) for EMDS.

Conclusion

Horizontal standards for Electric Motor Driven Systems are needed for industry, regulators and users. So far, few horizontal standards and MEPS exist because of lack of coordination. As the use of VFCs expands, so does the potential energy savings possible through the optimization of the components taking not only nominal loads but a variety of operating points and conditions into account at the system level.

IEC ACEE has defined the procedure to arrive at consistent Group or Basic Standards that help to lower market barriers and improve energy efficiency. A large number of IEC and ISO TCs are involved in the standardization of different components for EMDS. Tools exist to calculate ex ante the system performance. IEC also has the precedent of acceptance tests for complex and large machines that can only be assed in their final assembly at the factory site.

In order to move forward with the coordination and alignment of horizontal standards, ACEE has invited experts from various stakeholders for a workshop as a side event to EEMODS'19 in Tokyo to discuss a common path forward for horizontal standards of EMDS.

The global market transformation with advanced energy efficiencies of Electric Motor Driven Systems can only be successful with intelligent interfaces between electrical and mechanical products based on internationally agreed horizontal standards.

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Policy Guidelines for Motor Driven Units, Part 1: Analysis of standards and regulations, Zurich, Switzerland, 2016;
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