Technological Feasibility Studies for Super and Ultra Premium Efficient Motors

Working Group A1.47

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1. INTRODUCTION

In general, over 45 %[1, 2]of the global electric energy demand is used by electric motor systems. Energy efficient electric motors represent one of the largest opportunities for cost-effective electric savings and the action plans for the reduction of greenhouse gas emissions. In order to gain fast and efficient access to the energy efficiency improvements of electric motor systems, regulations mandating the energy labelling of products for minimum energy performance standards (MEPS) have been widely applied to three-phase electric motors and the MEPS efficiency has resulted in higher efficiency levels such as IE3 premium efficiency.

The IEC 60034-30-1, published in March 2014, widens the product range covered in the first edition of IEC 60034-30 significantly. The power range has been expanded (starting at 0.12kW and ending at 1MW). The Super Premium efficiency class motors (defined as IE4 in IEC 60034-30-1) are newly included and Ultra-Premium efficiency class motors (defined as IE5 in IEC 60034-30-1) are envisaged to reduce the losses of IE4 motors further by some 20%. The world would save about 108 nuclear reactors (108 GW) on power plants and about 378 TWh per year on electric energy consumption by improving 3% motor efficiency from class IE3 to IE5 in 2030 [3, 5]. The electric energy price for 378 TWh will be about 30.2 billion US$ (8 US cents / kWh). Total worldwide installed power generation capacity and power generation would be approximately over 8000 GW and 28,000 TWh in 2030. [3]

Three main efficiency gains in IE4 / IE5 motors can be accomplished in the materials, manufacturing and improvements in motor design.

It′s the intention of these technological feasibility studies for super and ultra-premium efficient motors to provide information about the feasible motor types, qualitative / quantitative loss reduction methods and Loss estimation for the IE4/ IE5 performance. The assessment focused on three motor sizes for a 0.75 kW, 37 kW and 250 kW motor with 4 poles, which are denoted as small, medium and large.

Finally, the time to set the IE4 and IE5 classes as mass production of motors and mandatory motor requirements is proposed.

2. SCOPE/ METHODOLOGY

CIGRÉ's Technical Committee approved in November 2014 the Term of Reference for the Working Group A1.47 "Technological Feasibility Studies for Super and Ultra-Premium Efficient Motors" .

Following CIGRÉ′s tradition a questionnaire was prepared and sent to all regular members, observers and technical experts in September 2015 to gather expert′s opinions and experiences with motors.

As a guide line for the upcoming new efficiency classes of motor the purpose of this study is to find feasible and realistic standards for the future in motor technology which will come with the IE4 super premium efficiency and IE5 ultra-premium efficiency classes for motors, therefore the motors are split up in 3 different sizes and classes of motors.

The information′s and requirements are found and defined by discussions within a group of experts in motor design and research as well as manufacturing and consulting from all over the world. There was acceptable response to this worldwide survey, with 14 specific responses from individual companies, universities or institutions coming from 9 different countries.

The results of discussions ended up in a conclusion. The questionnaires which were used to define the finale specified requirements are attached to the Appendix of these TB.

3. DESCRIPTION OF THE TECHNICAL BROCHURE

The Technical Brochure (TB) is divided in several parts, as follows:

a) Frequency

b) Size and efficiency

c) Feasible motor types

d) Qualitative / Quantitative loss reduction methods

e) Loss estimates for the IE3, IE4 and IE5 motors

f) Time table for mass production of motors and mandatory motor requirements

g) Conclusion

3.1. Frequency

IEC60034-30-1 has different levels of efficiency for 50Hz and 60Hz. Around two third of the world population is using 50Hz and one third is using 60Hz. The biggest efficiency difference can be observed in the range of the medium size rating motors where the average difference of 60Hz compared to 50Hz is about 1% higher efficiency for IE3 but only about 0.15% higher efficiency for IE4. For the small and large size rating motors the efficiencies are in the same range.

3.2. Size and efficiency

The questionnaire is focusing on three motor sizes, which are donated as small, medium and large. The full range from 0.12kW to 1000kW follows that of IEC60034-30-1. The following table shows how the motors in this range are classified in the selected size classes.

Classification	Rated power
Small motor	0.12 – 3.7 kW
Medium-size motor	3.7 – 55 kW
Large motor	55 – 1000 kW

Table 1: Classification of size classes

In the range of these classes one motor is chosen within each class to concentrate on in the following chapters. The table below shows the chosen motors in terms of the rated power and the efficiency for the three standards IE3, IE4 and IE5 for 50Hz and 60 Hz as 4-pole motors.

Rated Power	Freq.	IE3 efficiency (%)	IE4 efficiency (%)	IE5 efficiency (%)	Power saved from IE3 to IE4 (W)	Power saved from IE3 to IE5 (W)
0.75 kW	50 Hz	82.5	85.7	88.2	34	59
	60 Hz	83.5	85.5	88.1	21	46
37 kW	50 Hz	93.9	95.2	96.1	538	911
	60 Hz	94.5	95.4	96.3	369	726
250 kW	50 Hz	96.0	96.7	97.3	1885	3591
	60 Hz	96.2	96.8	97.4	1611	3264

Table 2: Case motors for feasiblity study

3.3. Feasible motor types

This chapter concerns about which motor types could be feasible for the IE4 and IE5 performance

-Cage Induction Motor

-Synchronous reluctance motor with a starting cage

-Permanent magnet motor with starting cage

-Synchronous motor with a field winding and starting cage

3.4. Qualitative / Quantitative loss reduction methods

In this section there will be a qualitative and a quantitative evaluation for loss reducing potential, feasibility for series production and cost rise about different methods, such as use of new and upgrade materials, improved production technology and better cooling as well as some other methods.

3.5. Loss estimates for the IE3, IE4 and IE5 motors

This chapter focusses on the actual losses of the different classified sized motors for each standard from the presently standard IE3 over the coming IE4 to the future standard IE5. The Term "Methods" is the method by which the losses can be reduced from IE3 class to IE4 or IE5 class. Term "Year" is the year when this method is available for designing of motors. The values presented in the following tables represent the average values from the questionnaire. The losses for IE4 and IE5 are divided into two parts where the first part is considering a PM-motor(PM) and the second part is considering an induction motor (IM). Thus information about IE5 class motors are very spares and the estimate of their losses may involve significant departures from correct values.

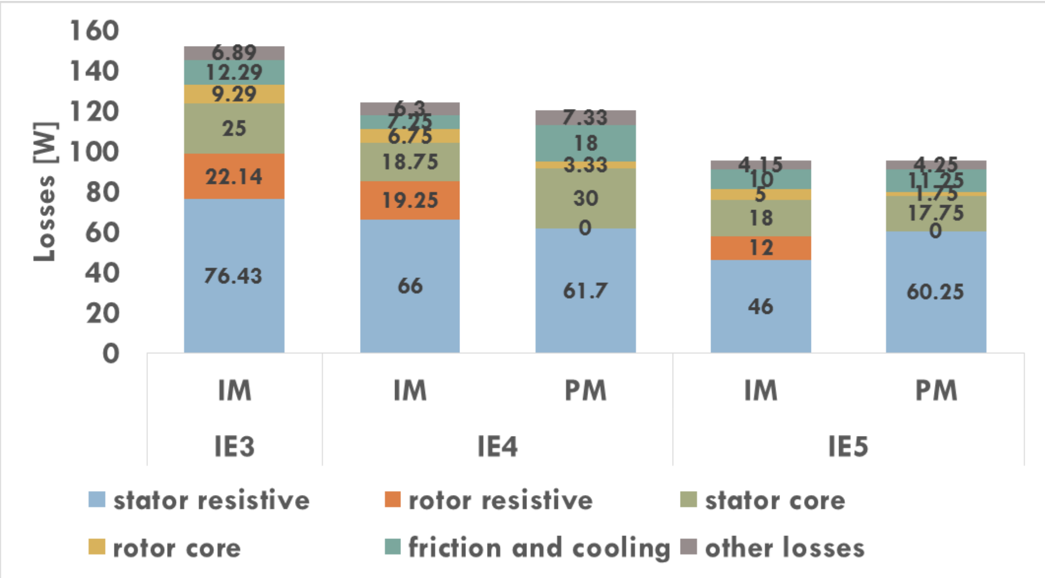

Figure 1: Losses for the 0.75kW motor for efficiency classes IE3, IE4 and IE5

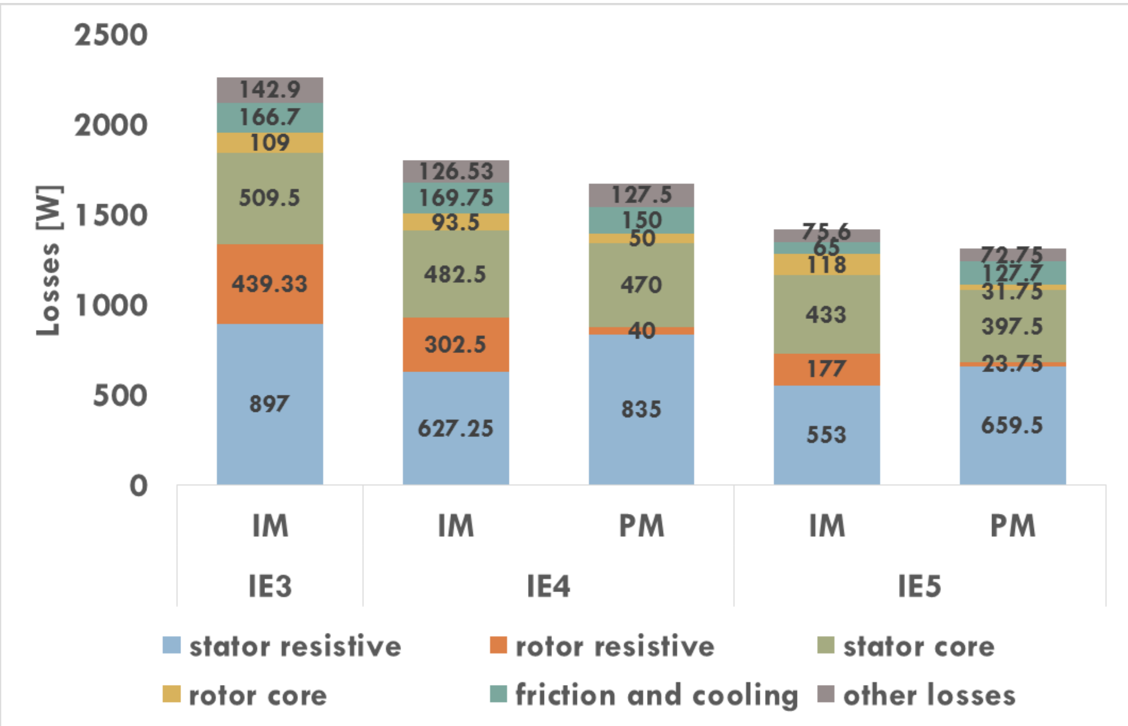

Figure 2: Losses for the 37kW motor for efficiency classes IE3, IE4 and IE5

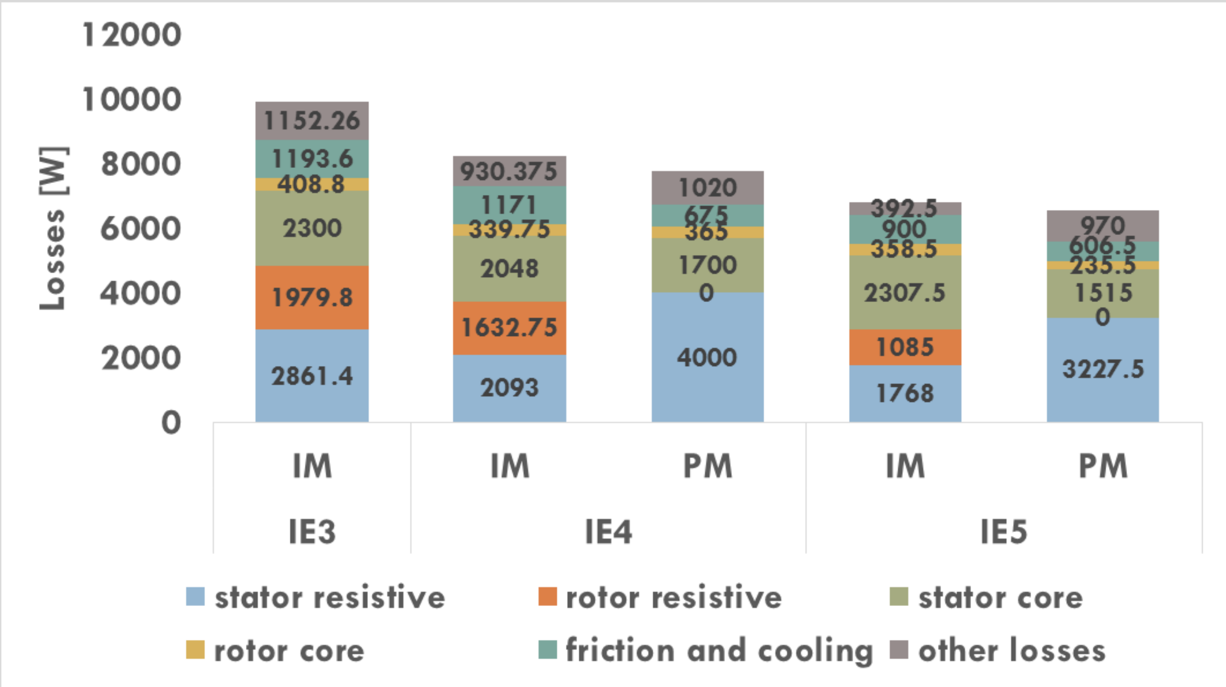

Figure 3: Losses for the 250kW motor for efficiency classes IE3, IE4 and IE5

3.6. Time table for mass production of motors and mandatory motor requirements

The possibility of mass production of the motors with IE4 efficiency class is seen in the middle of 2020s for small, medium size and large motors. For IE5 efficiency class mass production, about 10 more years are needed after the mass production of the IE4 efficiency class motors.

The year to set the efficiency classes as mandatory requirements for the IE4 efficiency class motors is seen at the beginning of 2030s for small, medium size and large motors. The year for setting IE5 class mandatory will be delay about 10 years after the IE4 class mandatory.

The time difference from mass production to mandatory requirements for both IE4 and IE5 efficiency class will be about 5 years, in between the different size classes the time difference is negligibly small.

This time table is highly influenced by the action of motor manufacturers, governments and also by the international political response to climate change.

IE class	Small motors	Medium-size motors	Large motors
Year for mass production of IE4 motors	2023	2023	2025
Year for mass production of IE5 motors	2031	2032	2036

Table 3 : Mass production of motors

IE class	Small motors	Medium-size motors	Large motors
Year for setting IE4 mandatory	2030	2029	2030
Year for setting IE5 mandatory	2038	2037	2038

Table 4: Mandatory motor requirments

4. CONCLUSIONS.

The world would save about 108 nuclear reactors (108 GW) on power plants and about 378 TWh per year on electric energy consumption by improving 3% motor efficiency from class IE3 to IE5 in 2030. The electric energy price for 378 TWh will be about 30.2 billion US$ (8 US cents / kWh).

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The technological feasibility studies according to IEC 60034-30-1 to provide information about the feasible motor types, qualitative / quantitative loss reduction methods and loss estimation for the IE4/ IE5 motors is performed. There was acceptable response to this worldwide survey, with 14 specific responses from individual companies, universities or institutions coming from 9 different countries.

In the future , the time to use IE4 and IE5 efficiency class motor is highly influenced by the action of motor manufacturers, governments and also by the international political response to climate change. The cost analysis should be performed because all methods for loss reductions will increase the price of motor production cost. Even though high efficient motors come at higher purchase costs, the lower operating cost in the first 3 to 5 years will compensate this purchase cost difference.

Bibliography/References

[1] Paul Waide, Conrad U. Brunner, Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems, International Energy Agency, 2011

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[3] World Energy Outlook 2011, International Energy Agency, 2011