COMPARATIVE ANALYSIS OF METHODS FOR THE ENERGY EFFICIENCY DETERMINATION OF INDUCTION MOTORS

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In the paper the effects on the induction motor efficiency determination due to the introduction of the EU, USA, Canada, Japan and Russian Standards have been analyzed and discussed. Industrial induction motor has been tested and a comparison between the efficiencies determined by various National Standards has been presented. In addition, the motor efficiencies have been compared with the efficiency classes defined by the EU Standardization.

СРАВНИТЕЛЬНЫЙ АНАЛИЗ МЕТОДИК ПО ОПРЕДЕЛЕНИЮ ЭНЕРГОЭФФЕКТИВНОСТИ АСИНХРОННЫХ ДВИГАТЕЛЕЙ

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В работе проанализированы и обсуждены особенности определения коэффициента полезного действия асинхронных двигателей согласно стандартам таких стран как ЕС, США, Канады, Японии и России. Проведены испытания общепромышленного асинхронного двигателя и осуществлено сравнение результатов, полученных согласно различным национальным стандартам. Кроме того, было проведено сравнение экспериментально полученных данных с классами энергоэффективности согласно стандартизации принятой в ЕС.

Nowadays, induction motors are used in biggest part of electric drivers mostly thanks to their reliability in contrast to DC motors, which have many production flaws. Usually, such machines present small-power motors with traction mode, induction generators are used rarely. Induction motors are one of the most important power equipment, the energy consumption of induction motors accounts for a large proportion. It is very significant to determine the efficiency of induction motors properly. The purpose of our article is to provide comparative analysis of the induction motor`s efficiency that determined according to various National Standards.

Broadly, the two major ways of efficiency determination of induction motors may be classified as: direct (measuring the output mechanical quantities and input electrical quantities) and indirect (using some means to determine all the losses in the motor and using their sum to calculate the efficiency). In the direct method, motor efficiency is determined from direct measurements of the input electrical power P_{in} and output mechanical power P_{out}. Both the output and the input power can be measured reasonably well with transducers and appropriate measuring instruments:

$$\eta = \frac{P_{out}}{P_{in}}.$$

In the indirect method, the input power and output power may also be measured and used to determine the constituent components of the losses in the motor. The efficiency is determined from the total losses, P_{loss}, by equation:

$$\eta = \frac{P_{in} - P_{loss}}{P_{out}}.$$

The process of determining the constituent losses is known as loss segregation. The efficiency determination methods that are based on loss segregation are known to be more accurate. There are five categories of losses in the motor: P_{core} is the core losses, P_{fw} is the friction and windage losses, P_{stator} is the stator copper losses, P_{rotor} is the rotor copper losses, and P_{stray} is the stray load losses, Fig. 1.

Both methods have direct connection with all losses in the motor. Engineers are trying to minimize the percentage of losses, cause each percent is very important for electrical energy industry. Energy losses are the determining factor in motor efficiency. The losses, as it shown earlier, could be divided into five main classes, Fig.1 [1,2]. In the next parts of this paper we will give an overview of various National Standards for efficiency determination and discuss the main differences between them.

Since the induction motor consumes about 90 % of all the electrical energy used by all motors combined, its efficiency reporting on the nameplate has become the industry standard. However, various international standards for testing and reporting the induction motor efficiency on the nameplate can be significantly different. National and International energy efficiency test standards have been developed to reduce the errors when motor efficiency is measured and make the procedure standardized. There are exist a number of international standards that are used to determined real efficiency according to experimental data. The major and the most important Standards for poly-phase induction motors efficiency measurement are [3]: IEEE Std. 112 – USA Standard; IEC 60034-2-1 – EU Standard; CSA C390 – Canadian Standard; JEC 37 – Japanese Standard; RIEC 60034-2 – Russian Standard; GOST 25941-83 – Russian Standard.

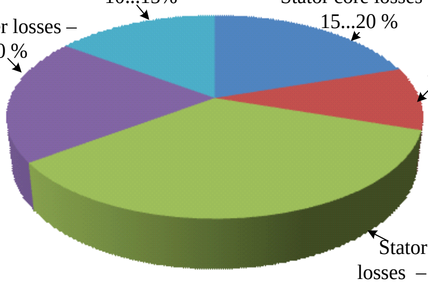

Fig. 1. The losses distribution in the induction motors

Most of these National Standards have more than one method for the efficiency determination, for example the IEEE Std. 112 has several methods identified as Methods A, B, B1, C, E, E1 F, F1, C/F, E/F, E1/F1. The IEEE 112 standard, method B, is widely used for determining induction motor efficiency. The method is based on the segregation of losses of the motor into conventional and stray load losses. The CSA 390 Standard uses an identical procedure to the IEEE Std. 112 method B for the stray load losses while the JEC 37 Standard ignores those losses [3]. The European standard for measuring motor efficiency, IEC 60034-2-1 has for a long time arbitrarily assigned 0.5 % input power as stray load loss, the same stray load losses determination we have in IEC 60034-2-1 and GOST 25941-83. The major differences between these standards is in the treatment of stray load losses, see Table 1 below.

The loss segregation method (used in IEEE, IEC, GOST and CSA) determines efficiency through the direct method or separation of loss method. This method requires a no-load test, where the core and windage and friction loss are obtained and a load test where the stator and rotor copper loss are obtained. The stray load loss is determined by subtracting all the major losses from the total measured loss. The Stray load loss is determined by subtracting all the major losses from the total measured loss. As stray load losses are the smallest one, they are sensitive to errors in measurement. The IEEE Std. 112 requires a correlation factor of 0.90 while the CSA C390 requires 0.95. The GOST 25941-83 method allocates stray load losses to be 0.5 % of rated load and the JEC 37 ignores stray load losses completely.

Table 1

The comparison between major test Standards

Standard	Stray load losses	Temperature correction
IEEE Std. 112	Loss segregation method	Yes
IEC 60034-2-1	Loss segregation method	Yes
CSA C390	Loss segregation method	Yes
JEC 37	Ignores SLL	Yes
GOST 25941-83	Assigns 0.5% of rated power of the motor	No
GOST 7217-87	Loss segregation method	Yes

These standards also play a important role in induction motor classification according to efficiency levels. In the European Union (CEMEP) and the U.S (EPAC) laws have been set to define the efficiency class of induction motors [10]. Table 2 shows the lower limits of the CEMEP classification. These limits are determined through testing according to a particular standard (IEC in this case). Previously in Europe, low voltage three-phase motors have been graded and marketed in three efficiency classes – EFF3, EFF2 and EFF1 – based on a voluntary agreement between motor manufacturers and the European Commission. Unfortunately, other countries have also developed their own national systems, which are very different from the European system. That was the reason for the European motor manufacturers in CEMEP, to develop an energy efficiency standard for the International Electrotechnical Commission (IEC). The new international standard defines efficiency classes IE1, IE2 and IE3 for three-phase motors. The efficiency classes for 1.1 kW induction motor is shown in Table 2.

The differences in treatment of SLL have been seen to produce different efficiencies on the same tested motor. A 1.1 kW induction motor was tested according to various National Standards. Due to the similarity in testing standards, only the IEEE Std. 112, IEC 60034-2-1 – direct method, JEC 37 and GOST 25941-83 loss segregation method were used. The experimental test results are shows the difference in efficiency values using different standards, Fig. 2.

Table 2

Efficiency classes of CEMEP classification for 4-pole, 50 Hz induction motor

Rated power, kW	IE1 (EFF2) Standard efficiency	IE2 (EFF1) High efficiency	IE3 Premium efficiency
1.1	75	81.4	84.1

Fig. 2 compares the efficiency of a 1.1 kW induction motor derived from four international standards, namely, the IEEE Std. 112, IEC 60034-2-1 (direct method), JEC 37 and the GOST 25941-83. The direct method IEC 60034-2-1 and IEEE Std. 112 result in the lowest efficiency. The difference comes from the different treatments of the stray load losses. The IEEE Std. 112 derives it indirectly from tests, and the GOST 25941-83 assumes to be fixed 0.5% of the rated power, whereas the JEC-37 ignores it altogether, resulting in the highest efficiency. The difference between founded levels of efficiency results in that the classification according CEMEP could have this motor as IE1 Standard efficiency or in a case of direct method the value of efficiency is lower than desired level and the difference would be more significant in the case of higher rated power motors. The main point is that a standard efficiency motor made in the one country cannot be compared with a motor made in another one for energy-saving considerations.

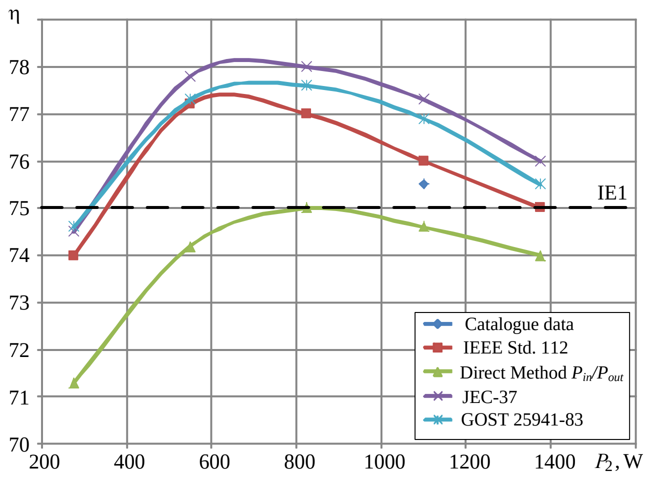

Fig. 2. Efficiency of 1.1 kW induction motor according various standards

The value of induction motor efficiency can be affected by various aspects one of them is National Standardization. The paper considers the influence of various standards on the value of induction motor efficiency and the efficiency level in accordance with CEMEP is evaluated. As efficiency level determined in accordance with National standards depends on the stray load losses accuracy determination in the future it is planned to work on the development of the experimental procedure for stray load losses determination.

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