Energy saver motor. How saving is it ?

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Abstract

Users of major industrial companies are frequently faced to the decision of buying more expensive motors, but always with a feeling of unsureness about the presumed economical advantages. That is because, the economic analysis rely on the declared motor efficiency. This work examine and compare the various methods for determining the efficiency measurements, covering motor ranging from 1 to 100 horsepower. That is an important factor to be considered when estimating the costs of an industrial plant.

1. INTRODUCTION

Following a worldwide tendency, the use of energy-saver motors has became a subject of considerable interest in Brazil in the last few years. As a matter of fact, in a country where motors consume energy magnitudes of about 180,000 GWh, the motor efficiency is always of assured importance. In round figures, the motor loss accounts for about 4,000 MW, that is, one third of the power generated by Itaipu Power Plant turbines, one of the largest hydroelectric plants on the world [1].

Because of the electrical energy shortage and the high costs for new investments in this field, it was mandatory to support the development of more efficient motors as well as their rational application, leading to a substantial economy of money and energy. From those needs, it was created in 1985, in Brazil, the National Electrical Energy Conservation Program (Programa Nacional de Conservação de Energia Elétrica). This program stimulated the development of high efficiency motors and the labeling of power factor and efficiency on it, remembering the consumer to make correct use of the energy.

Most motor manufacturers have provided a special category of product with increased efficiency and evidently higher price. However, questions arise about the application of energy-efficient motors. Users of major industrial companies are frequently faced to the decision of buying more expensive motors, but always with a feeling of unsureness about the presumed economical advantages. The frequent questions are related to the reliability of the declared motor efficiency associated with the appropriate testing method, mainly because tests executed according to different methods show significant disagreement on the efficiency measurement. Moreover, the duty cycle application, the power factor, the harmonic contents in the supplier voltage, are all factors affecting losses in an electric motor, which puzzle the end user. Trying to answer some of this questions, the Institute of Electricity and Energy of the University of Sao Paulo is presently developing a survey on this subject.

2. EFFICIENCY MEASUREMENT

Nowadays, there are two basic test standards: the first is the IEC 34-2 recommendation, titled “Methods for determining losses and efficiency of rotating electrical machinery from tests”, the second is the IEEE 112 standard, named “Standard test procedure for polyphase induction motors and generators”. However, there are other standards widely discussed, as the CSA C-390 from the Canadian Standards Association, which is very similar to the IEEE 112 standard. The main difference is that the IEEE and CSA standards are basically laboratorial practices and the IEC is a methodology.

The first step in this research was to examine and compare the various methods for determining the efficiency measurement, covering induction motor ranging from 1 to 100 horsepower, an area of special importance in industrial applications.

In the course of the experiments, it was found that the main difference between the various recommended methods is the treatment of the stray-load losses, which is the most difficult loss to be measured. Furthermore, the stray-load loss is an important item to be monitored, as it is sensible to any alteration the motor manufacturing process may suffer. In fact, the stator and rotor winding losses, friction and windage losses and the core loss are much more related to the material and design, while the stray-load loss accounts for variations that may occur during the production process of a series of motor components.

Thus, it is possible to find motors of same design and materials having different efficiencies due to variations in the manufacturing procedure. For instance: even subtle modifications introduced in the core sheet, caused by the wear of the pushing tool, for instance, may be detected by the amount the stray-load loss is increased. Example like these may, of course, challenge the efficiency declared by the manufacturer, which is obtained during tests on a prototype motor.

The authors agree with the opinion of the American writers [2,3,4], stating the dynamometer method, which measures input and output directly, as the preferable procedure for efficiency determination. When using this method, the stray-load loss is usually obtained by deducting from the total loss the stator and rotor winding losses, the friction and windage losses and the core loss, this last two assumed as constant. Nevertheless, the efficiency tests are not ordinary performed to verify its possible variation.

3. THE TECHNICAL STANDARDS

The test methods to be analyzed are described in the standards IEEE 112/1991, IEC 34-2/1972, CSA C-390/1993 and ABNT NBR 5383/1982 (Brazilian standard).

From those four above mentioned standards, five groups of methods for determining the motor efficiency can be obtained.

Method 1: Method in which the input and output powers are directly measured, according to IEEE, IEC and NBR standards.

The measurement of input and output is done after the rated load temperature rise test is obtained. The IEEE standard asks for a correction of the stator loss to a specified temperature before determining the motor efficiency.

In this method efficiency, current, power factor are plotted versus output power. Normally the resultant points should be smoothed doing verification of the parameters consistence obtained from traced curves.

Using these normalized curves, the product of the input power by the efficiency is equal to the output power, considering the measurement uncertainty.

Method 2: Method in which the input and output powers are measured with losses segregation and indirect measurement of the stray-load loss, according to IEEE and CSA standards.

The total losses is divided in its components. The stray-load loss is defined as the total losses minus the sum of the conventional losses (stator and rotor I^2R losses, core loss, friction and windage loss). There are corrections to a specified temperature for the slip and stator and rotor I^2R losses. The stray-load loss is obtained from a linear regression analyses to reduce the effect of random errors in the test measurements.

The CSA standard establishes where and how to measure the stator winding temperature by inserting temperature sensors in the winding-end heads and slots, or measuring the winding resistance at every load point.

The method 2 can provide different results from method 1, mainly due to the stray-load loss adjustments in which all the test measurement errors are included.

Method 3: Method with duplicated machines, as seen in the IEEE, IEC and NBR standards.

When two identical machines are coupled together and supplied from two separate power source. Electrical power into and out of the two machines is measured and the difference is the combined loss of the two machines.

Method 4: Method with direct measurement of the stray-load loss and losses segregation, according to IEEE, IEC, NBR and CSA standards.

In this method, the efficiency is indirectly calculated by the total losses determination, which is the sum of the core loss, the friction and windage loss, the rotor and stator I^2R losses, the stray-load losses and the brush-contact losses (if there are any).

At the IEEE and CSA standards, the stray-load loss is obtained directly from specific tests, like the rotor removed test and the reverse rotation test, or alternatively a value assumed which is a function of the rated output.

Method 5: Method in which the equivalent circuit is determined, according to IEEE, NBR and CSA standards.

The motor efficiency is calculated based on the parameters of the equivalent circuit. In this method, it is very important to take the rotor impedance at the low frequency. The rotor impedance precision will affect greatly the characteristics under load.

When calculating the parameters, the reactances are corrected to the rated frequency and the resistances are corrected to a specified temperature.

4. Economic Payback

A Brazilian manufacturer publishes in its catalogs the following equation for calculating the investment return when one decides for buying a high efficiency motor:

$$\mathbf{R}\left(\mathbf{year}\right)=\frac{\mathbf{\Delta C}}{\mathbf{0{,}736\cdot cv\cdot Nh\cdot \$kWh}\cdot\left(\dfrac{\mathbf{100}}{\eta_{\mathbf{std}}}-\dfrac{\mathbf{100}}{\eta_{\mathbf{es}}}\right)}$$

where:

R = payback period in years

ΔC = cost difference between energy saver sizing and standard motors

cv = horsepower

Nh = hours of operation per year

$kWh = energy cost per kWh

$\eta_{\mathbf{std}}$ = standard motor efficiency

$\eta_{\mathbf{es}}$ = energy saver motor efficiency

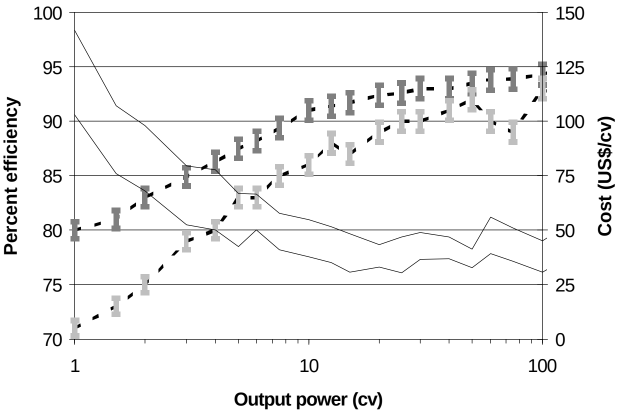

Figure 1: 4 pole, energy saver and standard, full load efficiency and motor cost versus output power

5. CONCLUSIONS

The application of the payback formula may lead to the conclusion that energy saver motors result in a good investment.

Nevertheless, when applying this formula one should consider the following points:

- the application of different methods to determine the efficiency usually leads to discrepant results, that may reach **output power (cv)**
- Identical motors may present different efficiencies due to variation in the production process.
- It is rare to find a motor operating at full load, all the time.
- The effect of the voltage variation, even for permissible amounts, affects the efficiency in several points [6]

All together, the above factors make very doubtful the convenience of applying energy saver motor and the payback period.

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