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Assessment of the achieved savings from induction motors energy efficiency labeling in Brazil

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ABSTRACT

Since 1995 Brazil has been applying its labeling program to increase the efficiency of application of many household appliances and equipment. From 2003 on inductions motors have also been receiving the PROCEL[2] prize, which helped push motors efficiency over than those limits established by the labeling program. Therefore, this work presents the development of a model to estimate the amount of savings obtained with the usage of the PROCEL endorsement labels in standard and in energy efficient motors. The estimated peak demand reduction is also inferred. The developed model makes the usage of sales information and of a discard function to estimate the Brazilian motor stock. Approaches such as the use of efficiency loading and efficiency aging factors are employed to estimate motors consumption.

1. Introduction

Labeling programs have diligently been applied as a worldwide effort to reach the highest levels of energy efficiency in household appliances and in industrial equipment, contributing to the reduction of greenhouse gases emissions and seeking overall energy efficiency increase.

In Brazil, the labeling process usually starts from testing and classifying given equipment and a label is stamped on it in order to show its efficiency indicator. The stamp has dual purpose: to inform the consumer about the efficiency of the appliances and equipment, and to stimulate manufacturers to economically improve the performance of their products regarding to the energy efficiency point of view. After classifying the equipment, minimum efficiency performance standards are established for equipment and appliances, along with a standard test method for efficiency evaluation [1,2].

International experience has shown significant amount of energy savings due to labeling programs [3–10]. One of the Brazilian Government efforts for energy conservation was the establishment of the Brazilian Labeling Program. In 1995, refrigerators and freezers were the first equipment to receive the label. Latter, fluorescent light bulbs, air conditioners, three-phase squirrel-cage induction motors, and solar heaters along with their associated boilers were included. More recently, washing machines and TV sets also have been considered in this program. In 2012, the label was applied to 3467 equipment, covering 36 products categories, achieving estimated energy savings of about 8.8 TW h.

When compared with the many appliances and equipment, three-phase induction motors deserve special attention whereas they are responsible for a great share of the energy consumption of a country [5–10]. In addition, motors are not only sold to final users, but also to appliance and heavy equipment manufacturers. Three-phase induction motors are responsible for about 60% of the Brazilian industry consumption and about 30% of the bulk electricity consumption, constituting a great potential of energy savings.

Within the several governmental measures to promote energy conservation, minimum efficiency performance standard has been established by a Federal Decree for all the squirrel-cage induction-motors up to 250 HP traded in Brazil [11,12]. Since 2003 the PROCEL prize of energy efficiency has been offered, and the PROCEL label has been applied to the most efficient motors.

Therefore, two types of motors have been manufactured: the standard motor and the high efficiency motor, in accordance to the above mentioned Federal Decree. In addition, those two categories can be divided into two other categories: the motors that were recognized with the PROCEL label and those that were not, resulting in four motor efficiency classes.

Both, the Federal Decree and the PROCEL label cover motors up to 250 HP, fed up to 600 V, from 1 to 4 pole pairs, i.e., synchronous speeds of 3600, 1800, 1200 and 900 RPM, respectively. Fig. 1 presents average efficiencies of motors of same power with different rated speeds.

It can be seen in Fig. 1 that some motors have efficiency greater than those established by the Federal Decree, showing that there

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2 The Brazilian National Energy Conservation Program.

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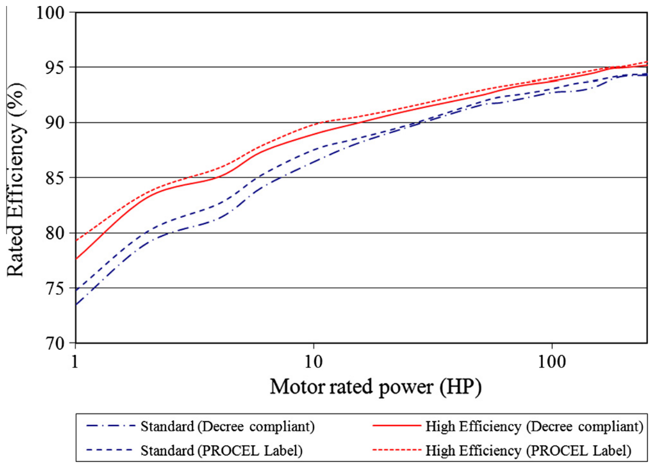

Fig. 1. Average efficiency of electrical motors.

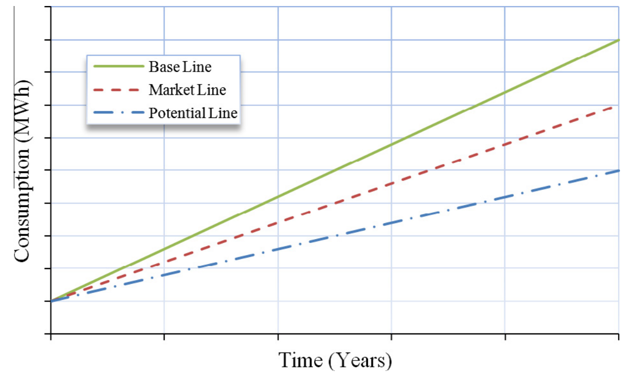

Fig. 2. Estimated motor market lines along the time.

was technology and knowledge enough to have a real increase in the motors efficiency. As a result of the manufacturers improvements in motor design and in the production procedures, from December 2009 on, the standard motors have not been manufactured in Brazil anymore [11,12].

The contribution of energy efficient motors to the energy savings in Brazil is quite noticeable. The determination of the amount of energy saved is a hard task, mainly due to the uncertainties inherent to the measurement process of energy efficiency programs results. Paradoxically, this work deals with the measurement of the energy that was not used.

In the past the calculation of the energy saved with the usage of energy efficient motors for each year, as a consequence of the Brazilian labeling program, was made simply by multiplying the number of new efficient motors in the market by the loss reduction estimate of each one [16]. The installed motors used to be divided in two categories 0–10 HP and >10–40 HP, considering two types of equipment with stated shares, standard (90%) and high efficient (10%). The working hours were established in 3000 h/year, with a constant average loading factor of 70%.

As an evolution to the previous techniques, and instead of estimating the energy saving potential based on an end use approach [17], this work presents the development of a model to estimate the energy consumption, peak demand reduction, and the saved energy due to the induction motors energy efficiency labeling program developed in Brazil. The model was constructed taking into account sales information from the manufacturers, motor scraping, annual working hours, and loading information from the industries; motor efficiency curves from accredited motor testing laboratories, and motor efficiency degradation with aging were also considered, to estimate the whole, considering standard- and high efficiency-motors, for four categories of motor rated power.

2. Model development

The proposed modeling to quantify the impact of the PROCEL induction motors labeling program in the energy savings and peak demand reduction is based on the knowledge of the Brazilian motor stock.

It is done by constructing three hypothetical lines: the base line, the estimated market line, and the potential line, reflecting market scenarios and referring to the estimated energy consumption of the motor stock along the time, as depicted in Fig. 2.

The upper line, known as base-line, represents a stock composed only by standard-efficiency no-labeled motors, resulting in higher energy consumption along the time, as the efficiencies in the beginning of the PROCEL Label Program were considered. The lower line, known as potential line, represents an ideal market composed only by high-efficiency motors, with eventual low energy consumption. The difference of both lines is the total potential savings with the replacement of labeled energy-efficient motors for the standard ones.

The intermediate line is the estimated market, composed by a mix of labeled and non-labeled, high- and standard-efficiency motors. It tries to represent the actual stock by establishing the market share between both types of motors along the time. The difference between the energy consumption of the base-line and the energy consumption of the estimated market line represents the achieved energy savings, whilst the difference between the energy consumption of the estimated market line and the energy consumption of the potential line represents the achievable potential of the induction motors energy efficiency labeling program.

The aforementioned market line should be constructed taking into account as much details as possible in order to get the best system representation, and to reduce the uncertainties of the obtained results. Therefore, the developed model considers motor sales information from the manufacturers; motor scraping, annual working hours, and loading information from the industries; motor efficiency curves from accredited motor testing laboratories, and motor efficiency degradation along the years from field experience of research centers and technical literature.

The model equations development is presented in the following sections. The general aim is to estimate the amount of installed motors and their consumption for a given scenario and year. It should be noted that both base line and potential line are market lines with biased mix of motors. The base line is a market line formed only by standard-efficiency non-labeled motors, whilst the potential line is a market line made only by high-efficiency labeled motors. The actual market line remains between these two lines, with a mix of high- and standard-efficiency, labeled and non-labeled motors, dictated by the sales along the time.

The following equations refer to a given motor type. Therefore, for an overall evaluation, they must be applied for all rated power, efficiency classes, and number of pole pairs.

2.1. Motor inventory estimation

The amount of installed motors in a given year is calculated by the summation of motor sales along its life expectance minus a motor discards function [13].

$$M_j = \left(\sum_{i=j-n}^{j} S_i \right) - D_j \tag{1}$$