Power transformer energy performance: landscape of market surveillance testing avenues

Worldwide and EU Technical standard and legislative framework

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***Abstract*—This paper reports the results of the research carried out by Power transformer Task 2.1 „Worldwide and EU Technical standard and legislative framework into the WP2 - Landscape of testing avenues“ of the INTAS project.**

Keywords—power transformres, energy performances, testing, technical standards, regulations, market surveillance

I. INTRODUCTION

The energy performance of power transformers is currently being improved around the globe. In the EU alone, total losses from inefficiencies in 2008 amounted to 93.4 TWh per year, equivalent to almost 12% of the continent's residential electricity consumption. A regulation covering this group was adopted in May 2014. The cost-effective improvement potential through more efficient design has been estimated in about 16.2 TWh per year in 2025, which corresponds to 3.7 Mt of CO2 emissions, with a projected loss of (aggregate of the 10-20% expected loss through non-compliance) of 1.6-3.2 TWh.

There is a need to strengthen the capacity of Market Surveillance Authorities (MSAs) to conduct Ecodesign related market surveillance activities with respect to new and pending industrial and tertiary sector products. Especially in the case of customised products which are unsuitable for testing in laboratories. There is a lack of expertise, experience, and resources available across Europe for such kind of testing.

There is therefore the need to determine the suitability and relevance of current regulations to deal with large industrial products from a market surveillance perspective, as well as to support from aspects of future legislation. It will also enable Market Surveillance Authorities (MSAs) to establish when and how to coordinate testing large industrial products on-site of manufacturers.

The focus of the research is to support Market Surveillance Authorities (MSAs) in monitoring, verification, and enforcement in order to ensure compliance for very large industrial products, specifically transformers and industrial fans, with the requirements of the Eco-design Directive. The research focuses on large power transformers with an aim to develop a methodology that could subsequently be extended to other categories of large products.

II. EXTENDED ABSTRACT

This paper reports the results of the research carried out by Power transformer (Group A) Task 2.1 „Worldwide and EU Technical standard and legislative framework into the WP2 - Landscape of testing avenues“ of the INTAS project.

More specifically, the research has been focused on:

- the identification of current EN/IEEE/IEC technical standards and national legislative documents of interest for testing energy performance of power transformers
- the analysis and comparison of these documents in order to identify the size and type of covered products and standardized methods for:
  - collecting mandatory information requirements, for both market inspectors and end users
  - evaluating energy performance
  - classifying and testing unique, very large, or customized products

The primary geographical focus of this research has been:

- Australia and New Zealand
- Brazil
- Canada
- China
- European Union
- India
- Israel
- Japan
- Korea
- Mexico
- United States of America
- Vietnam

This paper discusses critically the technical boundaries, the existing energy performance metrics, the standardized measurement methods and provides a comparison highlighting issues and criticalities.

The paper considers three-phase and single-phase power transformers (including auto-transformers) with a minimum power rating of 1 kVA used electricity transmission and distribution networks or for industrial applications with the exception of small and special transformers.

There are different metrics in use for assessing the energy performance of a power transformer. All of them fundamentally refer to two main features: maximum losses and minimum efficiency. Each approach offers certain strengths, but also has some weaknesses. Hereunder the different approaches are shortly discussed in light of the experience built up with the new European Regulation N 548/2014.

The measurement of losses is critical for any energy performance metric as losses underpin a policy requirement such as maximum loss levels as well as minimum efficiency level at a specified loading point or some other metric that can be calculated.

For the measurement of losses of power transformers, most countries and economies active on distribution transformers use a test standard based on IEC 60076 series. In some cases, there are slight local modifications that have been made due to specific or unique requirements.

United States and Canada, on the other hand, rely on test that are based on IEEE standards. US uses a test standard that was developed by the Department of Energy (DOE) and the National Institute of Standards and Testing (NIST).

Comparing different practices based on different standards is sometimes impossible mainly because of different:

- Rated power definition
- Reference temperature
- Rated frequency
- Rated maximum voltages of the equipment
- Rated power definition

In EN standards, transformer rated power represents the rated input to the transformer while for instance in IEEE standards the rated power is defined as the transformer output power. This affects transformer energy performance definition.

Although the two equations seem to give the same numerical results, in reality they are important underlying differences.

- Transformers with the same losses specified according to EN or IEEE practices can be considered to have the same efficiency only as long as the rated power definition is consistent (i.e. based on the same power, either input or output).
- Transformers with the same rated power (because of standardization of the series) and the same efficiency specified according to EN or IEEE practices do not have the same total losses, being the total losses of the transformer specified according to IEEE larger than the ones specified according to EN.

Although the first point above is quite evident, in the practice it is not considered, since both EN and IEEE refer to the same numerical values of rated powers in their series. Similarly, also loss values defined according to IEEE standards cannot be compared directly with the same figures specified to EN standards, because they are actually referring to different rated powers.

The EU Regulation for Ecodesign specifies a reference temperature of 75°C for load losses of liquid immersed transformers. US DOE refers instead to 55°C, while in IEEE standards 85°C are used. This is a remarkable difference, since an increase of few degrees in the reference temperature corresponds to several percentage points higher load losses.

The energy performance of power transformers is not the same when operated on electricity systems with different rated frequencies (50 Hz or 60 Hz).

Comparing the performance of transformers operating at different frequencies may require finding suitable conversion factors. However, since this is not so straight-forward, from a practical point of view it makes more sense to take note of the energy performances of each transformer at its specific operating conditions.

The energy performance of medium power transformers is not the same when operated on electricity systems with different rated voltages. Other conditions being equal:

- the lower the rated voltage of the LV winding / the higher the expected losses / the larger the quantity conductor material.
- The higher the rated voltage of the MV winding / the higher the expected losses.

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