

Title

**FINDINGS AND PROPOSALS  
BY THE ECODESIGN SUBGROUP ON LARGE POWER TRANSFORMERS  
FOR THE PREPARATION OF THE  
COMMISSION'S REGULATION IMPLEMENTING DIRECTIVE 2009/125/EC  
WITH REGARD TO SMALL, DISTRIBUTION AND POWER TRANSFORMERS**

## **1. INTRODUCTION**

This report contains the findings and the conclusions elaborated by the Ecodesign Subgroup on Large Power Transformers established after the consultation forum held in Brussels on April 20th 2012.

The mandate of the subgroup was to:

- Evaluate the technical feasibility to have a regulation on the efficiency of large power transformers
- Define a suitable equation to be used for defining large power transformers efficiency in the perspective of the EC Regulation
- Propose a technically suitable regulation method (scheme) for large power transformers

## **2. DATE OF MEETINGS**

The Subgroup on Large Power Transformers has met till now twice in Brussels on:

- June 29<sup>th</sup> 2012
- September 28<sup>th</sup> 2012

## **3. POSSIBILITY TO HAVE A REGULATION ON THE EFFICIENCY OF LARGE POWER TRANSFORMERS**

After deep and long discussion the subgroup confirmed that it is technically possible to specify a minimum efficiency requirement for large power transformers that would take into account no-load and load losses.

The discussion confirmed that Total Cost of Ownership could be complementary to the Ecodesign Regulation, but unfortunately it does not fit within the framework of the Directive because the Commission can only regulate the manufacturer and not the customer-side of the transformer sale.

## **4. ENERGY EFFICIENCY EQUATION**

The subgroup concluded that the definition of an equation suitable for defining large power transformers efficiency in the perspective of the EC Regulation should be based on the following main criteria:

- Based on measurable quantities

- Simple and easy to be used
- Independent of technology
- Conventional even if related real physical phenomena

In the case of large power transformers these requirements should mean to refer the efficiency equation to:

- Apparent (VA,  $\cos \varphi = 1$ ) instead of Active Power
- peak instead work point efficiency
- Standard rated conditions instead work point conditions:
  - Temperature
  - Sinusoidal wave forms
  - Including other ancillary service permanent losses

After the evaluation of several definitions of energy efficiency taken from international standards as well as suggested by attendees, the most suitable equation seemed to be:

$$\eta_{\max} = 1 - \frac{2 \cdot (P_0 + P_{c0})}{S_r \cdot \sqrt{\frac{P_0 + P_{c0}}{P_k}}}$$

- $\eta_{\max}$  is the energy peak efficiency
- $P_0$  are the no load losses\*
- $P_{c0}$  is the electrical power required by the cooling system for no load operation
- $P_k$  are the load losses\* corrected to reference temperature\*\*
- $S_r$  is the rated (apparent) power of the transformer on which  $P_k$  is based

\* measured at rated voltage and rated frequency, on the rated tap

\*\* 20 °C + Average winding rise (i.e. 90 °C for OD cooled transformers, 85 °C for ON or OF cooled transformers)

Notes:

- The equation is the simplification of the general formula of efficiency.
- The equation respects the philosophy of EN 60076 which refers the rated power to the input side of a transformer. With such an equation even with a loading factor  $k$  of 1 the transformer will never be overloaded.
- The additional cooling losses needed for operation at rated power have not been included in the losses due to load for maximum efficiency determination because usually the maximum efficiency is at a load factor much lower than unity.
- The reference temperature chosen for the losses reflects the actual use of transformers at rated power, and allows for comparing different insulation system with different guaranteed value of winding temperature rise. For instance an OD cooled transformer with a guaranteed average winding rise of 70 K will be referred to 90 °C, an ON or OF cooled transformer with a guaranteed average winding rise of 65 K will be referred to 85 °C, and a high temperature insulation transformer with a guaranteed average winding rise of 100 K will be referred to 120 °C.
- In case of third winding designed to supply a noticeable load in a three winding operation, the load losses shall be based on the three winding operation.
- It should be noticed that a transformer with a reference temperature of 75 °C will show a value of load losses about 4% lower than the same one with a reference temperature of 90 °C, the actual value depending on the respective share of eddy and  $I^2R$  losses.
- The use of an equivalent two winding design power in such an equation offers the advantage of taking care of the extra losses which can't be avoided if a large power

tertiary is used. This also take into account the lower losses generated by autotransformer due to their lower physical size.

- Two winding equivalent design power for transformer, is half the sum of the rated of each individual winding.
- For autotransformer the equivalent two winding design power is to be used

## 5. REGULATION METHOD FOR LARGE POWER TRANSFORMERS

The rationale of the regulation method (scheme) agreed by the subgroup is to base the method itself on:

- energy peak efficiency (EPE hereunder) as defined in the paragraph 4
- a limit for the minimum EPE set on the base of the actual population of large transformers

For achieving these goals the following 5 steps are requested:

1. To collect statistical data about the existing population manufactured in the last 10 years
2. to classify the existing population in homogenous sub-categories
3. To calculate EPE for each sub-category of the existing population of large power transformers
4. To define the EPE trend of each defined sub-category
5. To define the minimum EPE limit according to the trend for each sub-category

Notes:

- Over the minimum EPE limit the user can specify the transformer (load and no load losses, capitalized cost, etc.) according with its specific technical needs
- Being the minimum EPE limit based on the majority of the existing population, there is no risk of technical feasibility by the actual technology etc...
- In the first step the limit should not be too strict, the next tier(s) (3 and 6 years) should increase the level of ambition.

The subgroup agreed to include in the preparatory calculations for the regulation all type of Large Power Transformers manufactured or installed during last 10 years with  $U_m > 36$  kV, fitting with the 3 following subcategories:

- generator step up
- transmission
- primary substation transformers

Thank to T&D Europe some statistical data were already available, other data will be collected and elaborated by WG29 of Cenelec T14.

T&D Europe statistical data about existing population of large power transformers are shown in the presentation given during the meeting of September 28<sup>th</sup> 2012.

Cenelec T14 WG29 statistical data are foreseen by end of October 2012.

The two set of data will be compared (instead of merged) to check their significance.

Data available till now seems to indicate no need to distinguish inside of each subcategory on the base of the short circuit impedance.

The definition of EPE trend of each defined sub-category still require the consensus inside the subgroup on the trend definition method to be adopted.

The minimum EPE limit for each sub-category should be defined:

- shifting down the statistical EPE trend of actual population excluding a given percentage of existing transformers (for instance, 5%, 10% or 15%)

- making the limit flat for rated power larger than 100 MVA
- Making sure that the fit-curve and the flat limit match properly

The definition of the amplitude of the shift is a policy question, which requires a discussion at the full Ecodesign Consultation Forum..

The example shown in the following figure summarizes graphically and give a qualitative idea of the method of regulation of energy efficiency of large power transformers suggested by the subgroup at the conclusion of the second meeting.

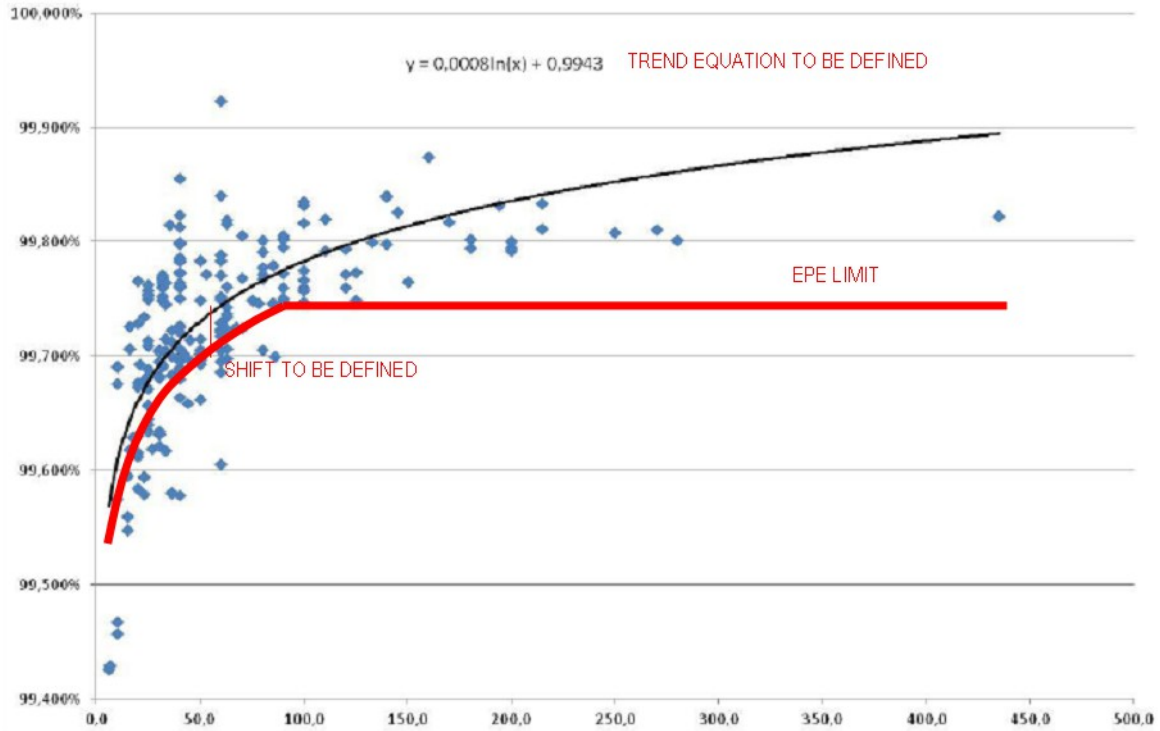


Figura 1 – Qualitative idea of the method of regulation of energy efficiency of large power transformers suggested by the small group at the conclusion of the second meeting. Example based on an elaboration of T&D Europe data collection.