The European Association of the Electricity Transmission and Distribution Equipment and Services Industry

T&D Europe position on Power Transformers based on "Working document on a possible Commission Regulation implementing Directive 2009/125/EC with regard to small, distribution and power transformers" and on final VITO report concerning Lots 2 distribution and power transformers task 1 (January 2011)

10 April 2012

1. Summary

The industry represented by T&D Europe[1] has been constantly active in improving the energy efficiency performance of its products. T&D Europe therefore welcomes the European Commission in its action aiming at achieving higher efficiency of energy consuming products. In particular, it supports the EU energy efficiency target of 20% by 2020, as well as the overall objectives of the Energy Efficiency Action Plan adopted in March 2011 and the European Commission proposal for a Directive on Energy Efficiency presented in June 2011, which should boost the deployment of energy efficient technologies and help reinforcing the EU's technological advance in this sector.

The VITO report suggests that the efficiency improvements required for power transformers can be achieved by using fixed Minimum energy performance standards (MEPS).In this position paper T&D Europe shows that the MEPS approach cannot effectively be used for Power Transformers due to **their large variability in specification requirements**. T&D Europe therefore proposes to use the Total Cost of Ownership (TCO) method to reach the goal for increased power transformer energy efficiency. It is expected that this method gives the same or higher reduction of losses and CO_2-emissions than the MEPS method when appropriates Minimum Loss Evaluations are specified

T&D Europe is willing to work with the European Commission and other stakeholders to develop a proposal for such minimum loss evaluations.

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[1] T&D Europe (www.tdeurope.eu) is the European Association of the Electricity Transmission & Distribution Equipment and Services Industry, which members are the European National Associations representing the interests of the electricity transmission and distribution equipments manufacturing and derived solutions. The companies represented by T&D Europe account for a production worth over € 25 billion EUR, and employ over 200,000 people in Europe.

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2. Power Transformers' role in T&D environment

Power transformers are the key elements in the transmission and sub-transmission electrical network and are placed in all nodes of the network. To fit the requirements and specification of a particular network, power transformers are in practice engineered to order, in other words tailor made. For historical reasons, networks are different in different countries as well as within the same country. For each new power transformer the design is guided by complex specifications issued by the customer. Here customers refer to private owners of production plants and industries but more often than not to transmission network owner, regulated by local governance.

3. Power Transformers, Definition

In the VITO report, the base for power transformers is defined as a 100 MVA 132/33 kV unit selected to represent all power transformers. The choice of transformers in Table 7-3 **does not well represent the variability** demonstrated by the cases given below

- Generator Step-up Transformers
- System Intertie transformers (connecting different networks)
- Special power transformers such as
  - Industrial Transformers
  - HVDC transformers
  - Phase Shifting transformers
  - Track-feeding transformers
  - Shunt and Series reactors

4. Important parameters in Power Transformers specifications

Power transformers are all unique. Several countries (e.g.: Germany, France, Italy….) in EU have historically developed their own specifications for typical transmission transformers including ratings and losses. However, most customers are using the general international standards only complemented by the specific requirements for the transformer application at a specific node in the network.

The specific requirements are power ratings, voltage ratings, number of voltage systems (Primary-Secondary-Tertiary), regulation ranges, short circuit impedances, loading pattern, short circuit force requirements, weight and limitations for transportation dimensions which all together make the majority of power transformers unique. There are also other design considerations for the special applications shown in section 3.

In order to demonstrate the large variety range of power transformers we give some simple examples by mentioning the major parameters and typical values for them:
Power ratings, from 5 MVA up to 1500 MVA
Voltage ratings:

Primary voltage: From 72.5 up to 400 kV
Secondary voltage: From 36 up to 240 kV

Tertiary voltage: From 10 up to 72.5 kV
Connection types
Short-circuit impedances: Normally from 6% to 24 % but in some cases even higher
With or without on-load tap-changer
With or without De-energized tap-changer
Regulation range and number of positions
Transport limitations

Combinations of all these parameters lead to thousands of different design specifications.

To demonstrate the consequences of the variety of design specifications, four different designs of a 350 MVA 400/230 kV transformer have been optimized with the same loss capitalization. Only the connection type was changed between auto connection and galvanically separated (full) windings and two different short-circuit impedances, thus only two of the above parameters were changed. The graphs below show the losses for the different designs compared to the VITO reference in Table 7-3 of their report.

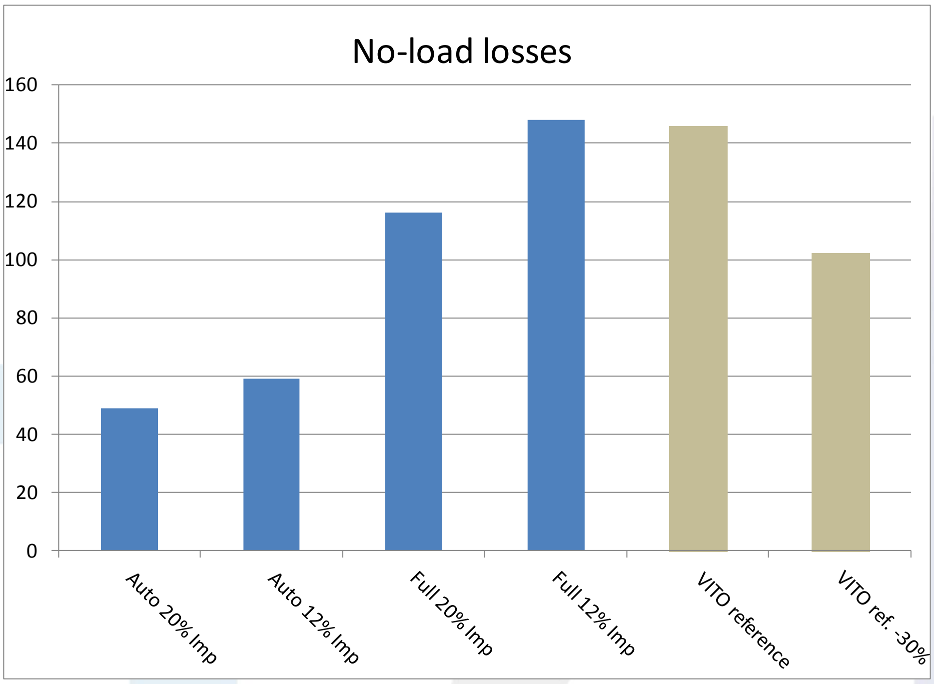

Fig. 1. Variation of no-load losses in four optimized 350 MVA 400/230 kV transformers from left: Auto transformer 20 % impedance, Auto transformer 12 % impedance, full transformer with 20% and 12 % impedance respectively. The VITO 350 MVA reference transformer and the VITO 30% loss reduced units are shown for reference.

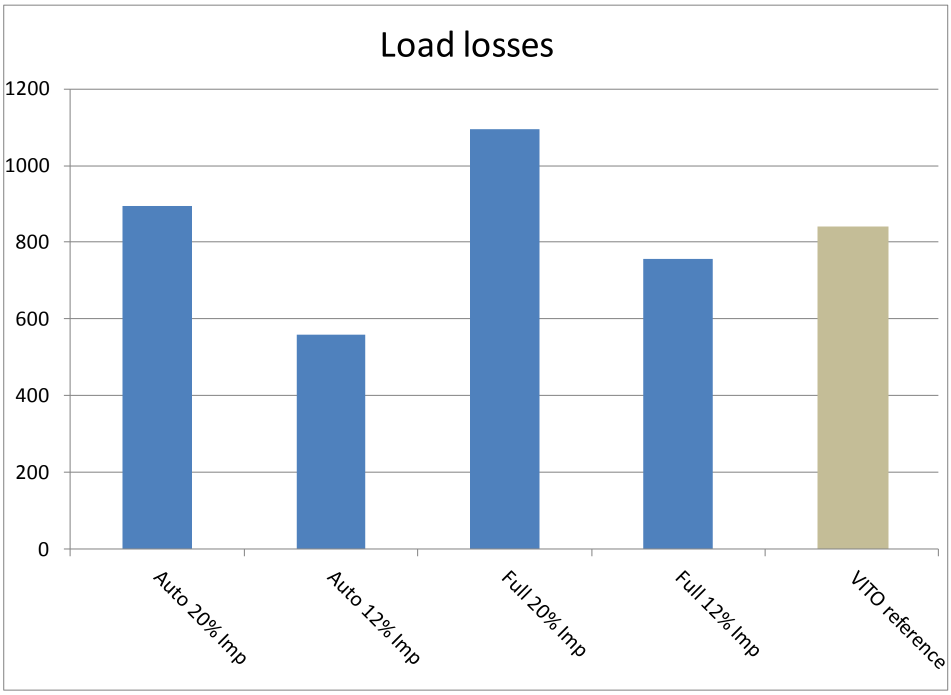

Fig. 2. Variation of load losses in four optimized transformers: Auto transformer 20 % impedance, Auto transformer 12% impedance, full transformer with 20% and 12% impedance respectively, compared to the VITO report reference power transformer

As can be seen from the above the specified connection type and required impedance has a major impact on the losses in a power transformer. It would be practically impossible to prepare a standard for each and every type of power transformer application which may be required in the European transmission and sub-transmission networks. By necessity the transformers then would have to be grouped in categories and for each category, the design with the highest losses would be setting the loss level for that category. As a consequence the other designs in the same category will have more relaxed requirements and the goal for energy efficiency would be harder to achieve.

In this position paper, T&D Europe concludes that it is not correct to extrapolate the loss values from one MVA rating to all other since there are several other specification parameters strongly influencing the transformer losses. The MEPS concept proposed in Table 7-3 of VITO report can therefore not be fully used for power transformers

5. Alternative methods for Power Transformers to improve efficiency and meet the targets for increased energy efficiency.

T&D Europe proposes that the goal to reduce losses in Power Transformers should be achieved by specifying Minimum Loss Evaluations.

Loss Evaluations[2] and TCO

Loss evaluations and the TCO are well described in the VITO report. The method is based on the principle of minimizing the sum of the product cost and the net present value of the future energy losses of the transformer. This method by nature allocates resources to reduce losses at the lowest cost when the correct capitalization values are applied.

The loss evaluations concept is used in EU since the first oil crisis 1973 to evaluate quotations from different transformer manufacturers. The customer associations at that time had set the loss evaluations based on the governmental interest rates, often about 3-4 %, and 30-40 years life time.

All major utilities in Europe as well as the rest of the world and most of the private enterprises are today using loss capitalization to differentiate between tender designs which are also mentioned in the VITO report.

Typical value of Loss Evaluations

Typical loss evaluation value used today in Europe is approximately 3000 - 5000 EUR/kW for no-load losses and 1000 – 2000 EUR/kW for load losses. However the variation is quite large between different countries and utilities, and there are examples from a few thousand Euro to twenty thousand.

Correct loss capitalization values can be derived in a straight forward way from the following parameters:

- Cost of energy
- Inflation rate
- Interest rate for investments
- Service time
- Load factor

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[2] Loss evaluation is the capitalized present value of 1 kW of loss considering transformer operation though out its estimated life time and is a direct mathematical function of the future cost of electricity, interest rate and inflation rate. As in the example used below let us consider the price of electricity as 0.05 €/kWh, then the cost of 1 kW of loss at the end of the first year will be, 0.05 €/kWh*8760 h *1 kW = 438 €. At the interest rate of 5% and time period of 40 years the net present value of 1 € is 17.16. Therefore the NLLE becomes 438 x 17.16 = 7,516 €/kW. If further an inflation rate of 2% is considered during 40 years then the NLLE becomes 10,021 €/kW.

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The table below shows the capitalization values for different reasonable values for these parameters

Energy price	Interest rate (%)	Inflation rate (%)			
		0.5	1.0	1.5	2.0
0.05 €/kWh	3	10963	11904	12962	14152
	4	9332	10072	10900	11828
	5	8045	8634	9290	10021
0.06 €/kWh	3	13156	14285	15554	16983
	4	11199	12087	13080	14194
	5	9655	10361	11148	12025

Table 1 Capitalized net present values of transformer losses versus realistic energy prices, inflation rates and interest rates. See footnote above

It is clear from the table that the loss capitalization values typically used today are considerably lower than what a straight forward calculation would suggest. A possible reason for this is that that the utilities after the deregulation in the 90'ties have not had any incentives from the Regulators to reduce network losses.

6. Conclusions

The MEPS concept cannot be used for power transformers because it is in practice virtually impossible to **predefine the maximum losses for all different types of power transformers** used in the European transmission and sub-transmission networks in a common standard.
The TCO method is the practical method to guide the efficiency requirements for power transformers.

T&D Europe suggests a deeper analysis on TCO approach should be made for power transformers. The energy efficiency requested can be achieved for all types of transformers by specifying Minimum Loss Evaluations (MLE). T&D Europe is willing to work with the European commission & and other stakeholders to develop a proposal for such minimum loss evaluations.

T&D Europe will submit a mapping of capitalization practice country by country in September 2012 to prepare a future regulation that should be applicable as soon as possible. The option 3 of the "Working document on a possible Commission Regulation implementing Directive 2009/125/EC with regard to small, distribution and power transformers" is preferred by T&D Europe but with a shorter time for implementation.