TECHNOLOGY NEUTRALITY IN POWER TRANSFORMER REGULATION AND STANDARDISATION

Angelo Baggini (University of Bergamo)

January 2023

ECI Publication No Cu0283

Document Issue Control Sheet

Document Title:	Technology neutrality Transformers
Publication No:	Cu0283
Issue:	01
Release:	Public
Content provider(s)	Angelo Baggini
Author(s):	Angelo Baggini
Editorial and language review	Bruno De Wachter, Andrew Wilson
Content review:	Bruno De Wachter, Fernando Nuno

Document History

Issue	Date	Purpose
1	January 2023	Publication on the Leonardo Energy website
2		
3		

Disclaimer

While this publication has been prepared with care, European Copper Institute and other contributors provide no warranty with regards to the content and shall not be liable for any direct, incidental or consequential damages that may result from the use of the information or the data contained.

CONTENTS

1 Abstract

The EU's mandatory minimum efficiency performance standards (MEPS) differentiate power transformers by rated power, rated voltage, and technology. The first two of these are self-evident and performance-based. This article addresses whether technology is pertinent as a differentiator.

The main differentiation is between liquid-filled and dry-type transformers. Higher losses are considered acceptable for dry-type transformers to compensate for their ability to fulfil a particular fire performance requirement. This technology-based concession has resulted from its historical development, but it hampers innovation and creates unfair competition. A better approach would be to formalise the concession to apply to all transformers that fulfil a certain requirement — in this case fire performance (but the same principle would hold for other performance requirements such as noise or recyclability).

Adopting a technology-neutral approach to transformer MEPS is among the aspects to be considered in the upcoming review of Regulation (EU) No 548/2014. Taking the example of fire behaviour, a "transformer with increased fire safety" should be defined in an unambiguous, technology-neutral way, based on its particular characteristics. Subsequently, minimum levels for these characteristics should be set, and a corresponding, harmonised test method covering all the relevant technologies should be developed.

2 INTRODUCTION

Power transformers operate 24 hours a day, 365 days a year and often have very long service lifetimes, typically exceeding 25 years. As a result, the energy they consume is the dominant factor in their environmental impact over their lifetime[1], despite the fact that energy efficiency is high — usually surpassing 98%. This means that any cost-effective measure that could reduce energy losses and their impact on the environment must be considered.

Technical solutions to improve the energy efficiency of power transformers are mature and commercially available. They are driven by minimum energy performance standards (MEPS) mandated by policy measures in major countries and regions around the world. This article analyzes some of the implicit assumptions in these policy measures which have resulted in the variation in MEPS for different types of power transformers.

Adopting a technology-neutral approach to transformer MEPS is among the aspects to be considered in the upcoming review of Regulation (EU) No 548/2014. Taking the example of fire behaviour, a "transformer with increased fire safety" should be defined in an unambiguous, technology-neutral way, based on its particular characteristics. Subsequently, minimum levels for these characteristics should be set, and a corresponding, harmonised test method covering all the relevant technologies should be developed.

[1] Preparatory Study – Transformers; Final Report, Lot 2: Distribution and power transformers, Tasks 1 – 7; VITO and BIOIS, 2010/ETE/R/106, January 2011.

3 CURRENT REGULATIONS AND STANDARDS

The electrical power sector is characterised by its many technical standards and legislative regulations. Their number and importance continue to increase due to the greater attention given to the environmental impact of human activities and the growing share of electricity in the energy mix. Power transformers have been made subject to regulations imposing minimum energy performance requirements in every major economy, as for many other electrical devices.

LEGISLATIVE REGULATION

Table 1 lists countries with policy measures in place to promote the use of energy-efficient power transformers, through MEPS, HEPS, energy labelling, the Chinese JB/T standard, or the Japanese Top Runner programme.

MEPS apply to every power transformer on the market. Utilities and other customers may decide to purchase transformers with higher performance levels, but cannot purchase units below MEPS.

High-efficiency performance specifications (HEPS) promote higher performance levels, but do not set a minimum standard, so customers may still purchase a transformer with energy performance levels below the HEPS.

TABLE 1 - COUNTRIES WITH STANDARDS AND LABELS FOR POWER TRANSFORMERS [6, 9].

Country	Liquid-filled three-phase	Liquid-filled single-phase	Dry-type three-phase	Dry-type single-phase	Large power transformers
Australia	MEPS / HEPS	MEPS / HEPS	MEPS / HEPS	MEPS / HEPS	---
Brazil	Label	Label	---	---	---
Canada	---	---	MEPS	MEPS	---
China	MEPS / Grade 1	JB/T (industrial)	MEPS / Grade 1	---	MEPS
European Union	MEPS – Tier 1, 2	---	MEPS – Tier 1, 2	---	MEPS
India	Label – 3, 5 star	---	---	---	---
Israel	MEPS / HEPS	---	MEPS / HEPS	---	---
Japan*	Top Runner	Top Runner	Top Runner	Top Runner	---
Republic of Korea	MEPS / HEPS	MEPS / HEPS	MEPS / HEPS	MEPS / HEPS	---
Mexico	MEPS	MEPS	---	---	---
Vietnam	MEPS	---	---	---	---
USA	MEPS	MEPS	MEPS	MEPS	---

*Japan's Top Runner programme does not apply to the Japanese electricity utility sector

Power transformer energy performance programmes in place around the world are summarised in the following tables, listed by country (or economy), the types of transformers covered, the requirements, whether mandatory or voluntary, and the standard or regulation referenced.

TABLE 2 - SUMMARY OF LIQUID-FILLED DISTRIBUTION TRANSFORMER PROGRAMME COVERAGE [6, 9].

Country / economy	Transformers covered	Indicative requirements	Mandatory?	Standard / regulation
Australia / New Zealand	1 phase: 10-50 kVA 3 phase: 25-2500 kVA	Efficiency at 50% load	Yes, since April 2004	AS2374.1.2-2003
Brazil	1 phase: 5 to 100 kVA 3 phase: 15 to 300 kVA	Max watts core and coil losses at 100% load	Yes, current regulation	ABNT NBR 5356
Canada	1 phase: 10-833 kVA 3 phase: 15-3000 kVA	Efficiency at 50% load	No, voluntary since 2000	CSA C802.1
China	1 phase: 5-160 kVA 3 phase: 30-1600 kVA	Maximum core and coil losses at 100% load	Yes	JB/T 10317-02 GB 20052-2013
European Union	3 phase: 25-3150 kVA; Voltage: 24 and 36kV	Maximum core and coil losses at 100% load	Yes	EN50708; (EU) No 548/2014
India	3 phase: 16-200 kVA for labelling	Maximum W losses at 50% and 100% loading	No, but utility required to purchase 3-Star	IS 1180
Israel	100-2500 kVA Voltage: 22kV or 33kV	Maximum W losses 100%	Yes, 2011	IS 5484
Japan	1 phase: 5-500 kVA 3 phase: 10-2000 kVA both 50 and 60 Hz	<500 kVA: 40% >500 kVA: 50%	Yes, March 2008; updated 2013	Top Runner
Republic of Korea	1 phase 10-100 kVA; 1 and 3 phase; 3.3-6.6kV, 100-3000 kVA 1 and 3 phase; 22.9kV, 100-3000 kVA and 10-3000 kVA	Efficiency at 50% load	Yes, July 2012	KS C4306; C4316 and C4317
Mexico	1 phase: 5-167 kVA 3 phase: 15-500 kVA Voltage: 15, 25 and 34.5 kV	Efficiency at 50% load	Yes, 1999	NOM-002-SEDE-1997
USA	1 phase: 10-833 kVA 3 phase: 15-2500	Efficiency at 50% load	Yes, January 2010; new January 2016	10 CFR 431
Vietnam	25-2500 kVA, 0.4-35kV	Efficiency	Yes, January 2013	TCVN 8525:2010

Source: SEAD Standards and Labelling Working Group Distribution Transformers Collaboration, Part 1: Comparison of Efficiency Programmes for Distribution Transformers. December 2013.

TABLE 3 - SUMMARY OF DRY-TYPE DISTRIBUTION TRANSFORMER PROGRAMME COVERAGE [6, 9].

Country/ economy	Transformers covered	Indicative requirement	Mandatory?	Standard / regulation
Australia	1 phase: 10-50 kVA 3 phase: 25-2500 kVA; Voltage: 11 and 22kV	Efficiency at 50% load	Yes, April 2004	AS2374.1.2-2003
Canada	1 phase: 15-833 kVA 3 phase: 15-7500 kVA Voltages: 20-45, >45-95; >95-199kV BIL	35% loading for low voltage (1.2kV) and 50% for >1.2kV	Yes, April 2012	C802.2-12/ Canada Gazette Part II
China	3 phase: 30-2500 kVA; Class B, F and H.	Maximum core and coil losses at 100% load	Yes	GB 20052-2013
European Union	3 phase: 50-3150 kVA ≤12kV, 17.5 and 24kV, ≤36 kV	Maximum core and coil losses at 100% load	Yes	EN50708; (EU) No 548/2014
Israel	100-2500 kVA Voltage: 22kV or 33kV	Maximum W losses 100%	Yes, 2011	IS 5484
Japan	1 phase: 5-500 kVA 3 phase: 10-2000 kVA both 50 and 60 Hz	<500 kVA: 40% >500 kVA: 50%	Yes, March 2008; updated 2013	Top Runner
Republic of Korea	1 and 3 phase; 3.3-6.6kV, 50-3000 kVA 1 and 3 phase; 22.9kV, 50-3000 kVA	Efficiency at 50% load	Yes, July 2012	KS C4311
USA	1 phase, LV, 25-333 kVA 3 phase, LV, 30-1000 kVA 1 phase, MV, 15-833 kVA 3 phase, MV, 15-2500 kVA MV: 20-45kV, 46-95, >96kV BIL	35% loading for low voltage (LV) (<600V) and 50% for medium voltage (MV)	Yes, January 2010; new January 2016	10 CFR 431

Source: SEAD Standards and Labelling Working Group Distribution Transformers Collaboration, Part 1: Comparison of Efficiency Programmes for Distribution Transformers. December 2013.

The US Department of Energy (DOE) has set mandatory energy efficiency standards for distribution transformers [4] covering liquid-filled and dry-type units, both single-phase and three-phase, rated at 60 Hz frequency and a primary voltage of 34,500 V or less. The power ratings are set between 10 and 2,500 kVA for liquid-immersed units, and between 15 and 2,500 kVA for dry-type units.

In this respect, the DOE has established the following in the Code of Federal Regulation (CFR):

- 10 CFR Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. These regulations include energy conservation standards and test procedures for distribution transformers;
- 10 CFR Part 429 – Certification, Compliance, and Enforcement for Consumer Products and Commercial and Industrial Equipment. These regulations cover statistical sampling plans, certified ratings, certification reports, record retention, and enforcement.

MEPS refer to 10 CFR 431 and are differentiated by rated voltage, rated power and technology [5].

The European Commission adopted Regulation (EU) No 548/2014 [2] on 21 May 2014, which implemented Directive 2009/125/EC on Ecodesign for small, medium, and large power transformers. The regulation applies to transformers put into service from 1 July 2015 and purchased after 11 June 2014 with a minimum power rating of 1 kVA, designed for a frequency of 50 Hz and used in transmission and distribution networks or in industrial applications. Efficiency requirements have been defined according to the types of transformers identified in the regulation.

The ecodesign MEPS are introduced in two phases, the first set of requirements entering into force on 1 July 2015 and the second, more stringent set of requirements, on 1 July 2021. The main basic MEPS are based on the IEC 60076 series of standards and are differentiated by maximum voltage (Um), rated power, and technology [1].

Article 7 of the Amending Regulation 2019/1783 [3] mandated a review no later than 1 July 2023 to address the following issues, among others:

- the extent to which requirements set out for Tier 2 have been cost-effective and the appropriateness to introduce stricter Tier 3 requirements;
- the appropriateness of the concessions introduced for medium and large power transformers in cases where installation costs would become disproportionate;
- the possibility to adopt a technology-neutral approach to the minimum requirements set out for liquid-immersed, dry-type and, possibly, electronic transformers;
- the appropriateness of the concessions for pole-mounted transformers and for special combinations of winding voltages for medium power transformers;
- the possibility and appropriateness of covering environmental impacts other than energy in the use phase, such as noise and material efficiency.

TECHNICAL STANDARDISATION

The current legislative regulations addressing power transformers are based on applicable technical standards which are the result of historical development. The expanding range of transformer technologies meant that new standards were added to ensure that all types were covered. As a consequence, standards are structured by technology, as are the regulations based on those standards. This has led to differences in the regulatory approach and minimum efficiency requirements depending on the transformer technology.

The set of international standards covering power transformers is published under IEC 60076 and is prepared and maintained by IEC Technical Committee 14, which is responsible for standards for power transformers, tap-changers, and reactors for use in power generation, transmission and distribution.

The IEC convened a technical committee to develop a guiding specification on energy-efficiency levels for power transformers. The published specification, IEC TS 60076-20:2017(E), states its objective as: ‘to promote a higher average level of energy performance for transformers’ due to the ‘need for energy saving and reduction of the emission of greenhouse gases.’ It proposes three methods of evaluating a transformer’s energy performance:

- the Peak Efficiency Index (PEI), which implicitly minimizes the Total Cost of Ownership (TCO);

- the no-load and load losses at rated power, mainly leading to an efficiency optimization of transformer cores and coils for units produced in large volumes; and
- the efficiency at a defined power factor and particular load factor (typically EI50, i.e. at 50%).

Each method is then further specified with reference to IEC and IEEE practices, resulting in a total of 2 x 3 = 6 alternative methods.

In the technical specification, the IEC recommends two levels of requirements for each of these three methods of evaluating a transformer’s energy performance. Level 1 relates to basic energy performance and level 2 relates to high energy performance.

4 MAIN MEPS COMPARISON

As discussed in the previous paragraph, current MEPS are different depending on the transformer technology. The main difference reflected in the MEPS is based on whether transformers contain liquid insulation or not.

The following tables compare the required energy performance of corresponding dry-type and liquid-filled transformers, as stipulated in Regulation (EU) No 548/2014.

The first table shows the ratio between maximum-load losses and no-load losses allowed for dry-type transformers and those allowed for liquid-immersed transformers under Tier 1 and Tier 2 of Regulation (EU) No 548/2014. The figure ranges between 0.8 and 2.86.

The second table shows the ratio between the minimum EIA50[2] allowed for dry-type transformers and that allowed for liquid-immersed transformers under Tier 1 and Tier 2 of Regulation (EU) No 548/2014. The figure ranges between 0.9894 and 0.9998.

TABLE 4 – RATIO BETWEEN MAXIMUM-LOAD LOSSES (LL) AND NO-LOAD LOSSES (NL) ALLOWED FOR DRY-TYPE TRANSFORMERS UNDER TIER 1 AND TIER 2 OF REGULATION (EU) NO 548/2014, AND THOSE ALLOWED FOR LIQUID-FILLED TRANSFORMERS (REF. SINGLE- OR THREE-PHASE, 50 HZ, 2 WINDINGS, MV UM ≤24KV, LV UM ≤1.1KV, OLTC RANGE ≤5%).

Rated power	Tier 1		Tier 2	
IEC 60076-1	LL	NL	LL	NL
kVA	W	W	W	W
≤25	189%	286%	250%	286%
50	155%	222%	200%	222%
100	117%	193%	144%	194%
160	123%	190%	149%	190%
250	117%	173%	145%	173%
315	--	--	--	--
400	120%	174%	138%	174%
500	--	--	--	--
630	117%	183%	154%	183%
800	95%	200%	133%	200%
1,000	86%	201%	118%	201%
1,250	100%	189%	116%	189%
1,600	93%	183%	108%	183%
2,000	89%	179%	107%	179%
2,500	86%	177%	103%	177%
3,150	80%	173%	96%	173%

[2] EIA50 is the efficiency index at 50% of load, evaluated using method A (IEC practices). EIA50 is the ratio of the transmitted apparent power of a transformer minus electrical losses including the power consumed by cooling, to the transmitted apparent power of the transformer, for a given load factor.

TABLE 5 – RATIO BETWEEN MINIMUM EI50 ALLOWED FOR DRY-TYPE TRANSFORMERS UNDER TIER 1 AND TIER 2 OF REGULATION (EU) NO 548/2014, AND THAT ALLOWED FOR LIQUID-FILLED TRANSFORMERS (REF. SINGLE- OR THREE-PHASE, 50 HZ, 2 WINDINGS, MV UM ≤24KV, LV UM ≤1.1KV, OLTC RANGE ≤5%).

Rated power	Tier 1	Tier 2
IEC 60076-1	**EIA50**	**EIA50**
kVA	**p.u.**	**p.u.**
≤25	98.296	--
50	98.926	98.596
100	99.115	98.738
160	99.217	98.946
250	99.314	99.1
315	99.35	--
400	99.4	99.208
500	99.426	--
630	99.463	99.301
800	99.479	99.346
1,000	99.481	99.366
1,250	99.483	99.397
1,600	99.49	99.434
2,000	99.495	97.78
2,500	99.504	98.596
3,150	99.509	98.738

5 NEED FOR A TECHNOLOGY-NEUTRAL APPROACH

The absolute values of minimum energy performances were set on the basis of preparatory studies analysing the available technologies, market needs, and the current population of power transformers (for an example of an EU preparatory study, see [11]).

MEPS required for power transformers decrease with voltage and increase with rated power. In case of increasing voltage, this approach balances the increase in unit dimensions and weight due to the additional need for electrical insulation. In case of decreasing rated power, it balances the relative increase in manufacturing material required to achieve energy savings.

In the author's view, this type of differentiation is needed, since it balances the various performance requirements. Under the current regulation, however, MEPs imposed on liquid filled power transformers *also* differ from the ones imposed on dry type units *for the same voltage and rated power*. This approach, which accepts higher energy losses in cases where a specific fire performance is required, was recommended in the preparatory studies with the aim of avoiding excessively high costs. While this aim was reasonable, the mitigation of MEPS applies to dry-type technology only – which was probably the only technology available for achieving the required fire behaviour at the time when the regulatory process started – instead of being formalised for all transformers exhibiting the requisite fire performance, no matter the technology used. By taking a technology-based approach for a goal that is in principle performance-based, unfair competition between technologies was introduced.

Most power transformers manufactured today are made of conventional materials and fit into the current approach, but the electrical energy sector in general, and power transformers in particular, are expected to see significant changes in the near future:

- New technologies are emerging, or are expected to emerge, providing the same performance that had been exclusive to one particular technology until recently. Examples include electronic power transformers and ester insulating liquids.
- There is now greater focus on performance factors other than energy efficiency, including sustainability, fire behaviour, noise, maintainability, and material efficiency and recyclability.
- Minimum performance levels are updated continuously, becoming increasingly demanding.
- New, special application areas, such as smart grids, are appearing on the market.

A regulation which limits concessions to only some technologies hampers innovation. Manufacturers are discouraged from developing alternative technologies to achieve the required performance, because these technologies are artificially disadvantaged by law. To avoid such market distortion, the ISO/IEC Directives formulated the *performance principle*: 'whenever possible, requirements shall be expressed in terms of performance rather than design or descriptive characteristics like a technology'[3].

A classic example revealing the consequences of neglecting this principle, is the design of castor-wheeled and swivelling office chairs. In the 1950s, when these products came on the market in greater volumes, stability was a concern. When using four-legged office chairs especially, users tended to tip the chair over when reaching for something. The test standard did not design a stability test for office chairs, instead it simply prescribed that all

[3] ISO/IEC Directives, Part 2:2018, edition 8.0 / *Principles and rules for the structure and drafting of ISO and IEC documents* / *5.4 Performance principle*

castor-wheeled office chairs should have five legs. But this inevitably stifled any innovative ideas for alternative ways to resolve the stability issues and, in fact, there has been no innovation in this field since.

Conversely, if mobile phone standards had limited their application to wireless phones with physical buttons, the smartphone would never have entered the market.

The concession of allowing higher energy losses was a way of facilitating another equally important performance factor, and must therefore not be abandoned, but rather reformulated. To follow the technology-neutral principle in the case of fire behaviour, the following actions would be required:

- Defining “a transformer with increased fire safety” in an unambiguous, technology-neutral way, for example as a power transformer in which flammability is restricted and the emission of toxic substances and opaque smoke is minimised;
- Developing technical standards that set maximum levels of flammability, emission of toxic substances and opaque smoke, as well as corresponding tests[4] covering all the technologies.

In general terms, this technology-neutral approach should be used to balance minimum energy performance levels — and in the future maybe material efficiency requirements such as recyclability and recoverability, the use of critical raw materials, durability and the ability to repair — with other performance factors such as fire safety or noise.

This principle should be taken into account when evaluating the adequacy of all upcoming regulatory documents and technical standards[5].

A technology-neutral approach and harmonised test procedures are means to facilitate technological innovation and provide fair trade conditions[6]. Well-designed regulations and standards encourage trade, the execution of

---

[4] For the present, available in the power transformer sector, IEC 60076-11:2018 Power transformers - Part 11: Dry-type transformers.

[5] From “ISO/IEC GUIDE 77-2:2008 Edition 1.0 (2008-09-01): Guide for specification of product properties and classes - Part 2: Technical principles and guidance / Introduction”:

> *“The capability to characterize products in an abstract way*, independently of any particular manufacturer, is a fundamental aspect of engineering knowledge. Such a characterization is done by *the name of a category of products that fulfils the same function*, […]. Such a category is called a characterization class. This first level of characterization is further detailed by means of some property-value pairs, which describe more precisely the target product within its characterization class. Examples of such properties are inner diameter, threaded length and capacitance.”

[6] From “ISO/IEC Directives, Part 2:2018, edition 8.0 (2018-05): Principles and rules for the structure and drafting of ISO and IEC documents / Chapter 4. Objective of standardization”:

> “The objective of documents is to specify clear and unambiguous provisions in order to help international trade and communication. To achieve this objective, documents shall:
> – […]
> – be consistent, clear and accurate;
> – be written using all available knowledge about the state of the art;
> – take into account the current market conditions;
> – […]

conformity assessments, performance level comparisons, technology transfer, and the adoption of best practices. Governments, as much as manufacturers, stand to gain from neutral, harmonised, consistent, and stable standards. Benefits to governments include:

- lower development costs for test methods;
- comparative test results;
- the ability to incorporate innovative technical solutions;
- reducing the number of exceptions in regulations;
- the ability to adopt a common set of upper thresholds that can be used for market pull programmes, such as labelling and incentive schemes; and
- faster and less costly testing – for compliance and other purposes — since harmonised testing leads to a wider range of laboratories able to conduct product testing.

For manufacturers, having one harmonised test method with specified measurement uncertainties used by markets around the world will reduce testing costs associated with demonstrating regulatory or product labelling compliance. In an ideal world, every manufacturer would always conduct exactly the same tests, in exactly the same way, and the results would be universally accepted as being accurate and representative of the performance of their product. A harmonised test method also means they can look forward to long-term rewards for innovative product designs.

Having a consistent test method encourages national governments to establish harmonised energy efficiency thresholds broad enough to encompass all current market circumstances, as well as aspirational efficiency thresholds as pointers for future market development.

EU Ecodesign requirements for electric motors

The EU Ecodesign regulation on electric motors from October 2019 (Commission Regulation (EU) 2019/1781) is an example of a more technology-neutral approach. The recitals introducing the legislation include a general statement about exceptions:

> (21) In particular situations, for instance, where safety, functionality or disproportionate costs are at stake, certain motors or variable speed drives (VSDs) should be exempted from efficiency requirements.

In the Regulation, *Article 2, Section 2* lists motor types exempted from the energy efficiency requirements, while *Section 2, Subsection (d)* specifies particular environments where the regulation does not hold.

> (2) The requirements (…) of Annex I shall not apply to the following motors:
>
> (d) motors specifically designed and specified to operate exclusively:
>
> (i) at altitudes exceeding 4 000 metres above sea-level;
>
> (ii) where ambient air temperatures exceed 60 °C;
>
> (iii) in maximum operating temperature above 400 °C;
>
> (iv) where ambient air temperatures are less than – 30 °C; or

---

– *provide a framework for future technological development;”*

(v) where the water coolant temperature at the inlet to a product is below 0 °C or above 32 °C;

These exemptions are expressed entirely in terms of the required performance — in this case the ability to withstand certain extreme environments — and not in terms of the technologies commonly used to achieve this performance.

6 CONCLUSIONS

The analysis demonstrates that:

- current legislative regulations addressing power transformers are based on applicable technical standards;
- these technical standards have been developed on a technology basis;
- this approach was adopted based on preparatory studies analyzing the available technologies, market need, and the existing population of power transformers, and aimed to avoid the disproportionately higher cost in cases where a specific fire performance is required;
- this aim is reasonable, but the way the mitigation was formalised introduced a technology bias;
- energy efficiency requirements are reduced for only one particular technology instead of these lower requirements being formalised for any transformer that provide the required performance, no matter the technology used.

In the context of legislative regulations and technical standardisation of power transformers, the approach should be updated to one that is technology-neutral.

- MEPS should be differentiated on the basis of other performance attributes of the unit;
- Performance should be classified in a technology-neutral way;
- A harmonised way to test each performance aspect should be developed.

This will:

- stimulate innovation;
- prevent unfair competition between technologies included in the legislation;
- define the limits and application domains of exemption categories;
- avoid major deployment of applications that escape standards and create an unfair market.

Adopting a technology-neutral approach to transformer MEPS is mentioned among the aspects to be considered in the upcoming review of EU Regulation No 548/2014. To develop such an approach for the case of fire behaviour, the following actions would be required:

- Defining “a transformer with increased fire safety” in an unambiguous, technology-neutral way, for example as a power transformer in which flammability is restricted and the emission of toxic substances and opaque smoke is minimised;
- Developing technical standards that set maximum levels of flammability, emission of toxic substances and opaque smoke, as well as corresponding tests covering all the technologies.

The same approach should be used to balance minimum energy performance levels and in the future maybe material efficiency requirements with other performance factors of interest, such as noise.

These principles should be taken into account when evaluating the adequacy of all upcoming regulatory documents and technical standards.

REFERENCES

[1] IEC 66076 series – Power transformers

[2] Commission Regulation (EU) No 548/2014 of 21 May 2014 on implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to small, medium and large power transformers

[3] Commission Regulation (EU) 2019/1783 of 1 October 2019 amending Regulation (EU) No 548/2014 on implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to small, medium and large power transformers

[4] EN 50708 series: "Power transformers - Additional European requirements"

[5] DOE 78 FR 23335: "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers"

[6] 10 CFR Part 431: "Energy efficiency program for certain commercial and industrial equipment"

[7] U4E United Nations Environmental Programme: "Distribution Transformers: Accelerating the Global Adoption of Energy-Efficient Transformers" https://united4efficiency.org/products/distribution-transformers/

[8] ISO/IEC Directives, Part 2:2018, edition 8.0 (2018-05) "Principles and rules for structure and drafting of ISO and IEC documents"

[9] Commission Regulation (EU) 2019/1781 of 1 October 2019 laying down ecodesign requirements for electric motors and variable speed drives pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Regulation (EC) No 641/2009 with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products and repealing Commission Regulation (EC) No 640/2009 (Text with EEA relevance)

[10] INTAS Industrial and tertiary product testing and application of standards: "Deliverable 2.1: Database and report on EN/IEC/ISO technical standards" https://www.intas-testing.eu/transformers

[11] Lot 2 Ecodesign Preparatory Study for small, medium and large power transformers, https://transformers.vito.be/