Standards relevant to transformers – Part I

It took 52 years from Faraday's discovery of electromagnetic induction to the first AC electrical power system that uses transformers

KEYWORDS

standards, transformers, historical development, IEC, IEEE, CIGRE, BSI, CENELEC

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1. Introduction

Standards are formulated to meet the generally recognised demands, minimum performance and safety requirements, as well as to make sure that the product from different manufacturers is similar and consistent. A survey is done on the evolution of national standards for transformers, and on the range of IEC / IEEE standards available today for transformer engineers. Of course, standards are dynamic and are under continuous revisions and additions. Hence, no claim is made that the listings provided are the latest or include all relevant standards connected with transformers. A listing of standards, if made as in this contribution in groups – viz. Application guides, Specification, Testing, Transformer Oil, Accessories, Raw Materials, Installation, Operation, Maintenance and Protection, with relevant IEC and IEEE standard numbers for each subject – will be useful as a quick reference for transformer engineers engaged in the selection, procurement, manufacturing, testing, installation, operation, maintenance, and protection of transformers. A list of CIGRE technical brochures relevant to transformers is also included.

2. Genesis of transformer

Michael Faraday discovered electromagnetic induction on 29th August 1831, by winding two pairs of windings on a soft iron ring of 6 inches outer diameter and 7 / 8 inches thickness – the forerunner of a modern electrical transformer. When he supplied current from a battery to one pair of windings, he found momentary deflection of a magnetic needle located near the shorted winding on the opposite side of the iron ring. But it took another 52 years for AC electric power transmission to come into practice using transformers. The first AC distribution line came into London in 1883, when secondary generators (the term used for transformers then) were used in a 12 KMs underground line for lighting. The first AC transmission line was erected for the Turin-Lanzo Railway line, Turin, Italy in 1884, using Gaulard and Gibbs converters. Modern transformers with a closed magnetic path and parallel-connected primaries were demonstrated in 1885 at the industrial exhibition of Budapest, for public lighting using Ganz, Hungary made transformers, and in 1886 in Great Barrington, Massachusetts, the USA, using William Stanley transformers. As the volume of transformer production increased at various centres, the need was felt in all countries for standardising the ratings, voltage, and testing of transformers and other electrical machinery.

3. IEC-International Electro-Technical Commission

IEC (International Electro-technical Commission) is the world's leading organisation for the preparation and publication of international standards for all electrical, electronic and related technologies, collectively known as "electro-technology".

Founded in 1906, IEC provides a platform to companies, industries and governments for meeting, discussing and developing the international standards they require. It is a not-for-profit, non-governmental organization with national committees as members who

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Table 1. Standards (rules) for electrical machinery in 1911

Sl no	Country	Title of standard	Year	Standard organisation
1	Belgium	Prescriptions normales for reception of electrical machines and transformers	1908	Chambre syndicale des Electriciens Belges
2	France	General instructions for the delivery and reception of electrical machines and transformers	1910	Union des Syndicats de l' Electricite
3	Germany	Standard rules for the utiliation and testing of electrical machines and transformers	1910	Verband Deutscher Elektro-techniker
4	Great Britain	Electrical machinery	1907	British Engineering Standards Committee
5	Sweden	Testing and the reception of electrical machines and transformers	1909	Association of Swedish Engineers
6	USA	Standardization rules	1911	The American Institute of Electrical Engineers

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appoint experts and delegates to participate in the technical and conformity assessment work of the IEC.

IEC is one of the three global sister organisations (IEC, ISO, ITU) that develop international standards for the world. When appropriate, IEC co-operates with ISO (International Organization for Standardization), or ITU (International Telecommunication Union), to ensure that international standards fit together seamlessly and complement each other.

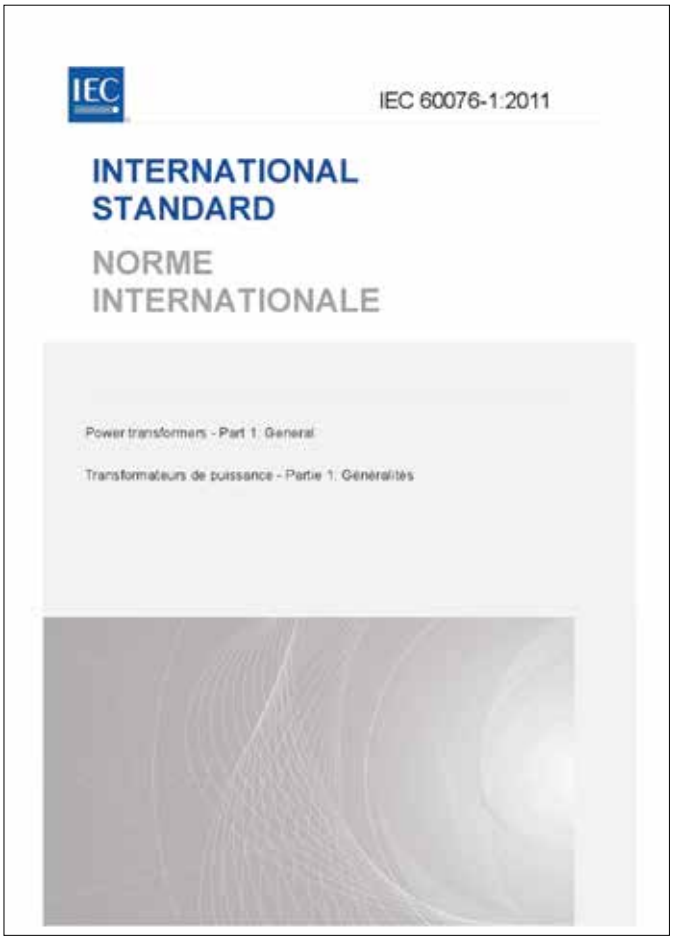
The International Electro-Technical Commission was set up on 26th June 1906 in London, at a meeting of 33 delegates from 14 countries. Lord Kelvin (name at birth William Thomson), was the first President-elect with Col R.E.B. Crompton as Secretary.

The immediate concern of the IEC was to secure practical uniformity with respect to terms, definitions and units used in electro-technology. The diversity and confusion prevalent at that time can be seen in Table 1, showing the documents of rules on electrical machinery as followed in various countries in 1911.

Work on standards within IEC is carried out through technical committees and subcommittees, each dealing with a specific subject. At present, there are nearly 200 technical and sub-committees active within IEC. Major technical committees of IEC, relevant for transformer engineers are shown in Table 2. These TCs develop standards relevant to transformers and components / accessories going into the manufacture of transformers, e.g., TC 10 concentrates on transformer oil and other alternate insulating fluids, TC 36 A issues standards for bushings, TC 55 issues standard for paper covered / enamelled winding wires, while TC 112 studies evaluation of insulating systems used in transformers. Experts from all over the world work to develop these standards. More than 300 experts contribute to developing power transformer standards from TC 14.

TC 14 Power transformers was set up in 1926, and the first separate IEC standard on power transformers was published in 1955 as Publication No. 76 titled "IEC recommendations for power transformers". It has been revised a couple of times ever since, and complemented sub-documents widely to reach the current IEC 60076 series in many parts.

At present, there are 33 standards issued by TC 14 for transformers, as shown in Table 3 [1].



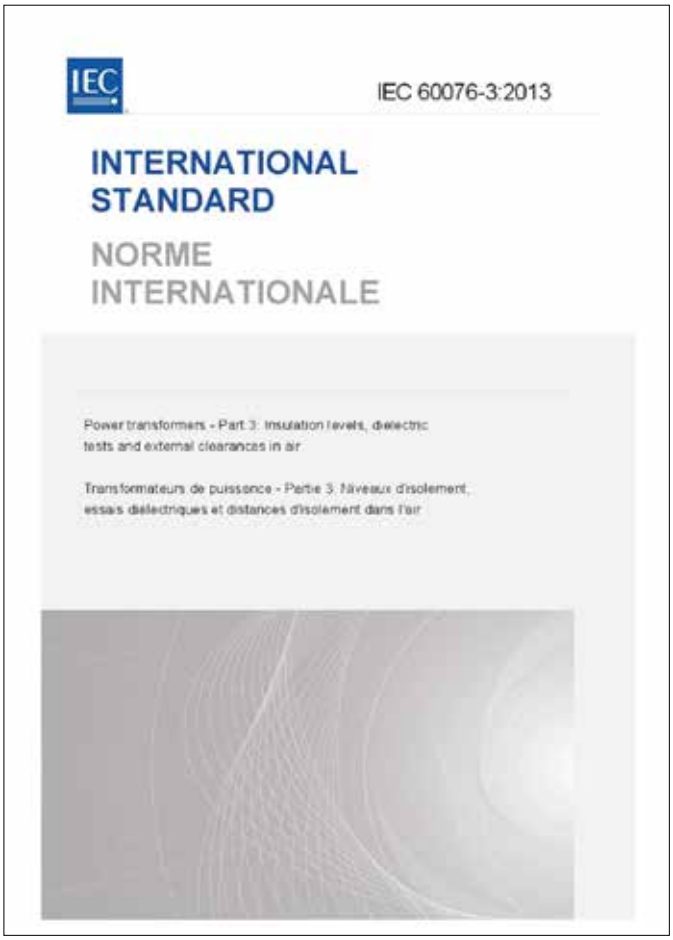


Table 2. IEC technical committees related to transformers

Technical committee	Title
IEC/TC 1	Terminology
IEC/SC 3 C	Graphical symbols for use on equipment
IEC TC 8	Systems aspects for electrical energy supply
IEC/TC 9	Electrical equipment and systems for railways
IEC/ TC 10	Fluids for electro technical applications
IEC/TC 14	Power transformers
IEC/TC 15	Solid electrical insulating materials
IEC/TC 28	Insulation co-ordination
IEC/ TC 31	Equipment for explosive atmospheres
IEC/ TC 36	Insulators
IEC/TC 36 A	Insulated bushings
IEC/TC 37	Surge arresters
IEC/TC 38	Instrument transformers
IEC/ TC 42	High voltage and high current test techniques
IEC/TC 55	Winding wires
IEC/TC 68	Magnetic alloys and sheets
IEC/TC 70	Degrees of protection for enclosures
IEC/TC 73	Short circuit currents
IEC/TC 77	Electromagnetic compatibility
IEC/TC 82	Solar photovoltaic energy systems
IEC/TC 88	Wind turbines
IEC/TC 89	Fire hazard testing
IEC/TC 95	Measuring relays and protection equipment IEC TC 96
IEC/TC 96	Transformers, reactors, power supply units and combinations thereof
IEC/TC 104	Environmental conditions classification and methods of test
IEC/TC 105	Fuel cell technologies
IEC/TC 112	Evaluation and qualification of electrical insulating materials and systems
IEC/TC 114	Marine energy, wave tidal and other water current converters
IEC/TC 115	High voltage direct current transmission > 100 kV DC
IEC/TC 117	Solar thermal electric plants
IEC/TC 122	UHV AC transmission systems

Table 3. IEC standards on power transformers

IEC 60076:2015 OC Edition 1.0 (2015-04-23) IEC 60076 – ONLINE COLLECTION – Power transformers
IEC 60076-1:2011 Edition 3.0 (2011-04-20) Power transformers - Part 1: General
IEC 60076-2:2011 Edition 3.0 (2011-02-23) Power transformers - Part 2: Temperature rise for liquid-immersed transformers
IEC 60076-3:2013+AMD1:2018 CSV Edition 3.1 (2018-03-22) Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-3:2013 Edition 3.0 (2013-07-31) Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-3:2013/AMD1:2018 Edition 3.0 (2018-03-22) Amendment 1 - Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-4:2002 Edition 1.0 (2002-06-06) Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors
IEC 60076-5:2006 Edition 3.0 (2006-02-07) Power transformers - Part 5: Ability to withstand short circuit
IEC 60076-6:2007 Edition 1.0 (2007-12-13) Power transformers - Part 6: Reactors
IEC 60076-7:2018 Edition 2.0 (2018-01-12) Power transformers - Part 7: Loading guide for mineral-oil-immersed power transformers
IEC 60076-8:1997 Edition 1.0 (1997-10-01) Power transformers - Part 8: Application guide
IEC 60076-10:2016 Edition 2.0 (2016-03-24) Power transformers - Part 10: Determination of sound levels
IEC 60076-10-1:2016 Edition 2.0 (2016-03-24) Power transformers - Part 10-1: Determination of sound levels - Application guide
IEC 60076-11-2018+COR1:2019 Edition 2.0 (2018-08-15) Power transformers - Part 11: Dry-type transformers
IEC 60076-12:2008 Edition 1.0 (2008-11-05) Power transformers - Part 12: Loading guide for dry-type power transformers
IEC 60076-13:2006 Edition 1.0 (2006-05-24) Power transformers - Part 13: Self-protected liquid-filled transformers
IEC 60076-14:2013 Edition 1.0 (2013-09-16) Power transformers - Part 14: Liquid-immersed power transformers using high-temperature insulation materials
IEC 60076-15:2015 Edition 2.0 (2015-04-22) Power transformers - Part 15: Gas-filled power transformers
IEC/IEEE 60076:2018 Edition 2.0 (2018-09-28) Power transformers - Part 16: Transformers for wind turbine applications

IEC 60076-18:2012 Edition 1.0 (2012-07-09) Power transformers - Part 18: Measurement of frequency response
IEC TS 60076-19:2013 Edition 1.0 (2013-03-22) Power transformers - Part 19: Rules for the determination of uncertainties in the measurement of the losses on power transformers and reactors
IEC TS 60076-20:2017 Edition 1.0 (2017-01-30) Power transformers - Part 20: Energy efficiency
IEC TS 60076-20:2017/COR1:2018 Edition 1.0 (2018-01-12) Corrigendum 1 - Power transformers - Part 20: Energy efficiency
IEC 60076-21:2018 Edition 2.0 (2018-12-07) Power transformers - Part 21: Standard requirements, terminology, and test code for step-voltage regulators
IEC 60076-22-1:2019 Edition 1.0 (2019-01-29) Power transformers - Part 22-1: Power transformer and reactor fittings-protective devices
IEC 60076-22-2:2019 Edition 1.0 (2019-01-16) Power transformers - Part 22-1: Power transformer and reactor fittings-removable radiators
IEC 60076-22-3:2019 Edition 1.0 (2019-03-08) Power transformers - Part 22-1: Power transformer and reactor fittings-insulating liquid to air heat exchangers
IEC 60076-22-4:2019 Edition 1.0 (2019-03-08) Power transformers - Part 22-1: Power transformer and reactor fittings-insulating liquid to water heat exchangers
IEC TS 60076-23:2018 Edition 1.0 (2018-01-09) Power transformers - Part 23: DC magnetic bias suppression devices
IEC/IEEE 60076-57-1202:2017 Edition 1.0 (2017-05-23) Power transformers - Part 57-1202: Liquid immersed phase-shifting transformers
IEC/IEEE 60076-57-129:2017 Edition 1.0 (2017-11-09) Power transformers - Part 57-129: Transformers for HVDC applications
IEC 60214-1:2014 Edition 2.0 (2014-05-22) Tap-changers - Part 1: Performance requirements and test methods
IEC/IEEE 60214-2:2019 Edition 2.0 (2019-06-14) Tap-changers - Part 2: Application guide
IEC TR 60616:1978 Edition 1.0 (1978-01-01) Terminal and tapping markings for power transformers
IEC 61378-1:2011 Edition 2.0 (2011-07-26) Converter transformers - Part 1: Transformers for industrial applications
IEC 61378-1:2011/COR1:2012 Edition 2.0 (2012-01-24) Corrigendum 1 - Converter transformers - Part 1: Transformers for industrial applications
IEC 61378-3:2015 Edition 2.0 (2015-02-05) Converter transformers - Part 3: Application guide
IEC 62032:2012 Edition 2.0 (2012-06-21) Guide for the application, specification and testing of phase-shifting transformers

TCs develop standards relevant to transformers, and components / accessories going into the manufacture of transformers

Table 4. IEC standards on bushings

IEC 60137:2017 Edition 7.0 (2017-06-22) Insulated bushings for alternating voltages above 1000 V
IEC 60137:2017/COR1:2018 Edition 7.0 (2018-05-07) Corrigendum 1 - Insulated bushings for alternating voltages above 1 000 V
IEC TS 61463:2016 Edition 2.0 (2016-07-06) Bushings - Seismic qualification
IEC TS 61464:1998 Edition 1.0 (1998-08-25) Insulated bushings - Guide for the interpretation of dissolved gas analysis (DGA) in bushings where oil is the impregnating medium of the main insulation (generally paper)
IEC TS 61464:1998/COR1:2003 Edition 1.0 (2003-01-17) Corrigendum 1 - Insulated bushings - Guide for the interpretation of dissolved gas analysis (DGA) in bushings where oil is the impregnating medium of the main insulation (generally paper)
IEC/IEEE 65700-19-03:2014 Edition 1.0 (2014-07-10) Bushings for DC application

Subcommittee on bushings 36 A, has issued four standards as shown in Table 4.

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[1] International Electrotechnical Commission, *International Standards and Conformity Assessment for all electrical, electronic and related technologies*, TC 14 Power transformers, viewed on 13 February 2020, <https://www.iec.ch/dyn/www/f?p=103:22:8102061491013::::FSP_ORG_ID,FSP_LANG_ID:1224,25#top>

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[3] L. Rupert, *History of IEC*, 1956

[4] *A year of anniversaries*, IEC Bulletin Special Issue, Vol 67, January 1981

There are nearly 200 technical and sub-committees active in IEC; more than 300 experts are developing standards for power transformer within the corresponding committee

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