Transformers

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Transformer bushings – A need for dimensional standardization

With diverse bushings configurations and evolving insulation technologies, the need for standardized dimensions has become increasingly apparent

In the intricate network of electrical power transmission, **transformer bushings** stand as vital conduits, ensuring the seamless flow of energy between the transformer and the external grid. These critical components, particularly Air to Oil Type High-voltage bushings, play a pivotal role in maintaining system integrity and reliability. With diverse configurations and evolving insulation technologies, the need for standardized dimensions has become increasingly apparent. As we delve into the realm of transformer bushings, it becomes evident that a unified approach to dimensional standardization is not merely a convenience but a necessity for the robustness and sustainability of our power infrastructure and the increasing global demand for electricity.

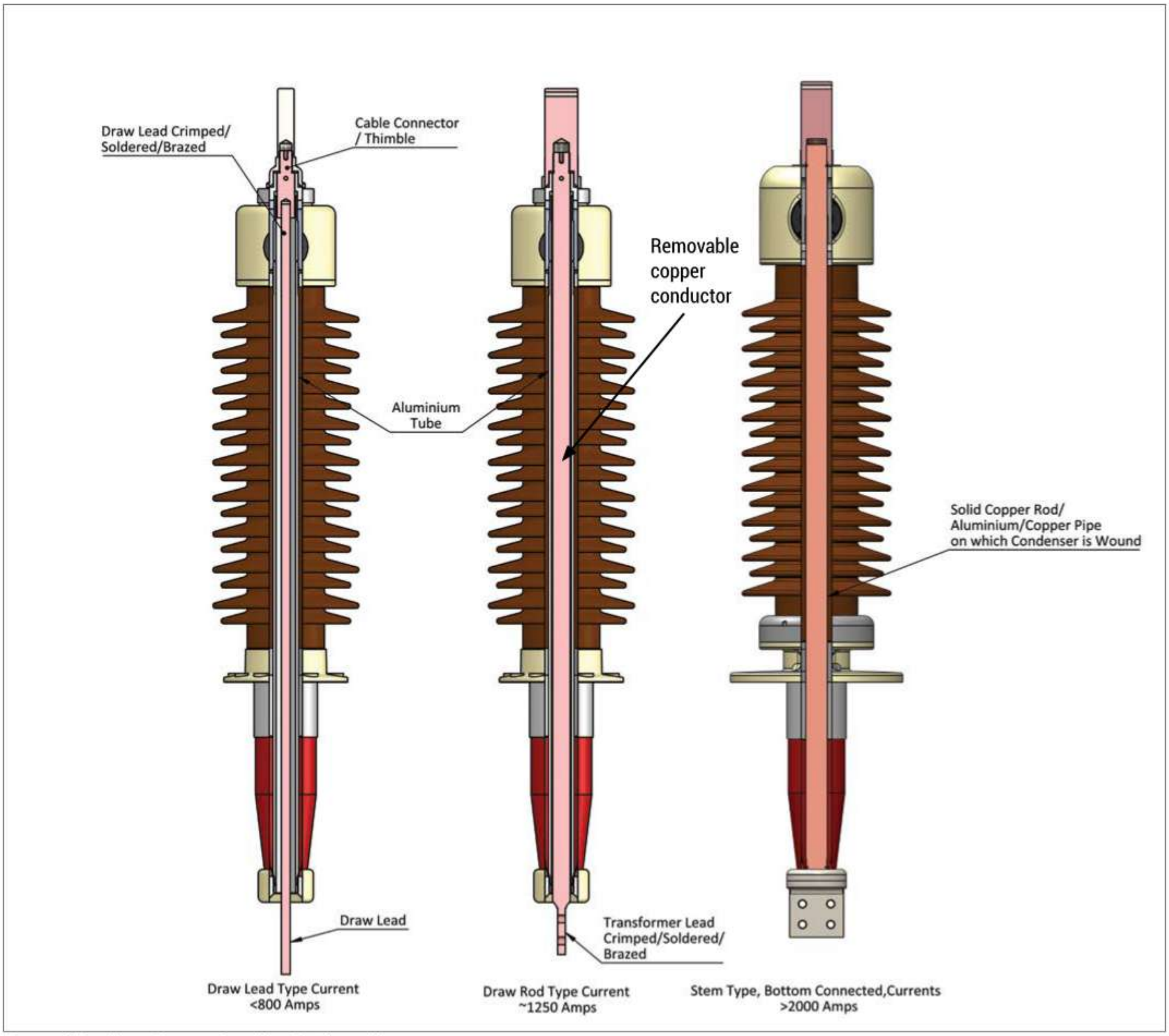
Introduction

Air to Oil Type Transformer Bushings are mounted on the top plate of a transformer tank or on the top plate of the turret, with the oil end of the bushing fully immersed in oil inside the transformer whilst the HV terminal on the Air End is connected to the Transmission line (ACSR Conductor) or Aluminium Bus in the substation.

There are three types of such transformer bushings, based on the configuration of current carrying parts, namely "Draw Lead", "Draw Rod", and "Solid Stem".

In the **Draw Lead Type**, the transformer lead connection from the winding is passed through the central tube of the bushing and is terminated on the thimble/cable connector by soldering/brazing/crimping. The Air End HV terminal is then connected to the thimble/cable connector either by screwing or through a multi-contact spring. Such draw lead type terminations are usually used in Bushings with a current rating of up to 800 Amps.

In the **Draw Rod Type**, the transformer lead connection from the winding is passed through the central tube of the bushing up to the mounting flange level and is terminated on a cable connector either by soldering/brazing/crimping and the cable connector is bolted to the Draw Rod. For some constructions, the Draw Rod end is right up to the Oil End electrode. The Air End HV terminal is then connected to the Draw Rod either by screwing or through a multi-contact spring. Such Draw Rod type terminations



Types of Bushings Current Carrying Configurations

The OIP (Oil Impregnated Paper) insulation is still a popular construction and has been manufactured for the past ~100 years

are usually used up to the Bushing's rated current of >800 Amps and <= 1250 Amps.

In the **Solid Stem Type**, the transformer lead is always terminated at the bottom of the oil end of the bushing. The current passes through the central tube of the bushing or through the central rod of the bushing. The HV terminal is either a part of the central rod, or the HV terminal is connected to the central rod/central tube either by screwing or through a multi-contact spring. Such Solid Stem type terminations are usually used in bushings with a rated current of up to >1600Amps. These bushings are also referred to as bottom connected bushings.

The bushings (36 kV to 1200 kV) are of the condenser type. Although still in service at a few installations, SRBP (Synthetic Resin Bonded Paper) insulation-based condenser bushings have not been manufactured for 30 years. In some of the installations with SRBP Bushings, the re-entrant-type bushings were used, and these bushings had their oil end shorter in length by around 30%. The OIP (Oil-Impregnated Paper) insulation is still a popular construction and has been manufactured for the past ~100 years. RIP (Resin-Impregnated Paper) and RIS (Resin-Impregnated Synthetics) are solid insulation systems that, in certain geographical regions, are becoming the most preferred bushing types. RIP bushings have been in use for more than 50 years, while RIS bushings have been seeing increasing usage over the past 10-12 years.

Different insulation constructions and configurations of current carrying parts, often in different parts of the world, contributed to the fact that a large number of manufactured bushings have different dimensions. This article describes the present level of dimensional standardization of transformer bushings in leading geographical markets and provides details on the need to standardize dimensions and other construction aspects of bushings further.

Existing bushing standards

Since 1980, the following standards (with their latest Revision Status) have been published and aim to address the standardization of bushings dimensions:

- IEEE C57.19.0-2017: IEEE Standard for Performance Characteristics and Dimensions for Power Transformer and Reactor Bushings.
- IS 12676-1989: Oil Impregnated Paper Insulated Condenser Bushings – Dimensions and Requirements.
- CLC/TS 50458-2006: Capacitance Graded Outdoor Bushings 52 kV up to 420 kV for Oil Immersed Transformers.

Only IS 12676 specifically mentions that it is applicable for OIP Insulated Bushings, whereas IEEE and CLS/TS are applicable for all varieties of insulation systems.

The IEEE standard covers kV classes of bushings from 25 kV to 765 kV (25 kV, 34.5 kV, 46 kV, 69 kV, 115 kV, 138 kV, 161 kV, 230 kV, 345 kV, 500 kV, 765 kV), whereas IS 12676 covers specific kV classes: 52 kV, 72.5 kV, 145 kV, 245 kV, 420 kV. The CLC/TS standard covers specific kV classes: 52 kV, 72.5 kV, 100 kV, 123 kV, 145 kV, 170 kV, 245 kV, 300 kV, 420 kV.

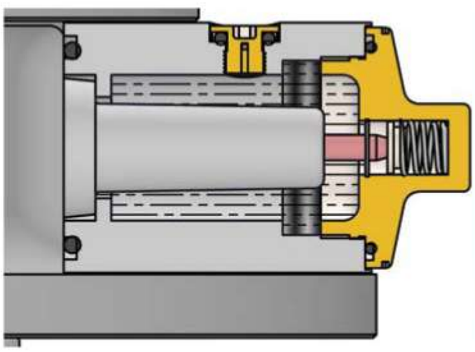
The IEEE standard covers the majority of the current ratings, i.e., up to 230 kV and up to 5000 Amps and 345 kV and 500 kV up to 3000 Amps and 765 kV up to 2000 Amps. The IS standard covers current ratings at 52 kV up to 3150 A; 72 kV,145 kV and 420 kV up to 1250 Amps; 245 kV up to 2000 Amps. The CLC/TS standard covers 52 kV and 72.5 kV up to 3150 Amps + 100-170 kV up to 2500 Amps + 245 to 420 kV up to 2000 Amps.

The Standard BCT (Bushing Current Transformer) lengths covered by the standards are as follows,

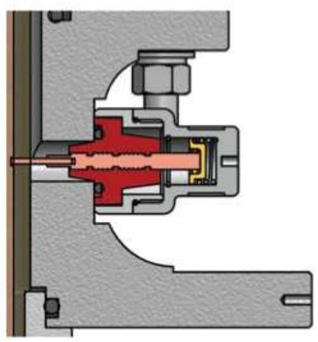
- IEEE: up to 69 kV- 534 mm and 115 kV and above – 584 mm.
- IS: 52-72.5 kV-100/300 mm; 145 kV – 100/300/600 mm; 245 kV-300/600 mm; 420 kV- 400 mm.
- CLC/TS: all kV ratings – 0/300/500 mm.

The maximum distance to earthed parts (on the oil end) for type testing of the bushing (plain oil gaps) is specified only in the CLC/TS standard. IEEE standards alone specify the standardized dimensions of the test tap zone, including the threading size and test tap stem diameter; this facilitates the connection of the test tap adapter of online monitoring devices.

The IS standard specifies the maximum diameter of "Oil End Shield/Oil End Electrode," whereas the CLC/TS standard specifies various configurations at the Bottom of Oil end, such as "Oil End Without Shield", "Oil End with Embedded Shield", "Oil End with Fixed/Removable Shield". IEEE standard specifies the diameter of the oil end terminal.



20kV Potential tap, 1 Minute Withstand as per IEEE, Must for >115kV



2kV Test tap, 1 Minute Withstand as per IEC

The following is a list of considerations which are required while replacing a bushing during service:

- Bushing mounting flange configuration; pitch circle diameter, hole diameter and number of holes.
- Bushing length on the oil end (below the mounting flange).
- Bushing oil-end maximum diameter
- Earth clearance on bushing oil end side
- Bushing BCT (CT space)
- Bushing connection to the transformer winding lead. Whether through draw lead or to draw rod or connected to oil end terminal at bottom end of the bushing.
- Oil End Terminal Configuration.
- Air End Height of bushing above the mounting flange.
- Bushing current rating.

The dimensional specification and standardization as in IEEE, IS and CLC/TS standards are aimed at achieving an easy replacement of bushings in the event of urgency, as any make of bushing complying with the requirement of the standard is suitable for replacement.

Brief comparison of IEEE, IS, CLC/TS requirements

Below is a table of various dimensional parameters specified in the standards for 138kV/145 kV bushings:

At Yash Highvoltage Ltd.R (Yash), we have successfully developed, manufactured and supplied bushings which are compliant with all IEC, IEEE, CLC/TS and IS specifications

As seen from the data above, CLC/TS specifies the optimal or lowest dimensions, whereas dimensions as per IS/IEEE are on the higher end and appear to be specified for an earlier generation of bushing designs.

Despite the CLC/TS standard having most of the optimal/lowest dimensions, there have still been some special designs of bushings, which are referred as "Short tail-Embedded Electrode" bushings. e.g. for 145 kV bushings as per the CLC/TS standard, 180 mm is specified as the maximum diameter of the oil end insulator, whereas some manufacturers have optimized the diameter and are offering 130 mm as the maximum diameter of the oil end insulator.

At Yash Highvoltage Ltd.® (Yash), we have successfully developed, manufactured and supplied bushings which are compliant with all IEC, IEEE, CLC/TS and IS specifications and have furthermore successfully developed bushings with special requirements such as Embedded Electrode short tail construction. It places Yash at the cutting edge of bushing manufacturing.

Yash make 245 kV OIP bushing

Brief comparison of IEEE, IS, CLC/TS requirements

	For 145 kV / 800 A / 300 BCT				
Sr. No.	**Description of Dimension**	**As per IEEE**	**As per IS 12676**	**As per CLC/TS**	**Remarks**
1	Length – Mounting flange to bottom of Oil End	1,188	800	690	IEEE is for BCT = 584
2	Maximum diameter of Oil End insulator	248	165	180	
3	Maximum Oil End electrode diameter	146	165	140	Oil End terminal diameter for IEEE
4	Mounting flange PCD of holes	362	290	290	
5	Hole diameter on mounting flange	32	15	15	
6	No. of holes on mounting flange	6	12	12	
7	Mounting flange to top end of Air End HV terminal	-	1,805	-	Not specified in IEEE and CLC/TS
8	Diameter of conservator / top cap	-	290	240	Not specified in IEEE

The need for enhanced standardization requires the collaboration of standards organizations, research and development designers, academics and other stakeholders

The way forward for standardization

The convergence in design and manufacturing requires a different approach to meeting market demand driven by the ever-increasing need for electrical power and new environmental carbon limiting legislation. **As a global player and leader in bushing manufacturing and with several decades of practical experience in meeting global customer demands and needs, Yash is an ardent campaigner for uniform global standards based on the following points.**

- Requirements specified in the IS standard need to be reviewed and revised accordingly to avoid misinterpretation of some dimensions and rationalize some dimensions inter alia:
  - Arcing Distance (L4) specified as minimum for some kV classes are on the higher side and can be optimized.
  - There is no tolerance specified for air-end height and for some kV classes, the dimensions mentioned are non-optimum.
  - The terminal diameters specified are standardized to Dia. 30 mm and Dia. 60 mm. For 1250 Amp the diameter can be reduced to Dia. 40 mm. Also, the minimum length of the terminal specified is 125 mm for currents up to 800 Amps, whereas at the site the terminal connector length used is around 60 mm.
- The test tap dimensions need to be standardized in the IS and CLC/TS Standards in line with the IEEE standard; thereby, the test tap adapter for online monitoring devices must also be standardized.
- The IS and IEEE standards can incorporate standardized minimum earth clearances of the oil end portion as specified in the CLC/TS Standard.

The need for enhanced standardization requires the collaboration of standards organizations, research and development designers and academics, utility and industry stakeholders, and manufacturers alike.

This bold approach will indeed challenge vested interest, preordained standards, and specification ideology across the geographical divide.

By aligning our practices with the latest advancements and streamlining dimensional specifications across standards, Yash paves the way for greater interoperability, efficiency, and resilience in power transmission systems. This is a key element in meeting and living up to customer expectations regardless of geographical location and bushing standards.

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Yash make 145kV OIP bushings on a 100 MVA power transformer

Authors

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Mr. Nirav Patel, an electrical engineer with ~18 years in the power industry, is a senior management team member at Yash playing a pivotal role in establishing global sales channels, domestic and international business development and marketing, and identification and strategizing for new markets and product development. He also serves on industry standardisation bodies such as the Central Electricity Authority (CEA) and Bureau of Indian Standards (BIS) committees for Transformer Bushings.