National Electrical Manufacturers Association

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Purchasing Specifications Guide
Liquid-Immersed Medium-Voltage Transformers (2.4kV–35kV)

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Overview

This document was produced by manufacturers of electrical transformers to assist customers in developing clear purchasing specifications for the type and rating of transformer indicated above. While comprehensive, it is not intended to be exhaustive or cover every possible feature that a customer may wish to include in an order. NEMA Members encourage customers to review this document and, where applicable, use the content to guide the development of their own purchasing specification materials.

Disclaimer

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a. **Ratings**. The transformer capacity should be selected based upon an analysis of the existing load to be served combined with any future load growth or necessary overload.

   Please define the rated capacity in units of kVA or MVA, which can be determined by multiplying the line current by the phase to neutral voltage. If the transformer is a single-phase design, the figure derived from the above equation is the rated capacity in VA (or kVA/MVA). If the transformer is a three-phase design, multiply the figure by 3 for the total capacity.

b. **Single-Phase vs. Three-Phase**. Specify which phase is required.

c. **Step-up vs. Step-down**. Specify the transformer's intended function.

d. **Winding Connections/Vector Group.** Provide the following information:

   1. Specify a combination of Wye, Delta, and/or Zig-Zag. Common combinations and applications are below, but others exist as well:

      i. Delta-Wye: the most common winding connection used widely for distribution and Industrial & Commercial application

      ii. Other common combinations and applications:
         1. Wye-Wye: used in utility transformers and some special applications
         2. Wye-Delta: used in generator step-up, high voltage transmission step-down, and grounding transformers
         3. Delta-Delta: special applications (i.e., large, low-voltage transformers when a neutral phase is not required)
         4. Zig-Zag: used in grounding transformers
         5. Delta – Zig-Zag or Wye – Zig-Zag: used in phase-shifting and power flow control applications

   2. Specify whether a neutral terminal or bushing is required.

e. **Standards.** List the Standards that the transformer(s) must meet.

   We recommend the following:

   1. C57.12.00: Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

   2. C57.12.90: Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

   If the transformer is for a special application, consider referencing one of the following IEEE Standards:

   3. C57.12.20: Overhead-Type Distribution Transformers 500 kVA and Smaller; High Voltage, 34 500 V and Below; Low Voltage, 7970/13 800Y V and BelowC57.12.34 – General Requirements 3 phase pad-mounted transformers

   4. C57.12.23: Submersible Single-Phase Transformers: 167 kVA and Smaller; High Voltage 25 000 V and Below; Low Voltage 600 V and Below

   5. C57.12.24: Submersible-Type Three-Phase Distribution Transformers 2500 kVA and Smaller; High Voltage: 34,500 GrdY/29 920 Volts and Below; Low Voltage: 480 Volts and Below

   6. C57.12.28: Pad-Mounted Equipment--Enclosure Integrity

7. C57.12.29: Pad-Mounted Equipment--Enclosure Integrity for Coastal Environments

8. C57.12.31: Pole-Mounted Equipment--Enclosure Integrity

9. C57.12.34: Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers, 10 MVA and Smaller; High-Voltage, 34.5 kV Nominal System Voltage and Below; Low-Voltage, 15 kV Nominal System Voltage and Below

10. C57.12.36: Liquid-Immersed Distribution Substation Transformers

11. C57.12.38: Pad-Mounted-Type, Self-Cooled, Single-Phase Distribution Transformers 250 kVA and Smaller: High Voltage, 34 500 GrdY/19 920 V and Below; Low Voltage, 480/240 V and Below

12. C57.12.40: Secondary Network Transformers Subway and Vault Types

13. C57.13: Instrument Transformers

f. **Insulation**. The following list of Basic Insulation (impulse) Levels (BILs) are the typical BILs specified for transformer windings with the corresponding voltage ratings.

The final BIL selection should be made by the customer based on the results of the system insulation coordination study. Adjustment to below BILs can be made in accordance with the requirements of the insulation coordination calculations, though significant adjustments could impact the availability of spares. Some customers prefer to increase the BIL for the bushings/terminals one level higher than the internal winding BIL—this is not a requirement but can be specified if that is the customer's standard practice.

Typical ratings are as follows, with some design flexibility:

Voltage (kV)	BIL (kV)
2.4	45, 60
4.16	60, 75
4.8	60, 75
6.9	75, 95
7.2	75, 95
8.32	75, 95, 110
12	95, 110
12.47	95, 110
13.2	95, 110
13.8	95, 110
20.78	125, 150
22.86	125, 150
23	125, 150
24.94	125, 150
34.5	125, 150

g. **Terminals**. Specify all the electrical characteristics and physical details required for the terminals.

The terminal BIL is typically the same as the winding BIL, but customers sometimes request that the terminal/bushing BIL be increased over the winding BIL. In these instances, the required BIL for the terminals should be specified separately from the winding BIL. We recommend that the customer

request approval drawings prior to ordering bushings/terminals to ensure that the equipment meets the customer's requirements.

Medium voltage terminals can be split up into three (3) main categories, namely dead front, plug type, and live front. Specify as follows:

1. Dead Front Bushings: These are typically cast resin-type bushings and can have aluminum or copper terminals. The customer should specify the dead front bushing/terminal configuration and materials.

2. Live Front Terminals: The customer should specify whether polymer or porcelain bushings are required. In addition, the customer should specify what electrical creepage distance is required if it needs to be increased from the Standard creepage distance due to atmospheric contamination/conditions or elevation above sea level. The customer should specify what size the connector terminal will be if a specific size or configuration is required.

Other important specifications include:

1. The current rating (if different than maximum transformer load current), including provision for emergency overloading conditions: This is mostly applicable to loop/ring feed configurations where the bushings/terminals need to be rated for the network current rather than only the transformer current.

2. The current transformer (CT) requirements: This will help the supplier account for mechanical and electrical clearance requirements for external mounted CTs. The customer should specify the following minimum requirements in order to adequately specify the CT requirements:
   a. Number of CTs on each bushing/terminal
   b. CT ratios for each CT
   c. Accuracy/burden requirement
   d. thermal Rating Factor for each CT
   e. Whether CTs will be installed internal or external to tank
   f. CT terminal and lead requirements (i.e., type of terminals to use, lead specification, how many terminals/which ratios to bring out/terminate, etc.)

3. Addition of cable support brackets or bus support insulators (if mechanical cable loading will exceed bushing capability): The customer should calculate what mechanical loading from the power cables or busbars applies to the bushings. This is important to ensure that bushings are not subject to cantilever loading, which exceeds the bushing capability. Overloading can lead to mechanical and/or electrical bushing failure and/or leaking.

4. The physical location of all the terminals and whether they will be enclosed by a cable termination cabinet/box or whether they will be open-air terminals: If a cable termination cabinet is required, the customer should specify the following:
   a. Level of protection (up to NEMA 3RX) required
   b. Materials (steel, aluminum, stainless steel, etc.) to be used for construction
   c. Door sizes and types
   d. Paint color and level of corrosion resistance
   e. Locking mechanism/method required

5. Whether neutral terminals will be grounded by the supplier and what method and materials to use for grounding the neutral terminals

h. **Accessories**. Specify which of the following accessories are required, if any:

1. De-Energized Tap Changer (DETC):

a. Tap winding position for HV side
b. Number of taps and step size for each tap
c. Operator handle requirements (position, lockable, labeling, etc.)

2. Moving Facilities:
   a. Lifting: requirements for lifting points (crane) for the main tank, cover, and active part (size, quantity, marking (i.e., with different color paint))
   b. Jacking: requirements for jacking pads (minimum pad size, minimum open free space around jacking pads, minimum or maximum height from bottom of tank)
   c. Rolling: requirements for base (type of base (i.e., wafer design), flat plate, direction of rolling)
   d. Sliding: rigging points (locations and quantity)

3. Oil Level Indicator:
   a. Type of mechanism: magnetic vs. prismatic
   b. Number and type of contacts, including voltage and current rating

4. Oil Temperature Indicator:
   a. Type and quantity of thermo wells, including drag arm requirements
   b. Location for mounting the gauge
   c. Number and type of contacts, including voltage and current rating

5. Cooling Fans:
   a. Type of cooling required: radiators with fans, coolers, water coolers, etc.
   b. Maximum sound requirement
   c. Motor and fan blade specifications: type of motor, bearing requirements, fan blade design, and material, etc.
   d. Fan blade enclosure/shroud requirements
   e. Wiring requirements: hardwired, connect with plugs, type of cable and conduit to be used, breaker requirements (breaker for each fan or each group of fans), control requirements (controlled by top oil or winding temp, etc.)
   f. Controller set points: On temperature, Off temperature, turn fans off when MV power is lost, etc.
   g. AC power requirements: single- or three-phase, voltage

6. Valves for drain sampling, filter, radiator, etc.:
   a. Specify which valves are needed and where they need to be installed
   b. Valve types and sizes for each valve: ball valves, globe valves, butterfly valves, X inch NPT, etc.
   c. Pipe thread and size as applicable: NPT, metric, etc.
   d. Attachment/feature requirements: oil sampling ports (size and other requirements), blanking plates, flanges, caps, gasketing, locks, etc.

7. Grounding for core, tank, bonding, etc.:
   a. Tank grounds: quantity of ground pads, ground pad size, and configuration (including hole sizes, tapping thread, and depth), ground pad material, location of ground pads, etc.
   b. Neutral grounding: material specification, connectors, insulated or not insulated from the main tank, separate ground pad or not, etc.
   c. Core and frame grounding: grounding method (internally grounded or externally), ground bushing requirements (voltage, BIL, connector size, ground strap specification, enclosure requirements, location), etc.
   d. Bonding requirements: bonding specification, bonding jumper material specification, etc.

8. Surge Arresters and Counters:

a. Arrester specification: type (MOV, gapless, gapped, under-oil, elbow, cubicle mount, distribution/intermediate/station class, etc.), material (porcelain or polymer, terminals, pressure vents, etc.)
b. Surge counters: type and model, communications (if online monitoring is required), location, etc.
c. Grounding: material specification, connectors, insulated or not insulated from the main tank, separate ground pad or not, etc.
d. Mounting brackets: location and orientation of arresters, structural requirements (if busbars or heavy cable jumpers are supported on arresters), power cable interface (when insulated power cables are used), etc.

9. Sudden Pressure or Rapid Pressure Rise Relay (RPRR):
   a. Type and model
   b. Valve requirements
   c. Number and type of contacts, including voltage and current rating
   d. Type of connection (typically a military spec connector)
   e. Seal-in relay requirements: location to be installed, contact requirements, reset requirements (remote or locally), etc.
   f. Gas space or oil.
   g. If under oil, direct connection to the tank or with shut-off valve

10. Cover Mounted Pressure Relief Device (PRD):
    a. Type and model
    b. Number and type of contacts, including voltage and current rating
    c. Type of connection: hardwired or plug/connector
    d. Seal-in relay requirements: location to be installed, contact requirements (voltage and current rating), reset requirements (remote or locally), etc.
    e. Oil direction pipe requirements: size, material, location, screen at the bottom, etc.

11. Online Monitoring Systems:
    a. Dissolved gas analyzer: type, model, communications, valve, mounting, wiring, etc.
    b. Electronic Transformer Monitor (ETM): type, model, communications, mounting, wiring, etc.

12. Conservator Oil Preservation System:

    i. Conservator Tank and Breather
       i. Oil preservation system requirements: sealed tank (with PVG), hermetically sealed flexible/corrugated tank, or positive pressure system
       ii. Breather (normal silica gel, maintenance-free, cryogenic principle etc.)
       iii. Preferred location of conservator tank

    ii. Gas Accumulation and Oil Flow (Sudden Pressure) Relay: main tank and LTC
       i. Type of relay
       ii. Number and type of contacts, including voltage and current rating
       iii. Oil/gas sampling device requirements
       iv. Seal-in relay requirements: location to be installed, contact requirements (voltage and current rating), reset requirements (remote or locally), etc.

    iii. Pressurized Inert Gas Oil Preservation System
       i. Pressure regulator and gauge requirements
       ii. Valve requirements: type, location, size, material, etc.
       iii. Nitrogen cylinder requirements: DOT certification, size, mounting, enclosure requirements, etc.

13. Hermetically Sealed: pressure gauge and valve requirements

When identifying required accessories, please also provide the following information for each accessory:

a. Approved accessory manufacturers

b. Approved models/types of accessories for each application

c. Required features for each accessory

d. Minimum requirements:
   i. Contacts
   ii. Communications ports
   iii. Accuracy
   iv. Longevity (design life)
   v. Others if applicable

e. Location where accessory should be mounted/installed

f. Wiring required:
   i. What needs to be connected
   ii. Type of wire to be used
   iii. Type of terminals to be used
   iv. Type of crimped lugs to be used
   v. Others if applicable

g. Peripheral accessory requirement:
   i. Oil direction pipes
   ii. Conduit for wiring type
      1. Size specifications
      2. Valves
      3. Plugs/connectors
      4. Rigid vs. Flex
      5. Metallic vs. PVC

h. Specific optional features required for each accessory (as applicable)

i. **Types of Cooling**: Specify the cooling media using the following letter combinations:

First letter: Internal cooling medium in contact with the windings

Mineral oil or synthetic insulating liquid with fire point <300 °C	O
Insulating liquid with fire point > 300 °C	K
Insulating liquid with no measurable fire point	L

Second letter: Circulation mechanism for internal cooling medium

Natural convection flow through cooling equipment and in windings	N
Forced circulation through cooling equipment (i.e., coolant pumps)	F
Forced circulation	D

Third letter: External cooling medium

Air (self-cooled)	A
Water	W

Fourth letter: External cooling medium

Natural Convection	N
Forced Circulation	F

Examples:

Natural ester filled transformer with fans	KNAN/KNAF
Mineral oil-filled transformer with no fans	ONAN

j. **Sound Levels**. Reference the appropriate Standards and tables to indicate sound level requirements: TR 1/CSA M88, Table 1 and Table 2.

k. **Tap Ranges and Locations.** Reference one of the following:

1. LTC: +/- 10%, or

2. DETC: +/- 5% or +/- 7.5%

While it is not necessary, the customer should consider specifying LTC classification and/or type according to the following options:

1. Classifications:
   i. Constant Flux Taps
   ii. Variable Flux Taps
   iii. Mixed Regulation

2. Types:
   i. Resistor type LTC
   ii. Reactor type LTC
   iii. Tank-mounted LTC
   iv. In-tank LTC
   v. Vacuum type LTC
   vi. LTC is Reversing type or Linear type or Coarse/Fine type
   vii. Preventive autos (LTC reactor)
   viii. Series Transformers
   ix. Compensating Transformers
   x. Non-linear devices
   xi. Tie-in resistors or potential switch
   xii. Extra current rating on LTC (1.5 p.u., 2 p.u. etc.)
   xiii. Particular make of the LTC
   xiv. Capability of the LTC to meet Low-ambient Temperature Load Capability

3. Specify if parallel LTC operation is required.

l. **Impedance.** Specify the acceptable impedance range, which may be identified through a system fault or arc flash study.

m. **Short-Circuit Withstand Characteristics and Capabilities**. Reference the following IEEE Standards:

1. C57.12.00: Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

2. C57.12.90: Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

n. **Overload Profiles**. Specify the overload criteria in % of load for time (i.e., 120% of load for 4 hours).

o. **Rating Plate**. Specify the appropriate Standard and any other information required to be displayed on the rating plate.

1. C57.12.00: Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers (Table 10)

2. Other information not covered under the Standards, as determined by the customer

p. **Ambient conditions**. Provide the following information:

1. Elevation above sea level

2. Atmospheric contamination

3. Ambient temperature (minimum and maximum)

4. Bus/isophase duct temperature

5. Other relevant environmental factors

6. Location – indoor or outdoor

q. **Seismic requirements**. Provide the following information:

1. G-force level required

2. Maximum lean angle on bushings

3. Seismic certifying body

4. Maximum tilt for transformer installation (e.g. 2.5 degrees)

r. **Special Requirements**. Provide the following information:

1. Transport requirements

2. Geomagnetically induced current

3. Harmonics requirements (K Factor)

s. **Tests and test levels**. Factory tests should include all Standard production tests as specified in ANSI C57.12.00 and other applicable ANSI, NEMA, and IEEE Standards.

The factory tests should include at least the following:

1. Transformer resistance measurements of all windings

2. Transformer turns ratio tests

3. Polarity and phase relation tests at the rated voltage connection

4. Impedance at rated current and rated frequency on the rated voltage connection and on the tap extremes

5. Applied potential tests on windings

6. Induced potential tests, neutral to be grounded as if transformer were in operation

7. Standard Impulse (BIL) test on all windings

The following optional tests may also be provided:

1. Insulation power factor test on all windings

2. Mechanical leak test on the transformer tank

3. Oil test for dielectric breakdown and moisture content

t. **Supply-voltage Wave Shape.** Specify what the transmission supply voltage wave shape is and what the maximum voltage and current distortion is that the transformer can be exposed to or needs to be designed for.

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