National Electrical Manufacturers Association

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Purchasing Specifications Guide
Liquid-Immersed Large Power Transformers (≥ 25kV)

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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 development of their own purchasing specification materials.

Disclaimer

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1. **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.

2. **Single-Phase vs. Three-Phase**. Specify which is required.

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

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

    a. 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 applications.

        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

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

    c. Specify whether a stabilizing winding is required.

5. **Standards.** List the Standards that the transformer(s) must meet. We recommend the following:

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

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

    c. C57.12.10: Liquid-Immersed Power Transformers (if the transformer is for a special application)

6. **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:

12kV	95kV, 110kV BIL
12.47kV	95kV, 110kV BIL

13.2kV	95kV, 110kV BIL
13.8kV	95kV, 110kV BIL
20.78kV	125kV, 150kV BIL
22.86kV	125kV, 150kV BIL
23kV	125kV, 150kV BIL
24.94kV	125kV, 150kV BIL
34.5kV	125kV, 150kV, 200kV BIL
46kV	200kV, 250kV BIL
69kV	250kV, 350kV BIL
115kV	350kV, 450kV, 550kV BIL
138kV	450kV, 550kV, 650kV BIL
161kV	550kV, 650kV, 750kV BIL
230kV	650kV, 750kV, 825kV, 900kV BIL

7. **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 to 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.

   Power transformers can have a variety of different types of terminals/bushings depending on the application. The following list of items will outline what needs to be specified to ensure that the transformer will meet the requirements of the customer:

   a. Type of terminal: oil-to-air, oil-to-oil, oil-to-SF_6, etc.

   b. Bushing/terminal design features condenser type, bulk oil type, solid insulation, pluggable, etc. Indicate whether the bushings/terminals require swapping out without draining oil.

   c. Material: porcelain, polymer, or cast resin

   d. Color

   e. Creepage length

   f. Type of internal insulation: Oil Impregnated Paper (OIP), Resin Impregnated Paper (RIP), Resin Impregnated Synthetic (RIS), solid, oil

   g. Basic Insulation Level (BIL) of line and neutral bushings

   h. Mechanical loading on bushings/terminals: define loading in all directions if they will exceed Standard bushing loading limits

   i. Overvoltage requirements: temporary and transient

   j. Overload capability, including neutral bushings/terminals (this is based on the emergency overload rating of the transformer)

   k. List of current transformers (CTs), characteristics, and requirements to define ground shield length/CT pocket depth of the bushings:
      i. Number of CTs
      ii. Ratios for each CT

iii. Accuracy/burden requirement
iv. Thermal rating factor for each CT
v. Whether CTs will be installed Internal or External to tank
vi. CT terminal and lead requirements: type of terminals to use, lead specification, how many terminals/which ratios to bring out/terminate, etc.

l. Terminal/Plug/Bushing physical location:
i. Order of bushings arrangement (H1, H2, H3 or H3, H2, H1, etc.) if non-Standard
ii. Cover-mounted or horizontally mounted on the sidewall
iii. Location (C57.12.10-2010 clause 5.1 indicates the segments)
iv. Terminal arrangement and markings (Ref: C57.12.10-2010 clause 5.2 Figure 3)
v. Bushings terminals heights from the transformer base, spacing, etc.
vi. Minimum external clearances (line-to-line, line-to-neutral, and line-to-ground) if non-Standard
vii. Special details (bus-duct or any other special requirements)

m. Connection type: bottom-connected or draw-lead/rod

n. Terminal requirements: test terminals, type of connection (threaded stud vs. NEMA pads), coating on terminals (not coated, tin coated, silver coated)

o. Requirements for cap tap and/or potential tap

p. Interchangeability with existing spares or with bushings of another Standard

q. Whether terminals will be enclosed by a cable termination cabinet/box or whether they will be open-air terminals. If a cable termination cabinet is required, specify the following:
i. Level of protection required: NEMA 1, 3, 3R, 3X, 4, 4R, 4X, etc.
ii. Materials to be used for its construction: steel, aluminum, stainless steel, etc.
iii. Door sizes and types
iv. Coating: galvanizing, paint, etc.
v. Locking mechanism/method that is required

r. Whether neutral terminals should be grounded by the supplier and what method and materials to use for grounding the Neutral terminals.

8. **Accessories**. Specify all the accessories required. The following list should be helpful:

a. Load Tap Changer (LTC):
i. Tap winding position: HV or XV windings
ii. Number of taps and step size for each tap
iii. Design life (minimum number of tap operations)
iv. Type: vacuum, oil, resistive bridging, reactive bridging, etc.
v. For reactive bridging only – specifications on preventative auto/reactor: core and coil construction, insulation requirements, losses, sound restrictions, etc.)
vi. Contact and lead routing requirements
vii. Drive mechanism requirements (type of mechanism, remote tap indication, remote tap control, tap dial requirements, drag arm requirements on tap dial, wiring, terminations, lugs, etc.)

b. De-Energized Tap Changer (DETC):
i. Tap winding position (HV or XV windings)
ii. Number of taps and step size for each tap
iii. Type (rotary, sliding, etc.)
iv. Operator handle requirements (position, lockable, labeling, etc.)

c. Moving Facilities:

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

d. Oil Level Indicator:
i. Type of mechanism (magnetic vs. prismatic)
ii. Number and type of contacts, including voltage and current rating
iii. Visibility (if higher than X ft. above the base of the transformer, the gauge should be angled downward at X˚)

e. Oil Temperature Indicator:
i. Type and quantity of thermo wells, including drag arm requirements
ii. Location for mounting the gauge
iii. Number and type of contacts, including voltage and current rating

f. Winding Temperature Indicator (WTI):
i. Type and quantity of thermo wells, including drag arm requirements
ii. Location for mounting the gauge
iii. Number and type of contacts, including voltage and current rating

g. Fiber Optics Temperature Sensors:
i. Type and model: specify the device or list of acceptable devices
ii. Number of fibers and monitoring locations: hotspot on each winding, bottom oil, top oil, bottom radiator/header, top radiator/header, tap changer compartment, etc.
iii. Recording and alarm requirements (should logs be recorded, set points for alarms, etc.)
iv. Communications hardware and protocol requirements: fiber, serial wired, Ethernet, Modbus, ICCP, DNP3, etc.

h. Cooling Fans:
i. Type of cooling required: radiators with fans, coolers, water coolers, etc.
ii. Maximum sound requirement
iii. Motor and fan blade specifications: type of motor, bearing requirements, fan blade design, and material, etc.
iv. Fan blade enclosure/shroud requirements
v. Wiring requirements (hardwired, connect with plugs): type of cable and conduit to be used
vi. Breaker requirements for each fan or each group of fans
vii. Control requirements (controlled by top oil or winding temp, etc.)
viii. Controller set points: ‘On’ temperature, ‘Off’ temperature, turn fans off when MV power is lost, etc.
ix. AC power requirements: single or three-phase, voltage

i. Pumps:
i. Type of pumps required (centrifugal is typical)
ii. Motor and pump specifications: type of motor, bearing requirement, pump material, etc.
iii. Valve requirements: type of valves, location, etc.
iv. Wiring requirements: hardwired, connect with plugs, type of cable, and conduit to be used
v. Breaker requirements for each pump or each group of pumps
vi. Control requirements (controlled by top oil or winding temp, etc.)
vii. Controller set points: ‘On’ temperature, ‘Off’ temperature, turn pumps off when HV/MV power is lost, etc.)
viii. AC power requirements (single or three-phase, voltage)

j. Valves: drain sampling, filter, radiator etc.:
   i. Specify which valves are needed and where they need to be installed
   ii. Specification of valve tags/nameplates: materials to be used, letter size and style, location, attachment methods, etc.)
   iii. Valve types and sizes for each valve (ball valves, globe valves, butterfly valves, X-inch NPT, etc.)
   iv. Pipe thread and size as applicable (NPT, metric, etc.)
   v. Attachment/feature requirements: oil sampling ports (i.e., size and other requirements), blanking plates, flanges, caps, gasketing, locks, etc.

k. Grounding: core, tank, bonding, etc.:
   i. Tank grounds: quantity of ground pads, ground pad size, ground pad configuration (hole sizes and tapping thread and depth), ground pad material, location of ground pads, etc.
   ii. Neutral grounding: material specification, connectors, insulated or not insulated from main tank, separate ground pad or not, etc.
   iii. Core and frame grounding: internally or externally grounded, ground bushing requirements (voltage, BIL, connector size, ground strap specification, enclosure requirements, location), etc.
   iv. Bonding requirements: bonding philosophy/specification, bonding jumper material specification, etc.

l. Surge Arresters and Counters:
   i. Arrester specification: type (MOV, gapless, gapped, etc.) and material (porcelain or polymer, terminals, pressure vents, etc.)
   ii. Surge counters: type and model, online monitoring requirements, location, etc.
   iii. Grounding: material specification, connectors, whether insulated from the main tank, separate or non-separate ground pad, etc.
   iv. 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.

m. Sudden Pressure or Rapid Pressure Rise Relay (RPRR):
   i. Type and model
   ii. Valve requirements
   iii. Number and type of contacts, including voltage and current rating
   iv. Type of connection (typically a military-grade connector)
   v. Seal-in relay requirements: location to be installed, contact requirements, reset requirements (remote or locally), etc.

n. Pressure Relief Device (PRD):
   i. Type and model
   ii. Number and type of contacts, including voltage and current rating
   iii. Type of connection (hardwired or plug/connector)
   iv. Seal-in relay requirements: location to be installed, contact requirements (voltage and current rating), reset requirements (remote or locally), etc.
   v. Oil direction pipe requirements: size, material, location, screen at bottom, etc.

o. Online Monitoring Systems:
   i. Dissolved gas analyzer: type, model, communications, valve, mounting, wiring, etc.
   ii. Electronic Transformer Monitor (ETM): type, model, communications, mounting, wiring, etc.
   iii. Partial Discharge Monitor: type, model, communications, mounting, wiring, etc.
   iv. Geomagnetic Induced Current (GIC) Monitor: type, model, communications, Hall effect transducer, mounting, wiring, etc.

p. Fall Arrest Systems:

i. Manufacturer and type: fall arrest tower and mounting brackets
ii. Ancillary equipment requirements: posts around tank perimeter, ropes, etc.

q. Rupture-Resistant Tank:
i. Typically requires Ester fluid and RIP, RIS or plugin type bushings/plugs
ii. Maximum arc energy

r. Deluge System (typically not included, unless part of turnkey scope). Detailed requirements: water source, flow rate, equipment to be protected, site conditions, oil containment area details, Structural constraints, etc.

s. Conservator Oil Preservation System

i. Conservator Tank and Breather
1. Oil preservation system requirements: bladder or no bladder in the tank, equalization valve requirements
2. Breather: normal silica gel, maintenance-free, cryogenic principle, etc.
3. Preferred location of conservator tank
4. Equalization valve requirements for tap changer

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

t. 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.

u. 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. Mounting and installation location

f. Wiring required
vi. What needs to be connected
vii. Type of wire to be used

viii. Type of terminals to be used
ix. Type of crimped lugs to be used
x. Others if applicable

g. Peripheral accessory requirement
xi. Oil direction pipes
xii. Conduit for wiring
1. type
2. size specifications
3. valves
4. plugs/connectors
5. rigid vs. flex
6. metallic vs. PVC
7. etc.

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

9. **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
Directed and 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

10. **Sound Levels**. Reference the following Standard and tables to indicate sound level requirements: NEMA TR 1 Standard for Transformers, Regulators, and Reactors, Tables 1 and Table 2.

11. **Tap Ranges and Locations**: Not applicable. If a de-energized tap changer is required, reference information in Section 8.

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

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

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

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

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

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

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

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

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

    a. Elevation above sea level

    b. Atmospheric contamination

    c. Ambient temperature (minimum and maximum)

    d. Bus/isophase duct temperature

    e. Other relevant environmental factors

    f. Location – indoor or outdoor

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

    a. G-force level required

    b. Maximum lean angle on bushings

    c. Seismic certifying body

    d. Maximum tilt for transformer installation

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

    a. Transport requirements

    b. Geomagnetically induced current

    c. Harmonics requirements (K Factor)

19. **Tests and test levels**. Reference IEEE C57.12.90 for testing requirements and IEEE C57.12.00 table 17 – add any additional tests that need to be performed and indicate which of the type tests need to be performed.

20. **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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