Replaced by TB 529, April 2013

204

GUIDELINES FOR CONDUCTING DESIGN REVIEWS FOR TRANSFORMERS 100 MVA AND 123 kV AND ABOVE

Working Group
12.22

August 2002

GUIDELINES FOR CONDUCTING

DESIGN REVIEWS

FOR TRANSFORMERS

100 MVA AND 123 kV AND ABOVE

Working Group 12.22
Convenor: G.S. Polovick (Canada)
Working Group Members ; N. Amano , B. Astrom , P. Austin , L. Bergonzi, P. Christensen, B. Damm, K. Eckholz , J. Fyvie, J. Lackey, L. Magallanes, J.O. Persson, L. Shifrin, R. Sobocki, J. Veens

CONTENTS

Foreword

This document has been prepared by CIGRE SC 12 as a guide to customers of power transformers for conducting design reviews with manufacturers of transformers rated 100 MVA and 123 kV and above.

A design review in a planned exercise to ensure there is a common understanding of the applicable standards and specification requirements, and to provide an opportunity to scrutinise the design to ensure the requirements will be met, using the manufacturer's proven materials and methodology.

This document is an outline, highlighting the various design features and technical requirements which should be reviewed to ensure compliance with the contract. It does not include design limits or parameters. It is the responsibility of the customer to ensure he or she has sufficient expertise to understand, and evaluate the design. This document does not supplant the responsibility for the adequacy of the design, or the design limits, which must remain with the manufacturer. Deficiencies which are identified shall be corrected. However any changes which are a "betterment" to the **Design** shall be subject to commercial resolution between the Purchaser and Manufacturer.

Because the review will include information which is proprietary in nature, it is considered essential that the discussions and information exchanged during the design review process be kept confidential.

1 Scope and Normative References

1.1 Scope

The scope concerns specific aspects of the electrical, mechanical, and thermal design of new transformer(s) rated 100 MVA and 123 kV and above purchased by a customer.

1.2 Normative References

This design review guide applies to transformers manufactured in accordance with IEC standards, and the requirements included therein. For reference these standards are listed below.

IEC 60044	Current Transformers
IEC 60050	International Electrotechnical Vocabulary
IEC 60050 (421)	International Electrotechnical Vocabulary – Chapter 421: Power Transformers and Reactors
IEC 60060-1	General Definitions and Test Requirements
IEC 60071	Insulation Coordination
IEC 60071-1	Part 1: Definitions, Principles and Rules
IEC 60071-2	Part 2: Application Guide
IEC 60076	Power Transformers
IEC 60076-1	Part 1: General
IEC 60076-2	Part 2: Temperature Rise
IEC 60076-3	Part 3: Insulation Levels and Dielectric Tests
IEC 60076-5	Part 5: Ability to Withstand Short-Circuit
IEC 60076-8	Application Guide for Power Transformers
IEC 60076-10	Determination of Transformer and Reactor Sound Levels
IEC 60137	Bushings for Alternating Voltage Above 1000 V
IEC 60214	On-Load Tap-Changers
IEC 60270	Partial Discharge Measurement
IEC 60289	Reactors
IEC 60296	Specification for Unused Mineral Oil for Transformers and Switchgear
IEC 60354	Loading Guide for Oil-Immersed Transformers
IEC 60542	Application Guide for On-Load Tap-Changers

The standard used should be that version in effect at the time of purchase.

Other standards may be specified throughout the world. Those standards specified by the customer should prevail. Other documents of relevance are:

ISO 9001	Quality System – Model for Quality Assurance in Design/Development
WG 12.15	Guide For Customers Specifications for Transformers 100 MVA and 123 kV and above.
WG 12.19	The Short Circuit Performance of Power Transformers

1.3 Quality Assurance

For the purpose of this design review guide it is considered the manufacturer is certified to be in compliance with ISO 9001, or has a Quality Assurance system in place which is acceptable to the Purchaser. The manufacturer will provide their Quality Plan during the design review.

2 Definitions

For the purpose of this design review guide, the definitions of IEC 50 are used.

(a) **Prototype Feature** – A first, full-scale application of a new design or fabrication feature.

(b) **NDT** – Non-destructive tests (or testing). Usually used in the context for examining welds by radiograph or ultrasonic methods or other non-destructive methods.

(c) **Betterment** – An improvement (in the design) that adds value to the transformer or increases safety margins.

3 Objectives

The basic objectives of the design review are:

- to ensure there is a clear and mutual understanding of the technical requirements,
- to verify the system and project requirements and to indicate areas where special attention may be required,
- to verify the design complies with the technical requirements,
- to identify any prototype features and evaluate their reliability and risks.

4 Schedules

Prior to award of contract, the manufacturer and customer should agree on the design review schedule.

4.1 Pre-award Review

Prior to award of contract, a Contract Review may be held to review and confirm the specifications and standards requirements of the contract, particularly when considering a new design or a new supplier. For obvious reasons it is especially important the subjects contained in sections 6, 7, 8, 9, 11, 13 and 14 be reviewed at this stage. Any special system or project requirements should be highlighted.

The Manufacturer should identify the major Subcontractors. The Purchaser should describe the intended inspection program.

4.2 Design Review

A design review, initiated and chaired by the Purchaser should be held for the purpose of conducting an in-depth review of the ordered power transformer and to allow the Purchaser to have a clear understanding of the overall design. This review is preferably held after the completion of the electrical design, the preliminary outline drawing, the rating plate drawing and before the start of any manufacturing activities. These reviews are normally held at the manufacturer's plant which allows for direct access to the manufacturer's design and factory personnel.

The Manufacturer and Purchaser shall establish a mutually agreeable reporting process.

4.3 Additional Design Review

Additional design review meetings may be required to follow up on any changes resulting from the first design review or to review those features for which the design had not been completed at the time of the first design review meeting. These may include review of:

- the seismic withstand,
- the tank design,
- protection and control wiring systems,
- accessories, including their arrangement on the tank,
- transportation,
- others.

5 Subjects for Design Review

The design review should examine the functionality of the transformer to perform within the specified operating requirements and includes the following considerations:

- system data,
- environmental data,
- specification requirements,
- transformer design,
- fabrication,
- inspection and test plan.
- transportation and installation (when applicable).

While it is expected the “transformer design” will consume most of the attention, each issue is important to assure successful completion of the purchase and reliable operation in service.

6 System Data

The system conditions under which the transformer will be required to operate should be reviewed. These should include:

(a) AC system voltage variations. Where a load tapchanger is specified, the usage of the tapchanger should be examined and how it will be operated. That is, will it be used as a constant flux unit, or a variable flux unit, or both.

(b) AC system frequency variation.

(c) DC or harmonic system components.

(d) System short circuit capacity including system operating data.

(e) System switching and transformer protection.
The type of transformer protective switching should be described by the customer. Is there a disconnect switch or a circuit breaker on the source side. The type and application of over-voltage protection should be reviewed.

(f) System earthing conditions.

(g) The system connections to the transformer should be discussed noting that the surge impedance is less for cable and bus connections. This may effect the terminal impedance used during impulse tests.

(h) High frequency transients. Some system operations such as switching of large capacitor banks, GIS or cables are known to produce fast transients (FTs), or very fast transients (VFTs). These and other possible sources of FTs and VFTs may result in excessive voltages within the transformer.

7 Environmental Information

The environmental conditions under which the transformer will be required to operate should be reviewed. Any conditions which result in a variation in the design or materials from the manufacturer's standards should be highlighted and be examined.

(a) Ambient temperature range.
(b) Site altitude.
(c) Humidity.
(d) Pollution.
(e) Seismic zone and response spectra.
(f) Geomagnetic currents.
(g) Isoceraunic level.

8 Specification Requirements

Although there are many specifications involved prescribing the requirements for transformers, including national and international standards, the intent of this section is to review the specific technical performance requirements of the contract as set out in the technical specifications and schedule.

(a) MVA ratings

In addition to the fundamental nameplate ratings, any requirements for planned or unplanned overloads should be reviewed.

(b) Terminal voltages

- no load,
- winding connections and vector relationships,
- tapchanger requirements.

(c) Insulation levels

(d) Winding impedances

The winding impedances should be reviewed including tolerances and anticipated differences between design values and test results. The variation in impedance across the tapping range and any special requirements for paralleling with existing transformers should be considered.

(e) Cooling provisions

(f) Temperature limits

(g) Sound levels

- no load, including any specific requirements for levels above 1.0 p.u. voltage,
- full load,
- variation with tap position,
- variation with tertiary loading (if applicable).

9 Transformer Design

The manufacturer should demonstrate how their design will function reliably within the operating requirements and meet the performance guarantees. Sufficient information should be provided for each basic element to review the design for functionality and for future reference, e.g. maintenance considerations.

If there are any prototype features in the design or fabrication, they should be highlighted and assessed for risk and reliability. Changes made to the design from that offered and/or discussed in detail during the pre-award review should be presented and described by the manufacturer. Unique or specialty transformers may require special or additional considerations.

9.1 Core

The manufacturer should describe their design for the core, explaining how it will perform within the operating parameters. Specific items which should be reviewed include the following:

(a) A general description of the core
- cross sectional areas
- operating flux density
- weight
- type or grade of material
- method used for joints

(b) Losses

(c) Thermal aspects
- limits
- control
- core asymmetry of the yoke

(d) Over-excitation limits

9.2 Windings

(a) General arrangement

The manufacturer should describe each of the windings in sufficient detail to provide a clear understanding of the physical arrangements. The description should include the following:

- number of turns,
- winding type and dimensions, including axial and radial spacer details,
- type of conductor or cable, including number of strands and conductor insulation,
- conductor arrangement,
- current densities.

(b) Insulation design

The manufacturer should provide an insulation layout sketch. Each major region of the insulation structure (i.e. main gap between windings, shielding and/or ground insulation at winding ends, inner winding to core, outer winding to tank, axially along windings) should be identified with the test or operating condition which is most critical to its dimensioning and design. A brief summary of the stresses in the critical regions for each test or operating condition should be reviewed.

The manufacturer should demonstrate how the insulation is designed to withstand the imposed stresses, i.e. indicate insulation structure, corresponding stress and resultant dielectric strength:

- turn to turn,
- section to section,
- winding to winding,
- winding to ground,
- phase to phase,
- location of electrostatic plates and shields,
- other winding stresses due to:
  - winding nodes,
  - leads,
  - transferred voltages from other windings.

Nodes are coil interconnections and changes in winding construction that cause a change in the series capacitance of the winding.

(c) Thermal design

1. Losses

The manufacturer should provide the calculated losses for I^2R and eddy losses. He should indicate these losses for the self-cooled and maximum ratings of the transformer and for the connection for the heat run position.

2. Cooling

The manufacturer should describe how the windings will be adequately cooled. This designation should include details on:

- oil ducts and dimensions,
- oil flow system,
- location of winding hottest spot temperature,
- oil velocities, including any concerns about static electrification.

Any special cooling or operating conditions specified, such as loss of one cooler, or other special cooling considerations should be reviewed.

3. Temperature

The manufacturer should provide a description of the thermal model of the windings and a summary of the calculated temperatures for the various ratings and cooling conditions. This should include:

- average winding rises,
- hot spot rises; the manufacturer should describe how the hot spot rises are calculated with pumps on and off if applicable,
- oil temperatures in the windings.

This should include consideration of temperatures over the tapping range where applicable, and for different loading combinations for three winding and auto transformers.

Where direct winding temperature measuring probes are required, the locations of the probes should be reviewed.

4. Overload

Where defined overloads have been specified, the manufacturer shall describe the following:

- top oil and hot spot maximum temperatures,
- anticipated temperatures and capabilities of accessories such as bushings, cable connections, tapchangers, leads and bus bars,
- provision for oil expansion.

(d) Mechanical strength

The manufacturer should provide a description of the capability of the windings to withstand the mechanical forces due to the specified external short circuits.

This description should include the following:

- calculation of fault currents, including impedance, pre-fault voltage,
- presentation on how the windings are designed and manufactured to withstand the stresses of each of the failure modes, all as described in the CIGRE W.G.12.19 report,
- coil clamping provisions,
- supportive evidence or experience.

9.3 Core and Coil Assembly

The manufacturer should describe the general assembly and mechanical features for the following:

(a) Core manufacture.

(b) Core clamping.

(c) Core insulation system - laminations
- bonding
- earthing.

(d) Coil clamping, including the clamping pressure used, and why.

(e) Provision for withstanding shipping stresses and the design values.

(f) Dryout and processing.

The manufacturer should describe their methods for moisture removal from the insulation ensuring the design dimensions of the coils are achieved. The acceptance criteria should be included.

9.4 Leads and Cleats

The manufacturer should describe the arrangements used for the winding leads and interconnections. This should include details for the following:

(a) Methods used for joining interconnections.

(b) Insulation design - shields
- dielectric stresses and strengths.

(c) Hotspots and provisions for cooling critical areas. The manufacturer should indicate what and where the critical areas are.

(d) Providing mechanical support.

9.5 Leakage Flux Control

The manufacturer should provide a description on how they provide for the control of, or accommodation of, leakage flux including flux densities at full load and at maximum overloads.

This description should include details of magnetic shielding or shunts where used and the methods used for fastening and grounding them.

9.6 Sound Level

The manufacturer and customer should have a mutual and clear understanding for the requirements for the sound level. That is, what is the guarantee, what is it based on and how will it be measured.

The manufacturer should provide a description of the design provisions which are used to meet the specified sound level.

It is generally considered that the core is the primary source of transformer noise, however other sources may also contribute to the operating sound levels. These sources may include:

- cooling fans,
- oil pumps,
- leakage flux shunts,
- load current in the windings,
- varying flux design for voltage regulation,
- internal reactors in the tertiary winding circuit.

While these sources may not contribute to the sound level measured per the “standard”, the customer may have an interest in knowing the effects for operational considerations.

9.7 Seismic

Many countries have regions which experience various degrees of seismic activity. Transformers which are purchased for those regions must withstand the rigors imposed during a seismic event. Generally the seismic activity stresses on the core and coil assembly are much less than the stresses which occur during shipping or system faults. However other structures should be reviewed.

(a) Structural analysis

The manufacturer should present a summary of the structural analysis of the transformer due to seismic loading. It should include the method of analysis and the design criteria for the following:

- weld design and loading,
- flexible expansion/contraction requirements of piping, etc.,
- adequacy of provision for anchoring to the foundation,
- stresses and strengths of the:
  - radiator assembly,
  - conservator,
  - bushings,
  - other ancillary components as appropriate.

10 Fabrication

10.1 General Construction

The manufacturer should provide the following Cover, Base and Tank Construction data:

- arrangement of stiffeners/bracing for distortion,
- details of gaskets and stops for all flanged joints on the main tank,
- fit of interfaces between cover, tank body; flanges. Ensure that all flange surfaces cannot trap water against the gaskets,
- location and details on lifting, jacking devices,
- tank draining location,
- Base Structure: design and mechanical strength considerations and fitness for the intended foundation,
- leakage and deflection tests,
- provision and location of required valves. Any required access during transformer operation should be identified,
- external insulation distances between phases and phase to earth.

10.2 External Cooling Equipment

- fit of interfaces; flanges,
- pressure leakage pre-test details,
- internal cleaning details,
- shut-off valves, review design and material,
- pumps.

10.3 Conservators/Preservation Systems

- fit of interfaces; flanges,
- volume considerations,
- details of air cell,
- pressure/vacuum capabilities,
- moisture controlling devices.

10.4 Fabrication Drawings

- conform to requirements with regard to welding and NDT,
- details to show all weld and NDT processes complete with symbols,
- location and identification of welds to receive NDT.

10.5 Gas Collection System Design

Review cover design to ensure all gas is directed to a collection point (or points).

- ensure non-gas pipe connections project below the cover,
- ensure all pockets are piped or blocked,
- cover supports or bracing has separate holes or slots to avoid trapping gas,
- slopes are adequate.

10.6 Surface Preparation and Painting

The manufacturer should detail the following data and processes for Tanks, Radiators, Conservator, etc.:

- blast material,
- checking of blast profile,
- paint system,
- calibration of dry film thickness gauges,
- adhesion testing.

11 Testing

The Inspection and Test Plan shall be made available and reviewed. The testing requirements of the contract and standards should be discussed and clarified in relation to each aspect of the design. Special attention should be given where the requirements and information required varies from the standards or normal practice of the manufacturer.

The following should be specifically clarified:

- Impulse testing: tap position(s), connections, grounded terminals, ability to generate the waveshape, detection traces required, number and polarity of impulses.

- Switching impulse: tap position(s), grounded terminals, clearances sufficient.

- Induced voltage test(s): connection(s), tap position(s), frequency used, duration, percentage of nominal induction, which terminals grounded.

- Partial discharge measurement: connections, tap position, required voltage profile, maximum background level, measurement units microvolts or picoCoulomb, and acceptance criteria.

- Heat run test(s): tap position(s), required power available, procedure for oil forced cooling when switching off, any special overload test, required Dissolved Gas Analysis.

- Heat run tests with autotransformers: are tests on more then one tap position required.

- Order of tests.

- Any extra tests required, e.g. during fabrication.

- Required details in the test report.

12 Ancillary Equipment

The manufacturer should provide details and data for the following major accessories, or ancillary equipment.

12.1 Bushings

- manufacturer,
- tests performed by the manufacturer,
- type and general construction of the bushing,
- use of lower terminal shields or insulation assembly,
- sensitivity of matching the shields and bushings,
- interchangeability.

12.2 Current Transformers

- manufacturer,
- ratio and accuracy,
- overload characteristics.

12.3 Tapchangers

- manufacturer,
- type and ratings,
- overload capabilities,
- dielectric capabilities.

12.4 Internal Surge Arresters

The manufacturer should provide descriptions for any internally connected arresters or non-linear resistors or other means of voltage control. The location and mounting arrangement should be reviewed.

12.5 Control Cabinet and External Cabling

The following items should be reviewed to ensure the needs of the Purchaser are met:

- ensure the cabinet size is adequate and can accommodate the Purchaser's cables and connections,
- wiring standards are correct,
- adequate heating and ventilation is provided,
- cables from transformer accessories are suitable for the climate and protected mechanically.

12.6 On-line Monitoring Equipment

The intended use of specified equipment and sensors for on-line monitoring should be reviewed. Fitness for the site conditions in view ambient, EMC and any mechanical stresses should be considered.

13 Transportation and Installation

The intended shipping process should be reviewed. This includes consideration of:

- routing,
- dimensional clearance limitations,
- shipping weight limitations,
- use of impact recorders,
- site handling,
- erection subcontractors and warranty considerations,
- oil supply.

14 Local Regulations

One area of review is frequently overlooked. This is the requirement, where specified, to comply with local regulations. Some examples of local regulations include the following.

(a) Worker safety

Local regulations frequently require specific provisions for:

- ladders,
- protection from rotating shafts,
- clearance to electrical parts,
- fall arrest systems,
- hazardous materials.

(b) Noise bylaws

(c) Environmental protection

Le CIGRÉ a apporté le plus grand soin à la réalisation de cette brochure thématique numérique afin de vous fournir une information complète et fiable.

Cependant, le CIGRÉ ne pourra en aucun cas être tenu responsable des préjudices ou dommages de quelque nature que ce soit pouvant résulter d'une mauvaise utilisation des informations contenues dans cette brochure.

Publié par le CIGRÉ
21, rue d'Artois
FR-75 008 PARIS
Tél. : +33 1 53 89 12 90
Fax : +33 1 53 89 12 99

The greatest care has been taken by CIGRE to produce this digital technical brochure so as to provide you with full and reliable information.

However, CIGRE could in any case be held responsible for any damage resulting from any misuse of the information contained therein.

Published by CIGRE
21, rue d'Artois
FR-75 008 PARIS
Tel : +33 1 53 89 12 90
Fax : +33 1 53 89 12 99