# Best Practices for Transformer Procurement

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*ALTANOVA, a Doble Engineering Company, provides diagnostic solutions to utilities and industries to improve the performance of their electrical assets through portable testing equipment, advanced monitoring systems, and professional services.*

# Altanova History

ALTANOVA
A DOBLE COMPANY

**1938** I.S.A. Istrumentazioni Sistemi Automatici S.r.l. is established in Taino ITALY

**1999** TECHIMP was born as a spin-off from the University of Bologna ITALY.

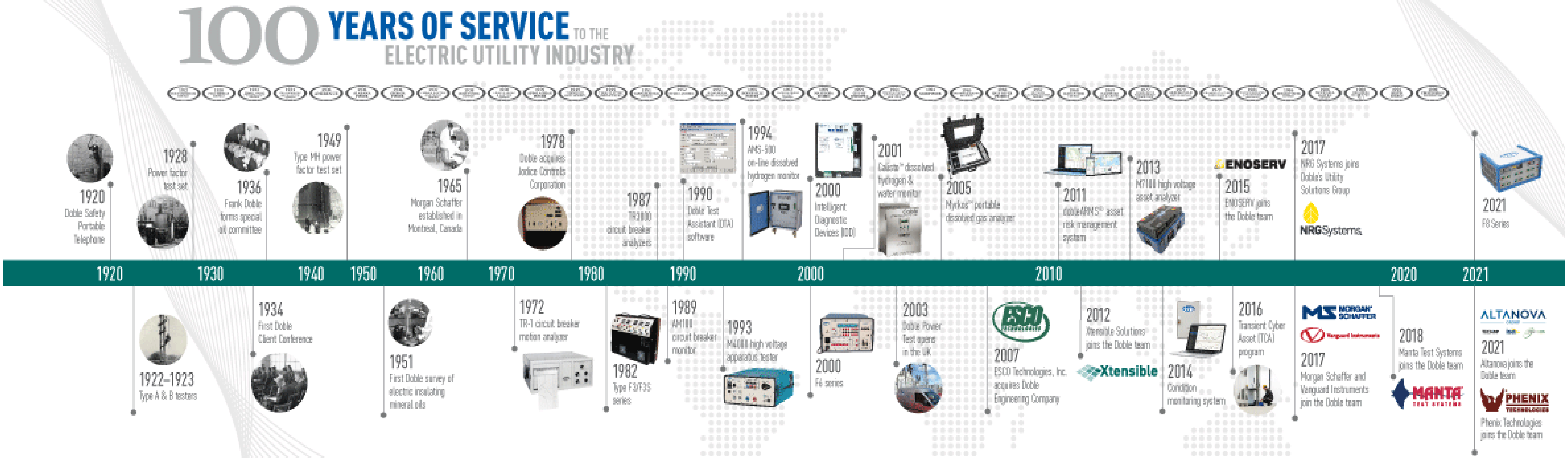
**2017** I.S.A. and TECHIMP merge giving birth to the ALTANOVA GROUP

**2019** INTELLISAW joins ALTANOVA GROUP

**2021** ALTANOVA GROUP becomes part of ESCO Technology Group and joins the Doble Engineering Company, as part of the USG division.

# Doble History

ALTANOVA
A DOBLE COMPANY



# Altanova Today

100
COUNTRIES

12 GLOBAL FACILITY LOCATIONS

150+
EMPLOYEES

150+
SALES PARTNERS

5550+
CUSTOMERS GLOBALLY

Part of ESCO Technologies' Utility Solutions Group

## PRODUCT BRANDS

# Our Solutions

ALTANOVA
A DOBLE COMPANY

## Electrical Test Equipment

Essential for day-to-day maintenance tests of electrical assets. Useful in specific phases of the asset lifecycle:

- Procure
- Operate
- Maintain
- Decommission.

## Professional Services

Diversified offer according to the electrical asset lifecycle:

- Installation and commissioning
- Diagnostic test
- Data analysis
- Consultancy
- Training.

## Monitoring Systems

Shift from a time-based maintenance to a condition-based maintenance.

Focus on predictive maintenance and shift in focus from electric asset value cost to network outage costs.

Strong evolution of digitalization trend in the power industry.

# Testing And Monitoring Solutions For:

- Power transformers
- Circuit breakers
- HV gas insulated switchgears
- MV/HV/EHV cables
- MV/LV switchgears
- Batteries
- Current & voltage transformers
- Protective relays
- Meters and transducers
- Rotating machines
- Variable speed drives
- Overhead lines






# Transformer Procurement Process

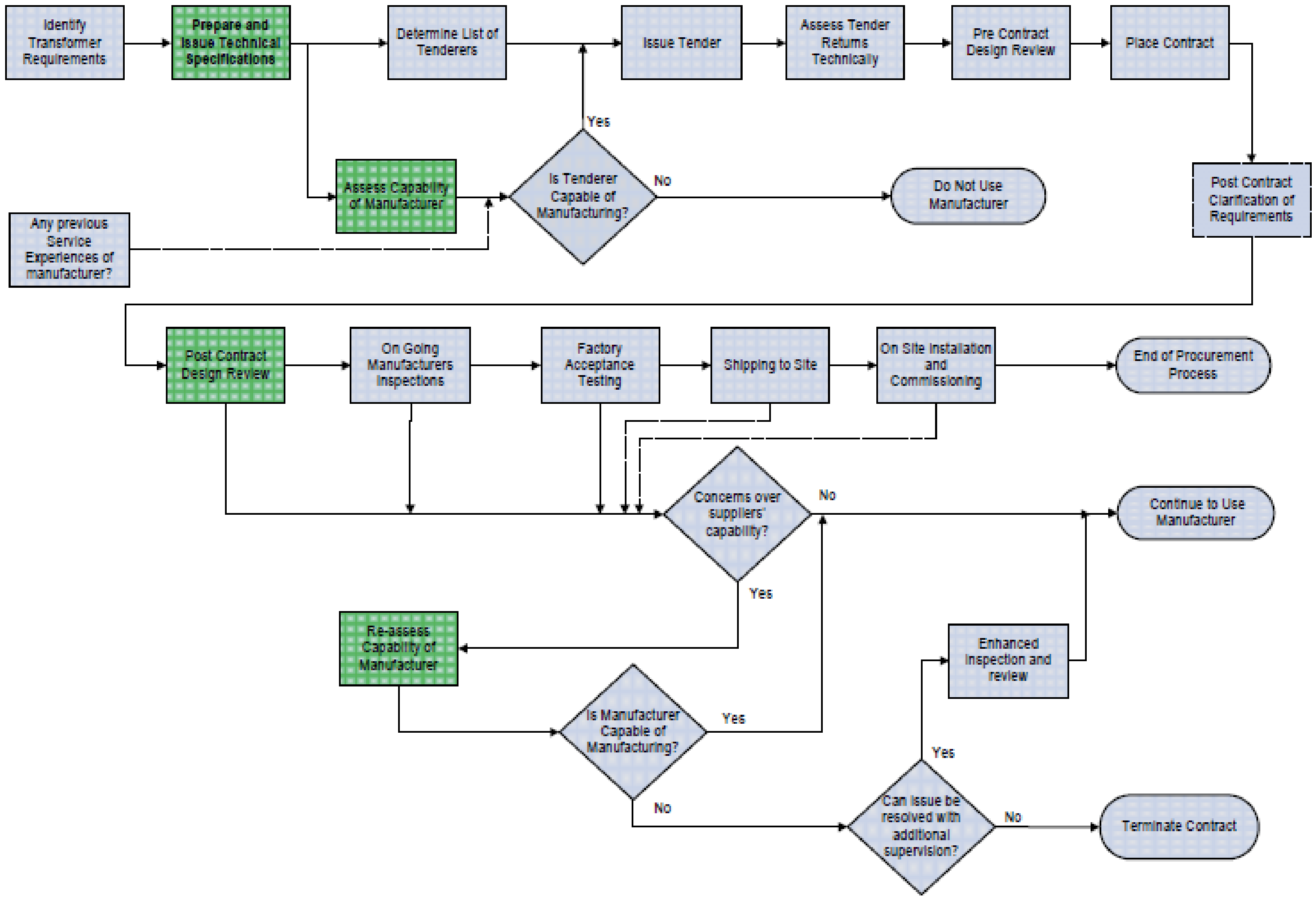
Theme for this presentation is: **How do I purchase one of these?**

# Transformer Procurement Process

Without this happening …

# Transformer Procurement Process

## One view (from CIGRE brochures 528-529-530)



# Transformer Procurement Process

- Step-by-step through the Procurement Process
  - Identification of Functional Requirements
  - Specification
  - Supplier Selection
  - Project Management and Design Review
  - Manufacturing and Progress Inspections
  - Acceptance Testing

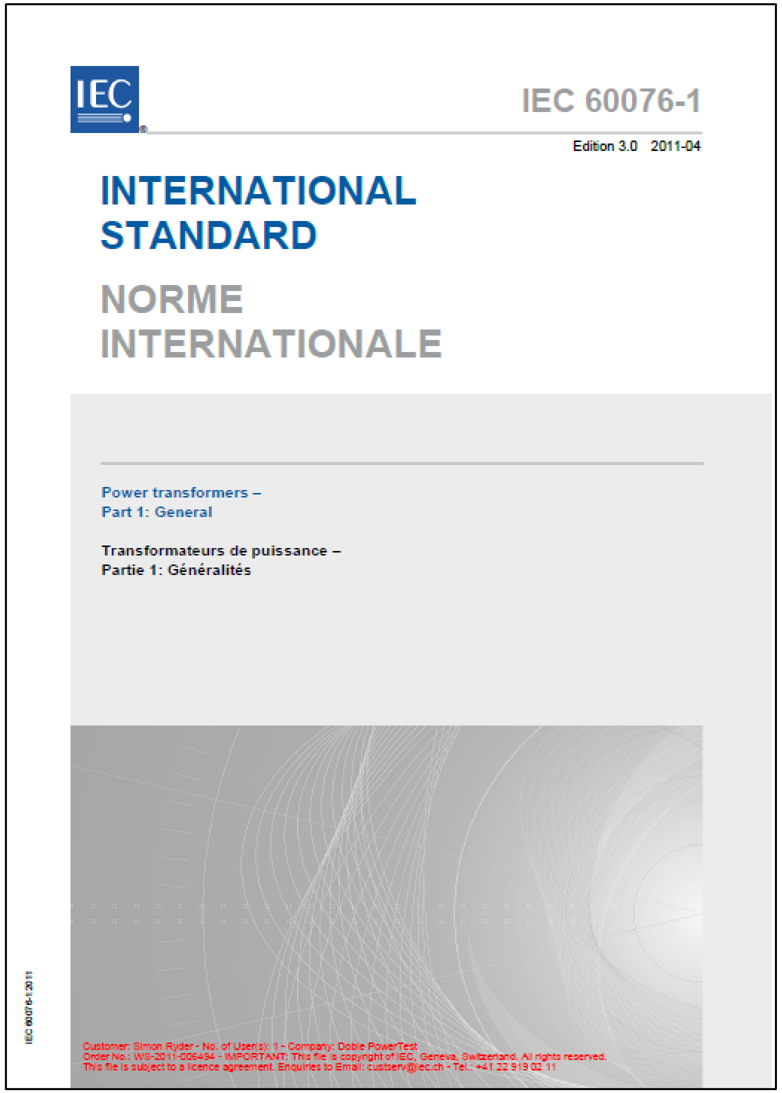
# Identification of Functional Requirements

IEC standard 60076-1 annex A lists a total of 49 different pieces of information to be provided with enquiry and order:

- Normal information
- Special information
- Parallel operation

For a completely new transformer, IEC 60076-8 can be used to identify rated quantities:

- Maximum primary/secondary voltage
- Maximum/minimum voltage ratio
- Maximum /minimum primary current


IEC 60076-1
Edition 3.0 2011-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Power transformers –
Part 1: General

Transformateurs de puissance –
Partie 1: Généralités

IEC 60076-1:2011

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Order No.: WS-2011-006494 - IMPORTANT: This file is copyright of IEC, Geneva, Switzerland. All rights reserved.
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# Identification of Functional Requirements

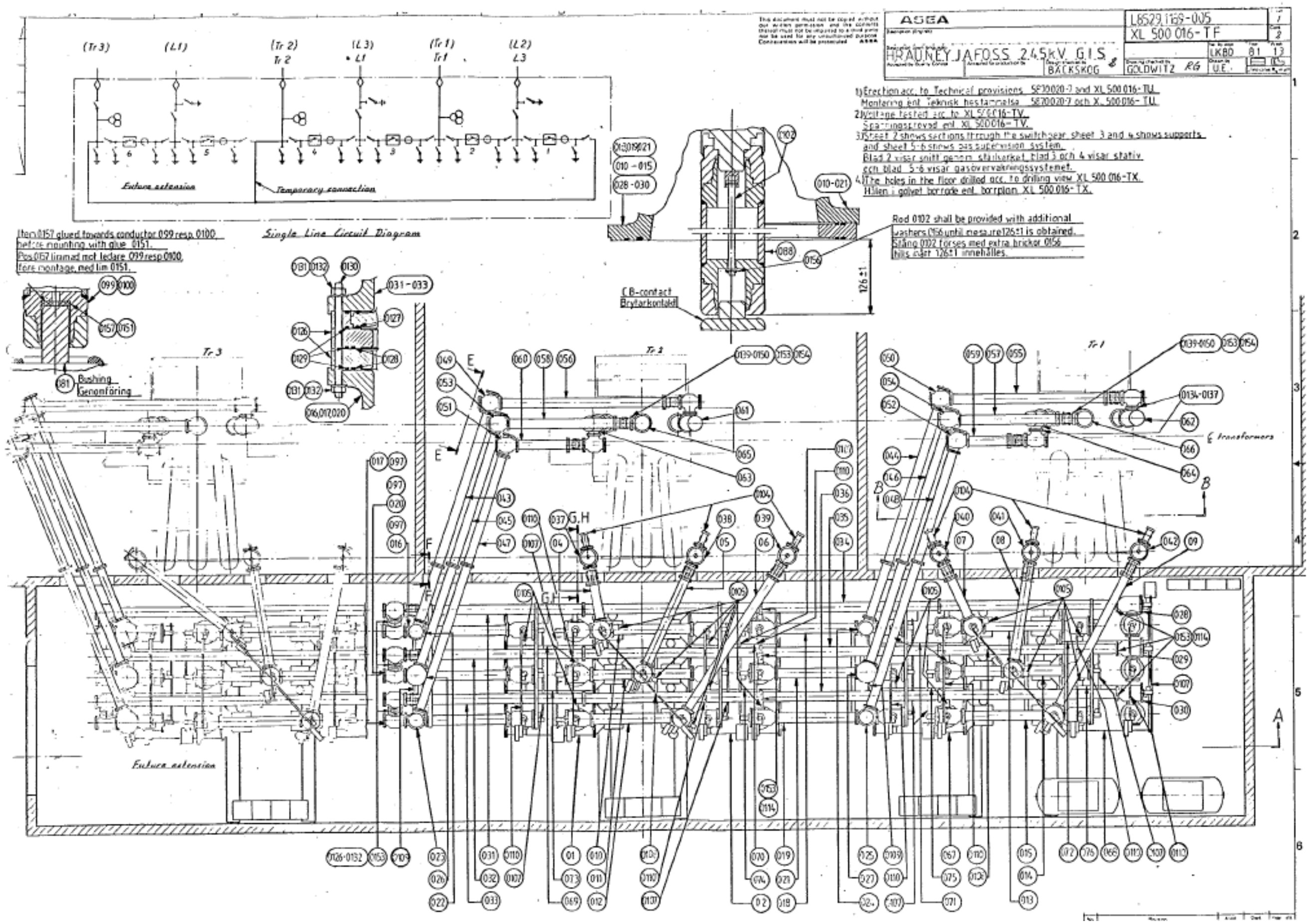
In case of a replacement transformer, then this may need to be dimensionally compatible with the existing transformer esp. in case of direct cable or GIS connections.

CIGRE brochure 528 recommends providing the following additional information in this case:

- Overall dimension drawing of existing transformer
- Foundation drawing of existing transformer
- Layout drawing of sub-station
- Details of connections

# Identification of Functional Requirements

… as in this case where the GIS was found not to be in accordance with this drawing as the replacement transformer was being installed.



# Transformer Procurement Process

- Step-by-step through the Procurement Process
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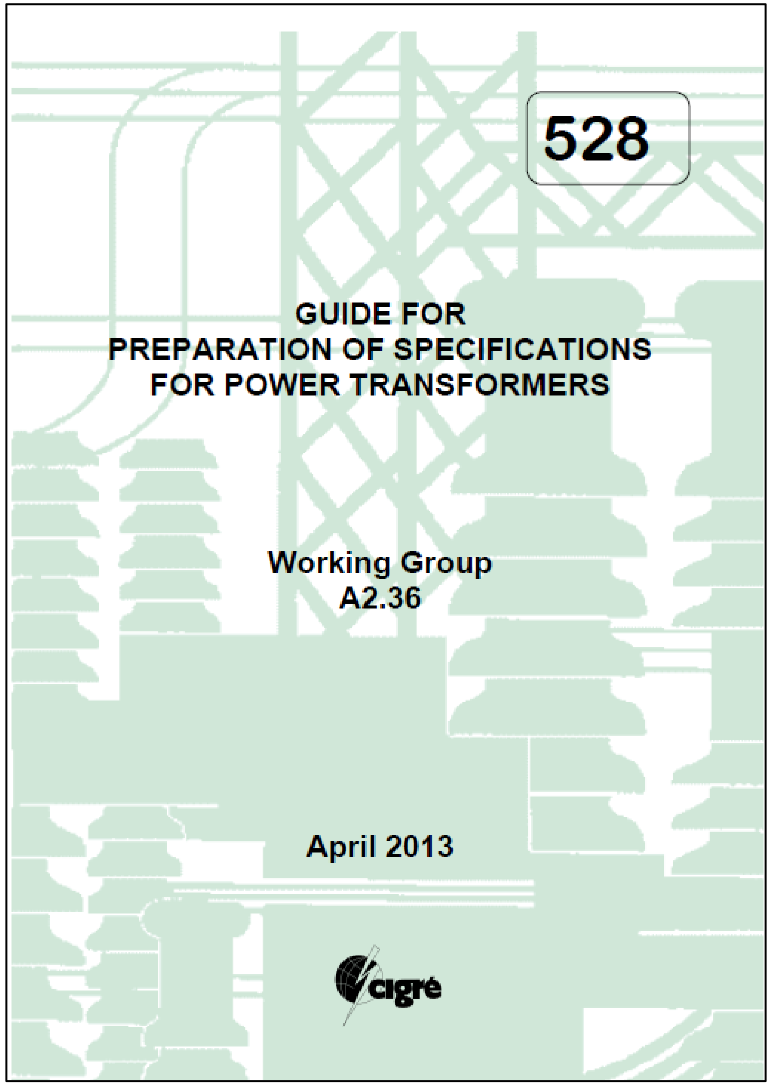
# Specification

- Refer to CIGRE brochure 528, which is a sort of application guide for IEC 60076-1 etc.
- An update of previous CIGRE brochure 156.



# Specification

According to CIGRE brochure 528, the first thing a specification needs to be clear about is the <u>scope of supply</u>.

- A basic outline of what is required (e.g. transformer complete all fittings required for service and first filling of oil)
- A basic outline of the limitations of what is required (e.g. terminals ready for connection, control cabinet ready for connection to sub-station/power station systems, anti-vibration mountings).

# Specification

## Example basic description of requirements for a replacement generator transformer

The Contractor shall furnish a 3-phase, two winding shell-type transformer. The transformer shall be of the outdoor type, oil immersed, ONAF cooled, rated 86 MVA - 245/13,8 kV, YNd1, 50 Hz, complete with off-load tap-changer and all required accessories. The transformer is intended for use as a generator step-up transformer for a hydro power generator. The no-load voltage on the HV-side and principal tapping shall be 241,5 kV and 13,2 kV on the LV- side.

# Specification

## Example basic outline of limitations of supply for the same replacement generator transformer

The basic limits of equipment supplies for the transformer and its appurtenances shall extend to and include:

- The HV and LV terminals of the transformer, ready for connection to external power circuits delivered by others.
- The terminal blocks in the control cubicle of the transformer.
- The wheels and earthquake fastenings to be installed on the rails and foundations.

Internal cabling, i.e. cables from sensors, and other auxiliary equipment delivered with the transformer, shall be furnished by the Contractor and connected to terminal blocks. All wires and terminal blocks shall be clearly marked. All cables shall enter the control cubicles from below.

# Specification

According to CIGRE brochure 528, the second thing a specification needs to be clear about is the purpose of the equipment.

For more guidance on normal service conditions, refer to IEC 60076-1.

# Specification

Example rectifier transformers installed in large thermal PS…
What’s special about this application:

- Harmonic distortion of load current >5%
- High ambient temperatures
- High levels of dust

Reports of 6 failures from a total of 30 transformer installed in the first 10 years of operation.

# Specification

According to CIGRE brochure 528, the third thing a specification needs to be clear about is the system operating conditions.

- Insulation levels
- Short-circuit levels
  - System fault level (usually in MVA, alternatively the kA rating of the switchgear)
  - Ratio of positive sequence impedance to zero sequence impedance
  - Ratio of system reactance to system resistance

# Specification

Dielectric failure of HVDC transformer where supplier applied lower insulation levels than normal practice for the user

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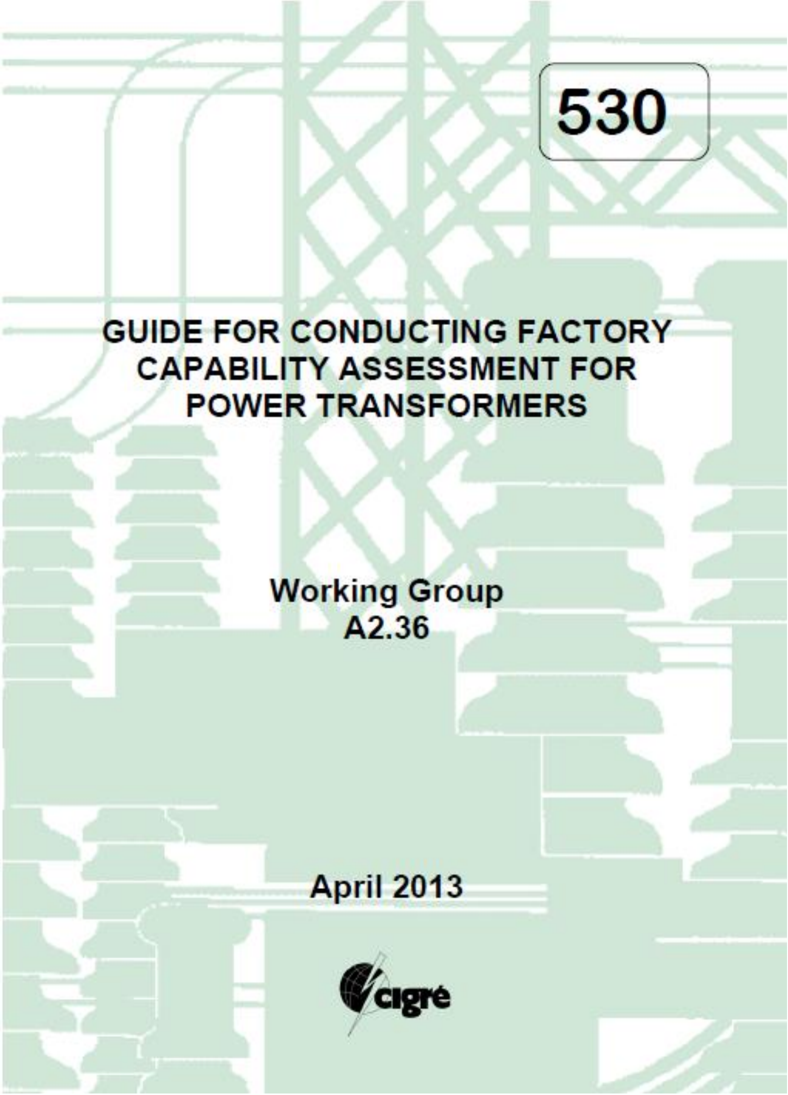
  - Acceptance Testing

# Supplier Selection

CIGRE brochure 530 on transformer supplier selection.

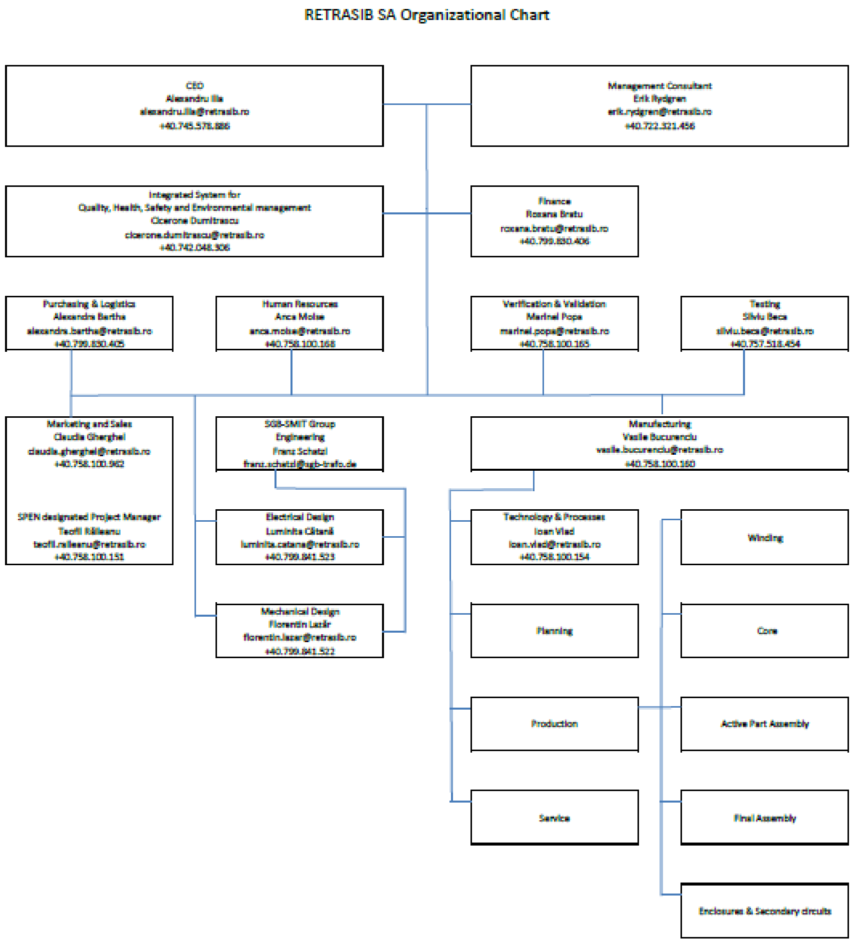
Quality management system ISO 9001



# Supplier Selection

How does the management structure support the quality management system?

What do the quality manager and the quality department do themselves? Who else to they work with?



# Supplier Selection

A good question for the quality manager (assuming there is one), is to ask what management procedures and systems are in place to ensure that <u>customer expectations and requirements</u> are met?

# Supplier Selection - Design

A good next question for the quality manager, is to ask what management procedures and systems are in place to ensure that they are building the transformer correctly (design verification) and that they are building the correct transformer (design validation).

Where does customer design review fit into the process?

# Supplier Selection - Source materials

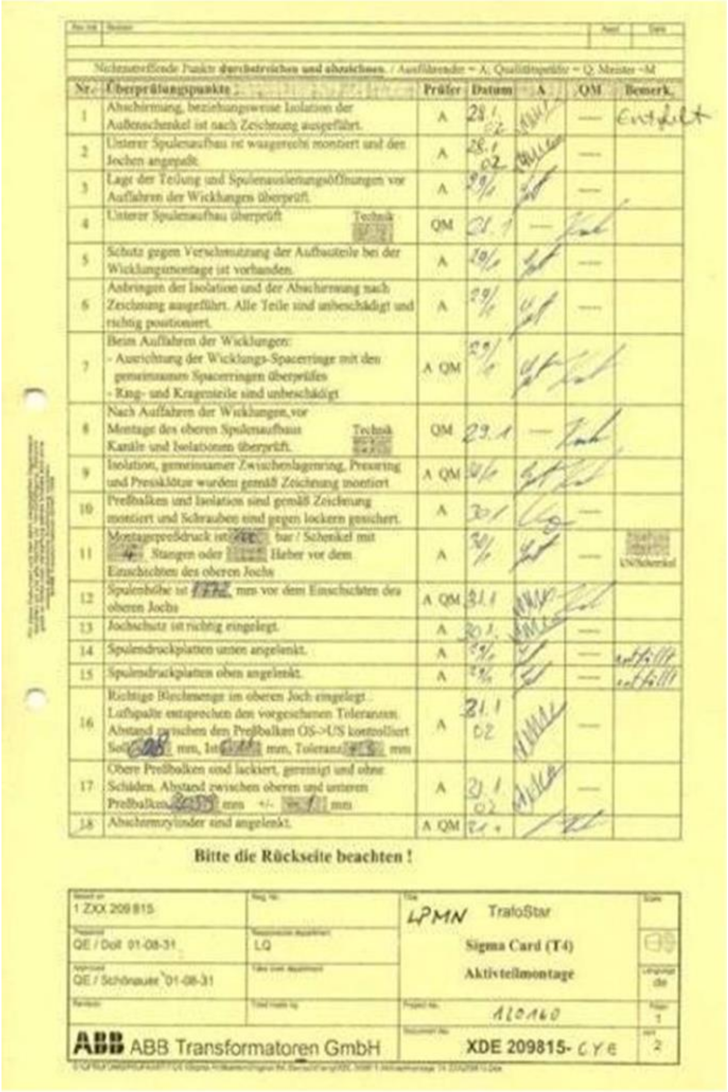
To do this, sub-suppliers need to be provided with adequate specifications and other documentation.  Can the quality manager provide some this documentation for review?

What quality management systems and procedures are in place for checking components and materials, including inspection and test?

# Supplier Selection - Production

What quality management systems and procedures are in place for checking work-in-progress, including inspection and test? What records are kept? This should be detailed in the documentation provided to production workers.

How are defects in work-in-progress, or in components and materials received, reported? Who reports defects, and who reviews the reports?



Bitte die Rückseite beachten !

TrafoStar

Sigma Card (T4)

Aktivteilmontage

ABB Transformatoren GmbH

XDE 209815-

# Supplier Selection - Testing

We would suggest asking the chief test engineer or the quality manager (assuming there is one) the following questions about each important test:

- What method or methods will be used?
- What equipment will be used?
- What is its performance?
- How are the results recorded?
- How will the result be presented to the customer on the test certificate or otherwise?

# Supplier Selection

A final question for the quality manager (assuming there is one): who is responsible for checking that the transformer meets all customer expectations and requirements; all tests have been passed successfully; all documentation is complete; etc. and the transformer can now be prepared for transport to the customer?

If this question seems a bit long, it can be summarized as: <u>who gives final approval for the transformer to be transported to the customer?</u>

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# Design Review

According to CIGRE brochure 529, the aims of customer design review are as follows:

- Ensure that there is a clear mutual understanding of the technical requirements
- Verify the system and project requirements as per the specification and to indicate areas where special attention may be required
- Verify that the design complies with the technical requirements

(continued)

# Design Review

(continued):

- Identify any prototype features and evaluate their reliability and risks
- Identify relevant design margins vs test requirements and the design margins’ possible significance for the lifetime performance of the transformer
- Identify any possible betterments

# Design Review

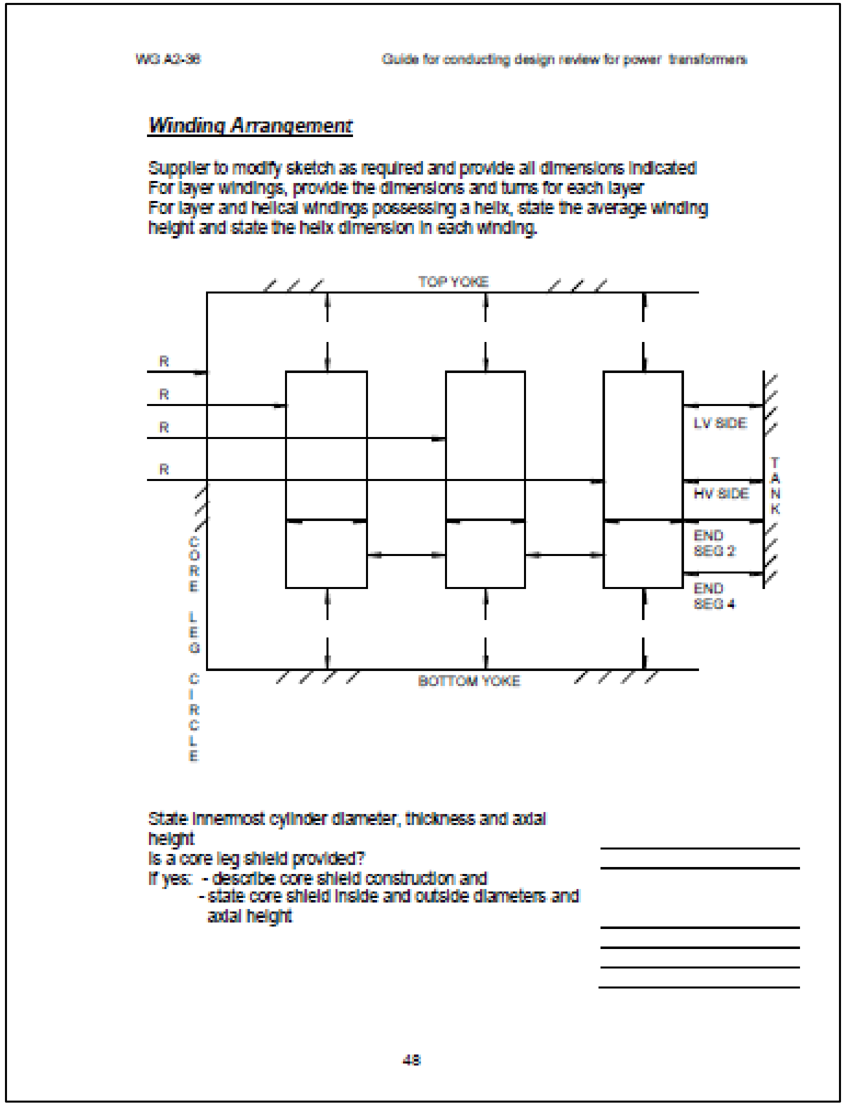
CIGRE brochure 529 recommends that the design review takes place before the supplier has ordered components and materials, so any changes do not have cost or delivery implications for either the supplier or the user.

In practice some components and materials may have to be ordered in advance of the design review meeting to meet the agreed delivery schedule.  This is most likely to be the case for HV bushings, which are the component with the longest lead time.

# Design Review

CIGRE brochure 529 includes a blank or model report on the electrical design, and a completed example.

A report on the electrical design using this model should contain enough information for basic design checks (transformation ratio; no-load loss and current; load loss and impedance).


WG A2-36 Guide for conducting design review for power transformers

***Winding Arrangement***

Supplier to modify sketch as required and provide all dimensions indicated
For layer windings, provide the dimensions and turns for each layer
For layer and helical windings possessing a helix, state the average winding height and state the helix dimension in each winding.



State innermost cylinder diameter, thickness and axial height
Is a core leg shield provided?
If yes: - describe core shield construction and
- state core shield inside and outside diameters and axial height

48

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# Manufacturing and Progress Inspections

Progress inspections are usually planned at the design review stage, using the quality plan and the manufacturing programme.

Based on our experience we can suggest the following progress inspections.

All projects:

- Core and windings, before dryout
- Final test

Critical projects (in addition):

- Completed windings
- Completed core
- Core and windings, after dryout

Additional inspections may be needed in some cases.

# Manufacturing and Progress Inspections

Some things to check during inspection, before final dryout :

- Work area clean and tidy
- Core and winding assembly, components, and materials all clearly labelled
- Drawings and other documentation required available, and all for the correct transformer
- Quality checklists completed correctly
- Components and materials stored correctly

(continued)

# Manufacturing and Progress Inspections

(continued)

- No tools or loose materials left on core and winding assembly
- Check core, esp. upper yoke
  - No visible gaps in core
  - No visible damage to the core laminations, esp. at the corners
  - No visible wave in core
  - Core blocking correctly aligned
  - Core bolts and straps correctly tightened, and preferably marked after tightening

(continued)

# Manufacturing and Progress Inspections

(continued)

- Core earthing strap correctly inserted
- Core ducts electrically “bridged” or equivalent
- Check any visible windings:
  - No visible conductor or insulation damage
  - No uncontrolled or excessive use of glue
  - No dirty marks
- Winding end blocking correctly aligned

(continued)

# Manufacturing and Progress Inspections

(continued)

- Tap leads correctly labelled
- Lead supports sufficiently robust and correctly aligned
- No visible damage to leads
- No uncontrolled or excessive use of glue
- No dirty marks on leads
- Any bolted connections correctly tightened, and preferably marked after tightening

(continued)

# Manufacturing and Progress Inspections

(continued)

- Lead clearances sufficient
- Fasteners on or adjacent to leads fitted with domed caps where necessary
- Tapchanger correctly supported, from frame or lid
- Tapchanger leads not excessively tight

# Manufacturing and Progress Inspections

Most suppliers also do some electrical testing at this stage, mainly to check that all leads have been connected correctly.

Recommended scope of electrical testing:

- Core/frame insulation check
- CT check (for any CTs mounted in connections)
- Transformation ratio
- Winding resistance

# Manufacturing and Progress Inspections

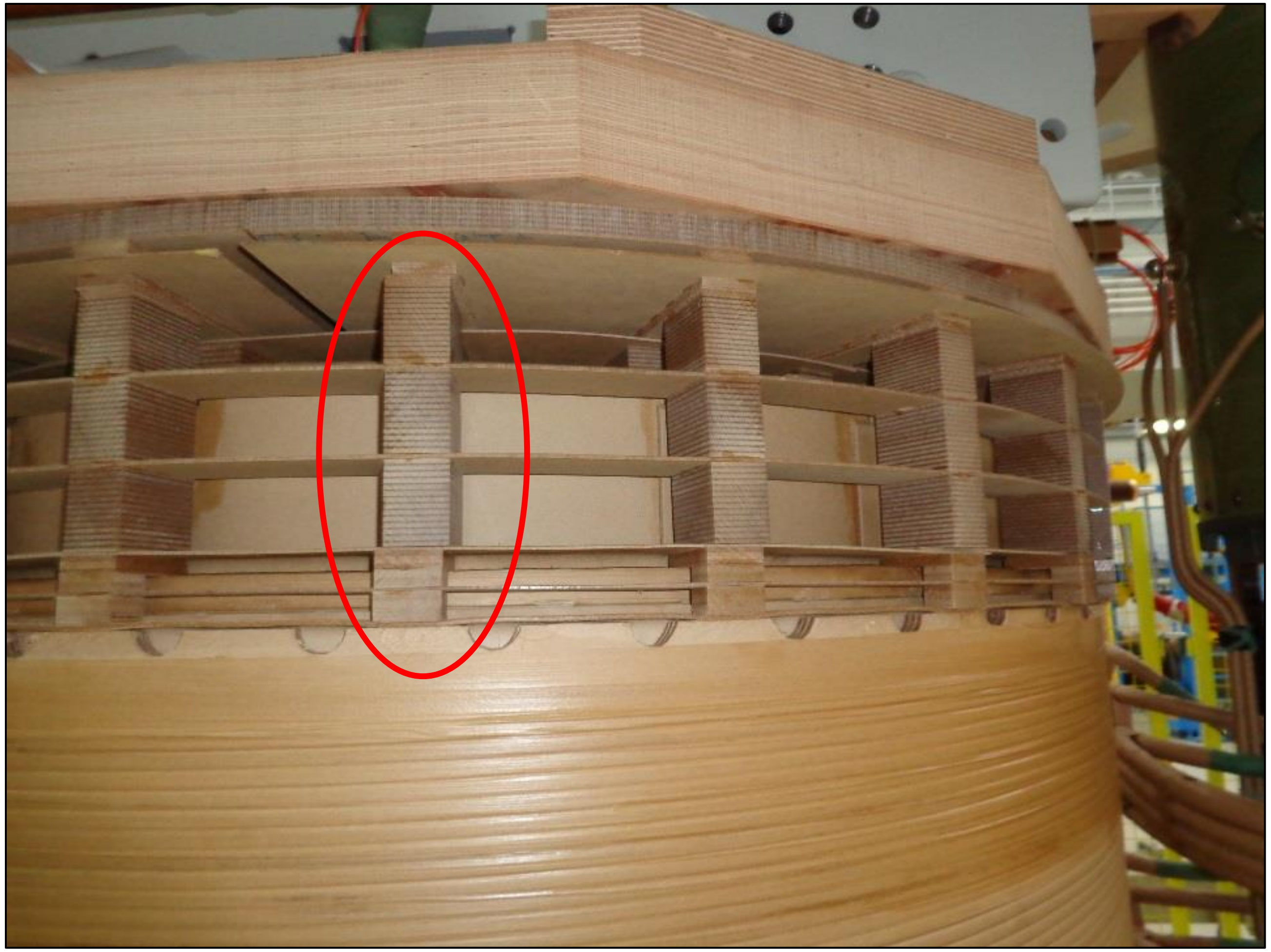
## Tools left in top end insulation

# Manufacturing and Progress Inspections

## Glue stains on top clamping platform

# Manufacturing and Progress Inspections

## Misaligned end blocking



# Manufacturing and Progress Inspections

## Debris on core blocking

# Manufacturing and Progress Inspections

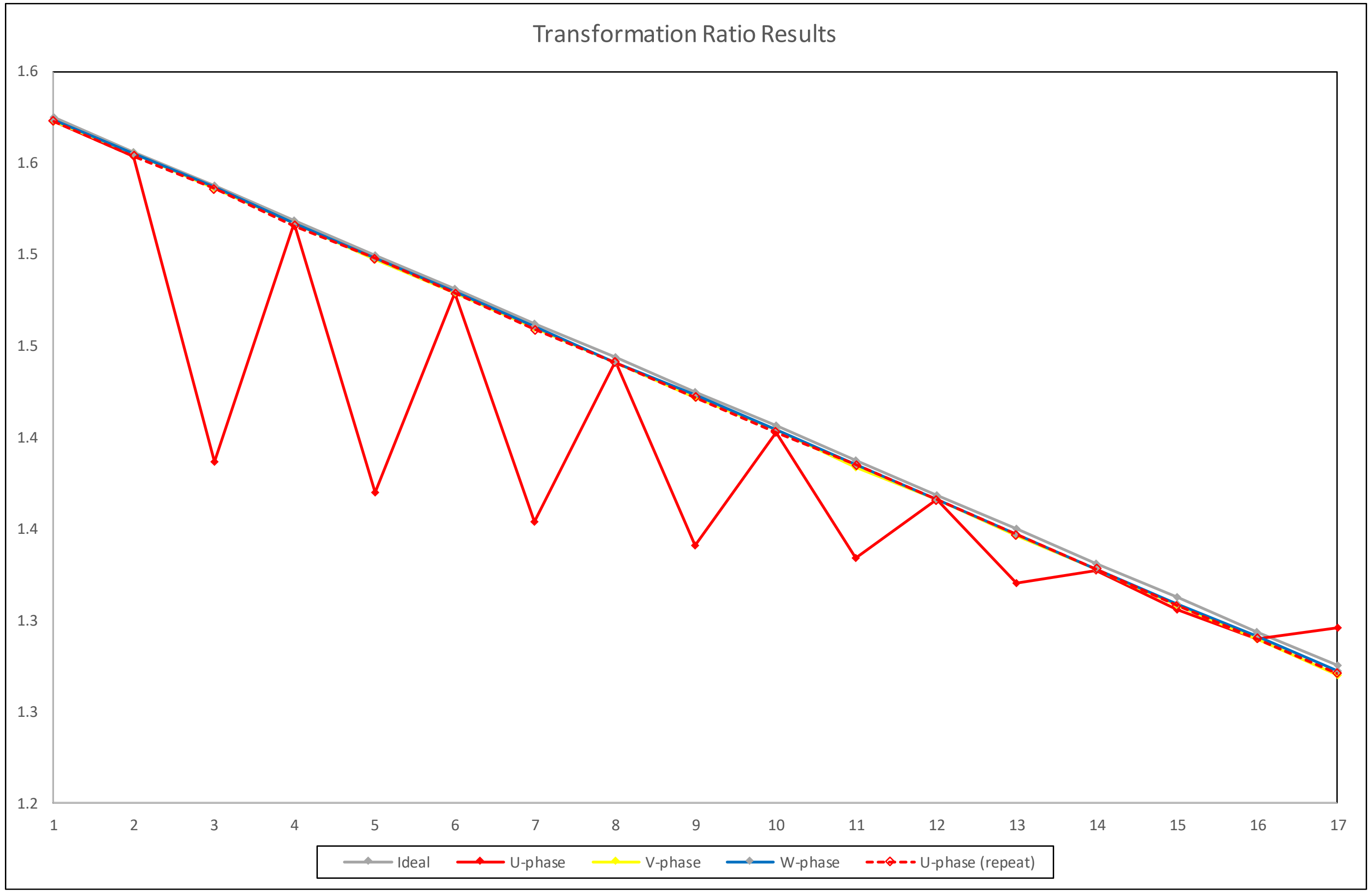
## Damaged lead insulation

# Manufacturing and Progress Inspections

## Missing tapchanger during inspection

# Manufacturing and Progress Inspections

## Incorrect transformation ratio results caused by defective on-load tapchanger



# Transformer Procurement Process

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  - Project Management and Design Review
  - Manufacturing and Progress Inspections
  - <u>Acceptance Testing</u>

# Acceptance Testing

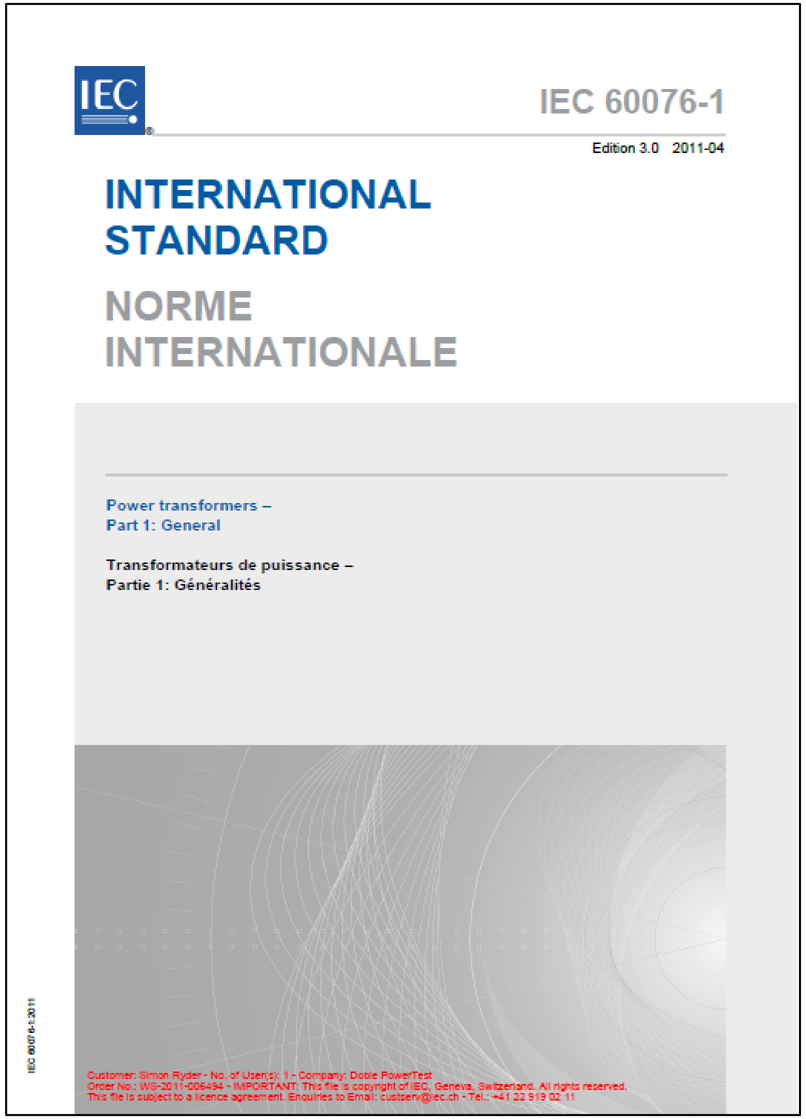
Why do we acceptance testing on transformers:

- Ensure design quality
- Ensure build quality
- Ensure compliance with customer expectations and requirements, esp. guaranteed values
- Provide reference results for pre-commissioning and condition assessment tests

# Acceptance Testing

Main applicable standard for power transformers is IEC 60076-1, which includes minimum requirements for routine and type tests.

Also includes methods for the main performance tests.  Most other tests have their own standard


IEC 60076-1

Edition 3.0 2011-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Power transformers –
Part 1: General

Transformateurs de puissance –
Partie 1: Généralités

IEC 60076-1:2011

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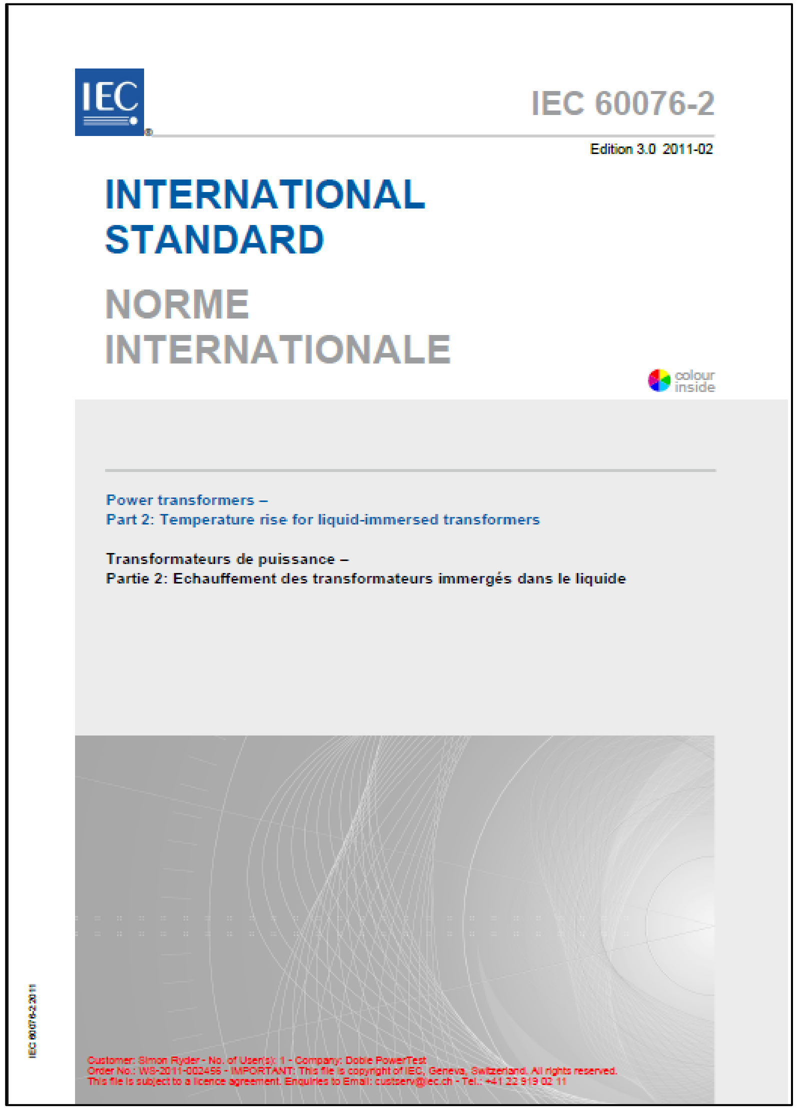
# Acceptance Testing

Temperature rise tests, and also specification of cooling and temperature rise, have their own standard –
IEC 60076-2.

Note this only covers temperature rise at rated power. Temperature rise beyond rated power, and also dynamic temperature rise is covered by the loading guide (IEC 60076-7).


IEC 60076-2

Edition 3.0 2011-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Power transformers –
Part 2: Temperature rise for liquid-immersed transformers

Transformateurs de puissance –
Partie 2: Echauffement des transformateurs immergés dans le liquide

IEC 60076-2:2011

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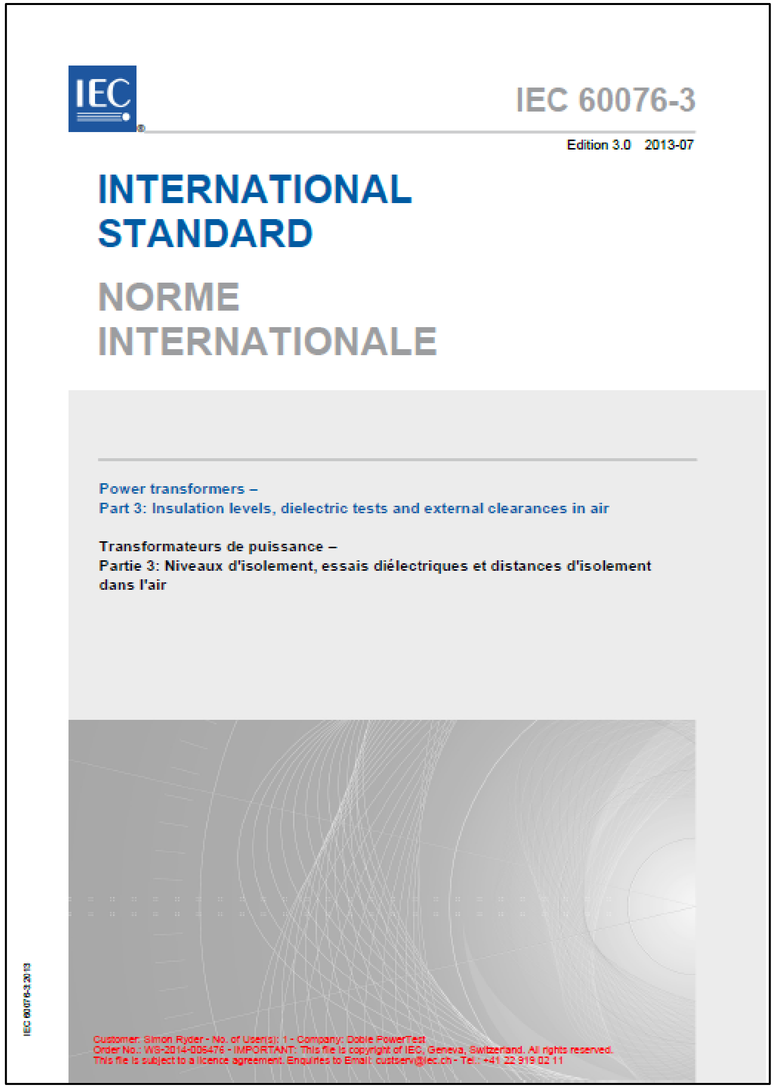
# Acceptance Testing

Dielectric tests, and also specification of insulation levels and external clearances in air, have their own standard –
IEC 60076-3.

Note that dielectric test procedures have their own standard – IEC 60060-1 – which applies to all kinds of equipment, not just transformers.



# Acceptance Testing

A quick reminder of some of the tests we may need to perform:

- Winding resistance
- Transformation ratio
- Load loss and impedance
- No-load loss and current
- Zero-sequence impedance
- Tapchanger functional tests
- Pressure (leak and deflection)
- Vacuum (leak and deflection)
- Insulation resistance (windings and core/frame)
- Capacitance and power factor (windings and bushings)
- Temperature rise
- Lightning impulse
- Switching impulse
- Applied voltage
- Induced voltage
- Sound levels
- FRA

# Acceptance Testing

In addition to the quality plan, we recommend the supplier provides a more detailed test plan giving details of each test, including:

- Purpose
- Method
- Equipment to be used
- Expected results, where applicable
- Acceptance criteria

CUSTOMER: LANDSNET
TAMINI JOB 20PN006, SN 67489
PST 42/60MVA, 220 / 132 / 10 KV
TEST PROCEDURE

Issued: 22/12/2020
Doc. n. 20201116
Rev.: 01

## 6. MEASUREMENT OF NO-LOAD LOSS AND CURRENT

This test will be carried out in compliance with IEC 60076-1, clause 11.5.
The PST will be supplied through the tertiary winding (see paragraph 1), at frequency 50Hz, in order to induce the rated voltage of 132kV at the terminal 2U-2V-2W.
The position of the changers shall be:

- CSC1 (in-phase REG) = pos. 10
- CSC2 (quadrature REG) = pos. 17

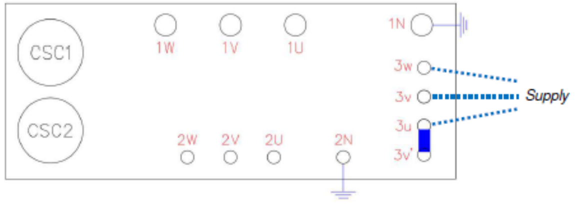



**Figure 3: No-Load test configuration**

Measurements at 90%, 100%, and 110% of the rated voltage will be carried out.

***Guaranteed values:***

- Reference: 60 MVA, ratio 220/132-66 kV, angle 0°,
- CSC1 (in phase REG) pos. 10, CSC2 (quadrature REG) pos. 17
- $P_0 \leq 34.5$ kW
- $I_0 \leq 0.2\%$

Being a variable flux transformer given the power supply on the LV side, the losses and no-load current will be measured considering the induction with the CSC positions in quadrature with maximum angle.

- Reference: 60 MVA, ratio 220/132-66 kV, angle ±15°,
- CSC1 (in phase REG) pos. 10, CSC2 (quadrature REG) pos. 17
- $I_0 \leq 0.25\%$

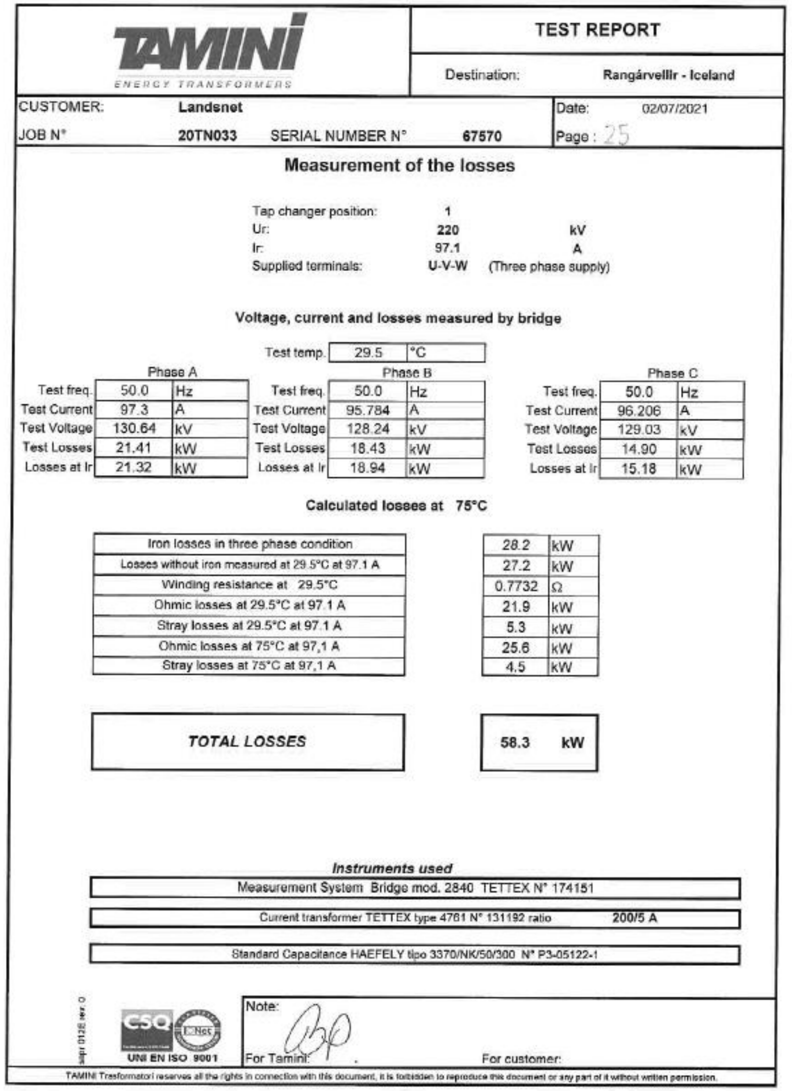


Page 7 of 19

# Acceptance Testing

When witnessing each test, check:

- Test equipment calibrated
- Test equipment connected correctly
- No unauthorized correction factors applied
- All results provided for review, including as much raw data as required
- All results acceptable according to agreed criteria



TAMINI ENERGY TRANSFORMERS

**TEST REPORT**

Destination: **Rangárvellir - Iceland**

CUSTOMER: **Landsnet**

Date: 02/07/2021

JOB N° **20TN033** SERIAL NUMBER N° **67570**

Page : 25

**Measurement of the losses**

| | | |
|---|---|---|
| Tap changer position: | 1 | |
| Ur: | 220 | kV |
| Ir: | 97.1 | A |
| Supplied terminals: | U-V-W | (Three phase supply) |

**Voltage, current and losses measured by bridge**

Test temp. 29.5 °C

| Phase A | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|
| Test freq. | 50.0 | Hz | Test freq. | 50.0 | Hz | Test freq. | 50.0 | Hz |
| Test Current | 97.3 | A | Test Current | 95.784 | A | Test Current | 96.206 | A |
| Test Voltage | 130.64 | kV | Test Voltage | 128.24 | kV | Test Voltage | 129.03 | kV |
| Test Losses | 21.41 | kW | Test Losses | 18.43 | kW | Test Losses | 14.90 | kW |
| Losses at Ir | 21.32 | kW | Losses at Ir | 18.94 | kW | Losses at Ir | 15.18 | kW |

**Calculated losses at 75°C**

| | | |
|---|---|---|
| Iron losses in three phase condition | 28.2 | kW |
| Losses without iron measured at 29.5°C at 97.1 A | 27.2 | kW |
| Winding resistance at 29.5°C | 0.7732 | Ω |
| Ohmic losses at 29.5°C at 97.1 A | 21.9 | kW |
| Stray losses at 29.5°C at 97.1 A | 5.3 | kW |
| Ohmic losses at 75°C at 97,1 A | 25.6 | kW |
| Stray losses at 75°C at 97,1 A | 4.5 | kW |

| | | |
|---|---|---|
| ***TOTAL LOSSES*** | **58.3** | **kW** |

***Instruments used***

Measurement System Bridge mod. 2840 TETTEX N° 174151

Current transformer TETTEX type 4761 N° 131192 ratio 200/5 A

Standard Capacitance HAEFELY tipo 3370/NK/50/300 N° P3-05122-1

UNI EN ISO 9001

Note:

For Tamini: .

For customer:

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