

Testing of Power Transformers

Routine tests, Type tests and Special tests



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under participation of

Åke Carlson

Jitka Fuhr

Gottfried Schemel

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1st Edition
published by
PRO PRINT

for



ABB Business Area Power Transformers

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Layout/Design
Typesetting/Reproduction: Pro Print GmbH, Düsseldorf
Typeface: Neue Helvetica
Printing: InterDruck, Büllingen
Paper: Bilderdruck matt 135 g/qm

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ISBN 3-00-010400-3 - € 76.00

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Remember school days? Nothing caused more excitement than the teachers' announcement of a test. Because a test confirms what you know, if you can apply in real life what you have learned in a classroom, under strict, rigorous and controlled conditions. It is a chance to demonstrate excellence. Testing of power transformers seems like a similar experience; and therefore ABB undertook to write this book.

Transformer testing has developed considerably over the past years. It evolved from the simple go-no-go verdict into a sophisticated segment within transformer manufacturing. In this book we have laid down important aspects on transformer testing in order to enhance the understanding of the testing procedures and its outcome.

The book represents the collective wisdom of over 100 years of testing power transformers. It has been written for transformer designers, test field engineers, inspectors, consultants, academics and those involved in product quality.

ABB believes that the knowledge contained in this book will serve to ensure that you receive the best power transformer possible. The more knowledgeable you are, the better the decisions you will take.

Zürich, October 2003

Table of Contents

Preface	7	4.2	Purpose of measurement	42	
Table of Contents	8	4.3	General	42	
1 Introduction	13	4.4	Measuring the voltage ratio	43	
1.1	Why transformer testing?	14	4.5	Test circuit	44
1.2	Types of tests	14	4.6	Measuring procedure	49
1.3	Test sequence	15	4.7	Measuring uncertainty	51
1.4	Remarks concerning this test book	17	A 4 Appendix	52	
2 Dielectric integrity and its verification	19	A 4.1	Determination and localization of errors	52	
2.1	References / Standards	20	5 Measuring the short-circuit voltage impedance and the load loss	55	
2.2	General	20	5.1	References / Standards	56
2.3	Voltage appearing during operation	21	5.2	Purpose of the test	56
2.4	Verifying transformer major insulation electrical strength	23	5.3	General	56
2.5	Test voltages	23	5.4	Measuring circuit	61
2.6	Test requirements	25	5.5	Measuring procedure	62
2.7	Examples for dielectric routine tests	27	5.6	Evaluation of the measuring results	65
A 2 Appendix	28	5.7	Measuring uncertainty	65	
A 2.1	Examples	28	A 5 Appendix	66	
3 Measurement of winding resistance	31	A 5.1	Interdependence of relative short-circuit voltage (or short-circuit voltage) and winding temperature	66	
3.1	References / Standards	32	A 5.2	Load loss separation when winding resistances are not known	67
3.2	Purpose of the test	32	A 5.3	Measuring equipment requirements	67
3.3	General	32	A 5.4	Instrument error correction	69
3.4	Principle and methods for resistance measurement	34	A 5.5	Instrument transformer error correction	69
3.5	Measurement procedure	35	A 5.6	Measuring the short-circuit voltage for starting transformers having an air gap	72
3.6	Interpretation of the measured values	36	A 5.7	Connection for investigation tests	72
3.7	Examples	36	A 5.8	Examples	73
3.8	Uncertainty in resistance measurements	36	6 Measuring the no-load loss and no-load current	79	
A 3 Appendix	37	6.1	References / standards	80	
A 3.1	General requirements on equipment	37	6.2	Purpose of measurement	80
A 3.2	Value of the DC-current of measurement	38	6.3	General	80
A 3.3	Kelvin (Thomson) measuring circuit	39	6.4	Measuring circuit	86
A 3.4	Examples	39	6.5	Measuring procedure	89
4 Verification of voltage ratio and vector group or phase displacement	41	6.6	Evaluation of the measuring results	90	
4.1	References / Standards	42	6.7	Measuring uncertainty	91

Table of Contents

A 6	Appendix	92	9.5	PD measurement on transformers	123
A 6.1	Measuring equipment specification	92	9.6	PD measuring procedure	126
A 6.2	Determination of the hysteresis and eddy current loss components	92	9.7	Procedure for Investigation of PD sources	128
A 6.3	Preliminary measurements of the iron core	93	9.8	Detection of acoustical PD signals	133
A 6.4	Special measuring circuits	94	9.9	Detailed investigation of the PD source	134
A 6.5	Examples	95	9.10	Measuring uncertainty	139
7	Separate source AC withstand voltage test or Applied voltage test¹	97	A 9	Appendix	140
7.1	References / Standards	98	A 9.1	Physics of partial discharge	140
7.2	Purpose of the test	98	A 9.2	Principle of quasi-integration	143
7.3	General	98	A 9.3	True charge, apparent charge and measureable charge	147
7.4	Principle and measuring circuit	99	A 9.4	Typical external noise sources	149
7.5	Measuring procedure	99	A 9.5	Advanced PD system	151
7.6	Measuring Uncertainty	100	A 9.6	Detection of acoustical PD signals	154
A 7	Appendix	101	A 9.7	Localization of the PD source using analysis of the electrical signals	157
A 7.1	Calculation of the capacitive load compensation requirements	101	A 9.8	Corona shielding	160
A 7.2	General requirements for the measuring equipment	102	10	Lightning impulse and switching impulse test	161
8	Induced voltage tests	105	10.1	References /Standards	162
8.1	References / Standards	106	10.2	Purpose of the test	162
8.2	Purpose of the test	106	10.3	General	163
8.3	General	106	10.4	Impulse shape	165
8.4	Principle and test circuit	107	10.5	Test connections	167
8.5	Measuring procedure	109	10.6	Test procedure / recordings	171
8.6	Measuring uncertainty	114	10.7	Assessing the test results and failure detection	174
A8	Appendix	115	10.8	Calibration – impulse measuring system / measuring uncertainty	175
A8.1	Calculation of the load for the induced voltage test	115	A 10	Appendix	176
A8.2	General requirements for the measuring equipment	117	A 10.1	Waveshape and its assessment	176
A8.3	Correction of the voltage drop across the protective resistance of sphere-gaps	118	A 10.2	Generation of high impulse voltages	177
9	Partial Discharge Measurements	119	A 10.3	Pre-calculation of impulse waveform	180
9.1	References /Standards	120	A 10.4	Test circuit parameters for switching impulse test	183
9.2	Purpose of measurement	120	A 10.5	Measuring high impulse voltages	183
9.3	General	120	A 10.6	Calibrating the impulse voltage divider ratio	190
9.4	Principle of PD measurement	121	A 10.7	Use of a Sphere-gap for checking the scale factor of an impulse peak voltmeter	190
			A 10.8	Measuring the impulse current	193
			A 10.9	Earthing the impulse circuit	194

Table of Contents

A 10.10	Switching impulse wave form	195		
A 10.11	Air withstand	196		
A 10.12	Impulse voltage stress on power transformers	196		
11	Temperature rise test	199		
11.1	References /Standards	200		
11.2	Purpose of the test	200		
11.3	Temperature / temperature rise	200		
11.4	Temperature measurements	201		
11.5	Principle and test methods	201		
11.6	Measurement circuit and procedure	203		
11.7	Hot spot temperatures	209		
11.8	Practical examples and analysis of the measured values	210		
11.9	Measuring uncertainty	210		
A 11	Appendix	211		
A 11.1	Definitions, temperature and temperature-rise	211		
A 11.2	Other test methods for temperature rise test	212		
A 11.3	Estimating the duration of the temperature rise test [2]	213		
A 11.4	Graphical extrapolation to ultimate temperature [2]	214		
A 11.5	Oil temperature measurement by measuring the surface temperature [61]	214		
A 11.6	Correction of the injected current with non-nominal frequency	214		
A 11.7	Correction factors according to IEEC Std.C57.12.90 [51]	215		
A 11.8	Conformance of the measured average winding temperature rise with the real winding temperature rise in operation	215		
A 11.9	Practical examples and analysis of the measured values	216		
12	Measurement of zero-sequence impedance(s) on three-phase transformers	225		
12.1	References / Standards	226		
12.2	Purpose of measurement	226		
12.3	General	226		
12.4	Definition of the zero-sequence impedance	227		
12.5	Measuring procedure	228		
A 12	Appendix	230		
A 12.1	Example for an unbalanced three-phase system	230		
A 12.2	Types of zero-sequence impedance	230		
A 12.3	Influence of winding connection and transformer design	231		
A 12.4	Examples and interpretation	234		
13	Short-circuit withstand test	237		
13.1	References /Standards	238		
13.2	Purpose of the test	238		
13.3	General	238		
13.4	Test conditions, testing techniques and test connections	239		
A 13	Appendix	244		
A 13.1	The difference between post-established and pre-established short-circuit [105]	244		
A 13.2	Examples for single-phase test connections simulating the three-phase test	244		
A 13.3	The calculation of the symmetrical short-circuit current according to IEC 60076-5 [5]	245		
A 13.4	The calculation of the symmetrical short-circuit current I_{sc} according to C57.12.00 [50]	246		
A 13.5	Low-voltage recurrent-surge oscilloscope method	246		

Table of Contents

14	Sound level measurement	247	17	Measurement of insulation resistance	271
14.1	References /Standards	248	17.1	References / Standards	272
14.2	Purpose of measurement	248	17.2	Purpose of the measurement	272
14.3	General [7], [51], [106]	248	17.3	General	272
14.4	Measurement and measuring circuit	249	17.4	The measuring circuit / The measuring procedure [51]	273
14.5	Measuring procedure	250	A 17	Appendix	274
14.5	Measuring uncertainties	254	18	Measurement of dissipation factor (tanδ) of the insulation system capacitances	275
A 14	Appendix	255	18.1	References / Standards	276
A 14.1	Human perception of sound [106]	255	18.2	Purpose of the measurement	276
A 14.2	Estimating load-sound power level, and the influence of the load [7]	255	18.3	General	276
A 14.3	Addition of no-load sound and load sound [7]	256	18.4	The measuring circuit / The measuring procedure [51]	277
A 14.4	Definitions [7]	256	A 18	Appendix	280
A 14.5	Calculation of the environmental correction factor K [51]	258	A 18.1	Examples	280
A 14.6	The calculation of sound power level, example	259			
A 14.7	Far-field calculations	260			
15	Test on on-load tap-changers and dielectric tests on auxiliary equipment	261		Index	283
15.1	References / Standards	262		References / Bibliography	289
15.2	Purpose of the test / General	262		Standards	290
15.3	Test procedure [1] / Test circuit	262		International Electrotechnical Commission (IEC)	290
15.4	Test of auxiliary equipment [3], [50]	263		IEEE / ANSI Standards	291
16	Measurements of the harmonics of the no-load current	265		Books	291
16.1	References / Standards	266		Technical Reviews	292
16.2	Purpose of measurement	266		Editors	293
16.3	General	266			
16.4	The measuring circuit [100]	267			
16.5	The measuring procedure	267			
16.6	Examples	267			
A 16	Appendix	268			
A 16.1	The relationship between flux density, no-load current and harmonic content. [106]	268			
A 16.2	Example	268			

Explanation to the vocabulary

The authors vocabulary in the test book is based on IEC Standards. There are no really important differences between the vocabulary applied in IEC and IEEE (ANSI) Standards. The only exception is the use of the words „earth“/„earthed“ (according to IEC) and „ground“/„grounded“ (according to IEEE).

Testing of Power Transformers

1. Introduction

1. Introduction

1.1 Why transformer testing?

Tests serve as an indication of the extent to which a transformer is able to comply with a customer's specified requirements; for example:

- Loading capability
- Dielectric withstand
- Further operating characteristics

Tests are also part of a manufacturer's internal quality assurance program. A manufacturer's own criteria have to be fulfilled in addition to requirements specified by customers and applicable standards.

Differing requirements are generally combined and published in national and international standards. The primary Standards Organizations are IEC and ANSI. These standards are often used directly to develop national standards. IEC is the abbreviation for International Electro-technical Commission and ANSI stands for American National Standard Institute, Inc.

In the electric area, ANSI has to a great extent delegated the writing and publication of standards to IEEE, the Institute of electric and Electronics Engineers, Inc.

The IEC and IEEE Standards specify the respective tests that verify compliance with the above requirements; e.g.:

Temperature rise tests to verify loading capability, see section 11

Dielectric tests to demonstrate the integrity of the transformer when subjected to dielectric stresses and possible over-voltages during normal operation, see section 2.

No-load and load loss measurements, short-circuit impedance measurements, etc. to verify other operating characteristics.

1.2 Types of tests

The IEC 60076-1 [1] and IEEE Std C57.12.00 [50] Standards distinguish between the following types of tests:

- Routine tests
- Type- or design¹ tests
- Special- or other¹ tests

Routine tests

Routine tests are tests required for each individual transformer.

Typical examples:

Resistance measurements, voltage ratio, loss measurements, etc.

Type- or design tests

*Type or design*¹ tests are conducted on a transformer which is representative² of other transformers, to demonstrate that these transformers comply with specified requirements not covered by routine tests.

Typical example:

Temperature rise test.

Special- or other tests

*Special- or other*¹ tests are tests other than type- or routine tests agreed to by the manufacturer and the purchaser.

Typical example:

Measurement of zero-sequence impedance, sound level measurement, etc.

¹ Term used in the IEEE Standards [50], [51]

² "Representative" means identical in rating and construction, but transformers with minor deviations in rating and other characteristics may also be considered to be representative [1].

Note:

Depending on the respective standard and the maximum system voltage, certain dielectric tests, such as lightning impulse tests, for example, may either be routine tests, type tests or special tests, (see section 2, table 1 and 2). The same is true for switching impulse tests.

1.3 Test sequence

As the Standards do not lay down the complete test sequence in an obligatory basis, it is often the source of long discussions between customer and manufacturer.

On the other hand the test sequence for dielectric tests is generally fixed in IEC and IEEE Standards.

Following all existing standard regulations and recommendations concerning this matter followed by recommendations of the authors, see section 1.3.3.

1. Introduction

1.3.1 IEC Standards

IEC 60076-3 (2000) [3], clause 7.3

“The dielectric tests shall, where applicable and not otherwise agreed upon, be performed in the sequence as given below:

- Switching impulse test
- Lightning impulse test (line terminals)
- Lightning impulse test (neutral terminal)
- Separate source AC withstand test (Applied voltage test)
- Short-duration induced AC withstand voltage test including partial discharge measurement
- Long-duration induced AC voltage test including partial discharge measurement”

This test sequence is in principle obligatory; but allows other agreements between customer and manufacturer.

IEC 60076-1 (2000) [1], clause 10.5

“In deciding the place of the no-load test in the complete test sequence, it should be borne in mind that no-load measurements performed before impulse tests and/or temperature rise tests are, in general, representative of the average loss level over long time in service. Measurements after other tests sometimes show higher values caused by spitting between laminate edges during impulse test, etc. Such measurements may be less representative of losses in service”.

This test sequence is a recommendation and not obligatory.

1.3.2 IEEE Standards

IEEE Std C57.12.90 [51], clause 4.3

“To minimize potential damage to the transformer during testing, the resistance, polarity, phase relation, ratio, no-load loss and excitation current, impedance, and load loss test (and temperature-rise tests, when applicable) should precede dielectric tests. Using this sequence, the beginning tests involve voltages and currents, which are usually reduced as compared to rated values, thus tending to minimize damaging effects to the transformer.”

Also this test sequence is recommendation and not obligatory.

IEEE Std C57.12.90 [51], clause 10.1.5.1

“Lightning impulse voltage tests, when required, shall precede the low-frequency tests. Switching impulse voltage tests, when required, shall also precede the low-frequency tests.

For class II power transformers, the final dielectric test to be performed shall be the induced voltage test.”

This test sequence is obligatory.

1.3.3 Recommendation of the authors

Taking into account all IEC- and IEEE regulations and recommendations and based on their own experience the authors propose the following test sequence:

- Ratio, polarity and phase displacement
- Resistance measurement
- No-load test (followed, if specified, by the sound level test)
- Load loss and impedance
- Zero-sequence impedance test (if specified)
- Dielectric tests:
 - Switching impulse (when required)
 - Lightning impulse test (when required)
 - Separate source AC voltage test
 - Induced voltage test including partial discharge test.

The test sequence of the tests preceding the dielectric test can be slightly changed due to test field loading or other operational reasons.

1.4 Remarks concerning this test book

This test book has an initial chapter covering dielectric integrity in general (section 2), since verification of dielectric integrity is the result of different types of successful dielectric tests. The first chapter is then followed by descriptions of each individual test.

The individual tests and measurements are covered in greater detail in the following sections (sections 3 to 18):

- Measurement of winding resistance (R), section 3.
- Measurement of voltage ratio and vector group (phase displacement) (R), section 4.
- Measurement of impedances and load losses (R), section 5.
- Measurement of no-load loss and no-load current (R), section 6.
- Separate source AC withstand voltage test (R), section 7.
- Induced voltage test (R alternatively also S), section 8.
- Partial discharge test (R alternatively also S), section 9.
- Impulse test (R and T), section 10.
- Temperature rise test (T), section 11.

1. Introduction

- Measurement of zero-sequence impedances (S), section 12.
- Short circuit withstand test (S), section 13.
- Sound level measurement (S), section 14.
- Test on on-load tap-changers and dielectric tests on auxiliary equipment (R), section 15.
- Measurements of the harmonics of the no-load current (S), section 16.
- Measurement of insulation resistance (S), section 17.
- Measurement of the dissipation factor ($\tan \delta$) of the insulation capacitances or insulation power-factor tests (S), section 18.

Note:

R = Routine test

T = Type test

S = Special test

The individual test items may be interwoven and carried out as part of a combined average to verify certain characteristics, such as resistance measurement.

Several aspects have been considered regarding the tests and test procedures, such as:

- Purpose of the test and what is to be achieved by a specific test.
- Means of generating the supply voltage and current for the test.
- Means to measure or indicate the test object response.
- Means to verify the integrity of the test object.
- Means to verify presence or absence of damage caused by a specific test.

Symbols and abbreviations in this test book follow present IEC Standards where applicable.