Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems

These specifications have been developed by the InterNational Electrical Testing Association for use by electrical power distribution system engineers.

© Copyright 2005
InterNational Electrical Testing Association
PO Box 687, 106 Stone Street
Morrison, CO 80465
Voice: 303.697.8441 Facsimile: 303.697.8431
Email: neta@netaworld.org • Web: www.netaworld.org
NETA Standards Review Council

These specifications were submitted for public comment and reviewed by the NETA Standards Review Council.

Charles K. Blizard
Timothy J. Cotter
Diane W. Hageman
Roderic L. Hageman
Mary R. Jordan
Ralph Patterson
Alan D. Peterson
Ron Widup

Contributors

Those who contributed and commented concerning this document:

Murray Ball
Tom Bishop
Vern Bucholz
Rick Cowan
Tony Demaria
Lyle Detterman
George Estano
Rick Eynon
Scott Falke
Don Genutis
Hans R. Gnerlich
Norbert Gilbert
Wayne Hansen
Kerry Heid
Dennis Johnson

Ben Lanz
Rick Lawrence
Ken Mastrullo
W.A. Moncrief
Francisco Oliveira
Stephen Peschel
Randall Sagan
Peter R. Sammy
Richard Sobhra
Alan Storms
Wally Vahlstrom
Chris Werstiuk
James (Jim) White
Jean-Pierre Wolff

MTS–2005
NETA Full Member Companies

Full member companies of NETA at the time this document was approved:

American Electrical Testing Co.  Charles Blizard
Apparatus Testing and Engineering  James Lawler
Applied Engineering Concepts  Michel Castonguay
ASET Power Systems Services Inc.  F.E. Dickens
Burlington Electrical Testing Co., Inc.  Walter Cleary
DYMAX Service Inc.  Gene Philipp
Eastern High Voltage  Barbara Wilson
ECP Tech Services, Inc.  Mike McDaniel
Electric Power Systems, Inc.  Charles Reed
Electrical & Electronic Controls  Michael Hughes
Electrical Energy Experts, Inc.  William Styer
Electrical Engineering & Testing Services, Inc.  Glen Chynoweth
Electrical Equipment Upgrading, Inc.  Michael Carbo
Electrical Reliability Services  John White
Electrical Technology Services, Inc.  Eric Hansen
Electrical Testing Services  Frank Plonka
Electrical Testing, Inc.  Steve Dodd
Elemco Testing Co., Inc.  Robert White
Hampton Tedder Technical Services  Matt Tedder
Harford Electrical Testing Co., Inc.  Vincent Biondino
High Energy Electrical Testing, Inc.  James Ratshin
High Voltage Maintenance Corp.  Dick Lussier
HMT, Inc.  Peter Thiemann
Industrial Electric Testing, Inc.  Gary Benzenberg
Industrial Electronics Group  Butch Teal
Infra-Red Building and Power Service
Instel Power Services, Inc.
M&L Power Systems, Inc.
Magna Group
MET Electrical Testing Co., Inc.
Nationwide Electrical Testing
North Central Electric, Inc.
Northern Electrical Testing, Inc.
Phasor Engineering
Potomac Testing, Inc.
Power & Generation Testing, Inc.
Power Engineering Services, Inc.
Power Plus Engineering, Inc.
Power Products & Solutions
Power Services, Inc.
Power Systems Testing Co.
Powertech Services, Inc.
PRIT Service, Inc.
Reuter & Hanney, Inc.
Shermco Industries, Inc.
Substation Test Co.
Taurus Power & Controls, Inc.
Tony Demaria Electric, Inc.
Utilities Instrumentation Service, Inc.
Utility Service Corporation

Thomas McDonald
Stuart Jackson
Milind Bagle
Kerry Heid
William McKenzie
Shashi Bagle
Robert Messina
Lyle Detterman
Rafael Castro
Ken Bassett
Mose Ramieh
Miles Engelke
Salvatore Mancuso
Ralph Patterson
Gerald Bydash
David Huffman
Jean Brown
Roderic Hageman
Michael Reuter
Ron Widup
Frank Ceci
Scott Kinney
Anthony Demaria
Gary Walls
Alan Peterson
NOTICE

In no event shall the InterNational Electrical Testing Association be liable to anyone for special, collateral, incidental, or consequential damages in connection with or arising out of the use of these materials.

This document is subject to periodic review, and users are cautioned to obtain the latest edition. Comments and suggestions are invited from all users for consideration by the Association in connection with such review. Any such suggestions will be fully reviewed by the Association after giving the commenter, upon request, a reasonable opportunity to be heard.

This document should not be confused with federal, state, or municipal specifications or regulations, insurance requirements, or national safety codes. While the Association recommends reference to or use of this document by government agencies and others, use of this document is purely voluntary and not binding.
PREFACE

It is recognized by the Association that the needs of commercial, industrial, governmental, and other electrical power systems vary widely. Many criteria are used in determining what equipment is to be tested, at what intervals, and to what extent. Ambient conditions, availability of down time, and maintenance budgets are but a few of the considerations that go into the planning of a maintenance schedule. The owner must make many decisions each time maintenance is considered.

To help the user better understand and navigate more efficiently through this document, we offer the following information:

The Document Structure
The document is divided into twelve separate and defined sections:

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1.0</td>
<td>General Scope</td>
</tr>
<tr>
<td>Section 2.0</td>
<td>Applicable References</td>
</tr>
<tr>
<td>Section 3.0</td>
<td>Qualifications of Testing Organization and Personnel</td>
</tr>
<tr>
<td>Section 4.0</td>
<td>Division of Responsibility</td>
</tr>
<tr>
<td>Section 5.0</td>
<td>General</td>
</tr>
<tr>
<td>Section 6.0</td>
<td>Power System Studies</td>
</tr>
<tr>
<td>Section 7.0</td>
<td>Inspection and Test Procedures</td>
</tr>
<tr>
<td>Section 8.0</td>
<td>System Function Test</td>
</tr>
<tr>
<td>Section 9.0</td>
<td>Thermographic Survey</td>
</tr>
<tr>
<td>Section 10.0</td>
<td>Electromagnetic Field Testing</td>
</tr>
<tr>
<td>Tables</td>
<td>Reference Tables</td>
</tr>
<tr>
<td>Appendices</td>
<td>Various Informational Documents</td>
</tr>
</tbody>
</table>

Section 7.0 Structure
Section 7.0 is the main body of the document with specific information on what to do relative to the inspection and maintenance of electrical power equipment and systems. It is not the intention of the document to list how to test specific pieces of equipment or systems.

Expected Test Results
Section 7.0 consists of sections specific to each particular type of equipment. Within those sections there are, typically, three main bodies of information:

1. Visual and Mechanical Inspection
2. Electrical Tests
3. Test Values
Results of Visual and Mechanical Inspections

Some, but not all, visual and mechanical inspections have an associated test value or result. Those items with an expected result are referenced under Section 3.1 Test Values – Visual and Mechanical. For example, Section 7.1 Switchgear and Switchboard Assemblies, item 7.1.1.7.2 calls for verifying tightness of connections using a calibrated torque wrench method. Under the Test Values – Visual and Mechanical Section 7.1.3.1.2, the expected results for that particular task are listed within Section 3.1, with reference back to the original task description on item 7.1.1.7.2.
Results of Electrical Tests
Each electrical test has a corresponding expected result, and the test and the result have identical numbers. If the electrical test is item four, the expected result under the Test Values section is also item four. For example, under Section 7.15.1 Rotating Machinery, AC Induction Motors and Generators, item 7.15.1.2.2 (item 2 within the Electrical Tests section) calls for performing an insulation-resistance test in accordance with IEEE Standard 43. Under the Test Values — Electrical section, the expected results for that particular task are listed in the Test Values section under item 2.
"Optional" Tests
It is the intent of this document to list a majority of the field tests available for assessing the suitability for continued service and reliability of the power distribution system. Certain tests are assigned an “optional” classification. The following considerations are used in determining the use of the “optional” classification:

1. Does another listed test provide similar information?
2. How does the cost of the test compare to the cost of other tests providing similar information?
3. How commonplace is the test procedure? Is it new technology?
4. Does the outage time required for the particular test greatly increase the total outage time required for all maintenance?

Manufacturer’s Instruction Manuals
It is important to follow the recommendations contained in the manufacturer’s instruction manuals. Many of the details of a complete and effective maintenance testing procedure can only be obtained from this source.

Copyright Laws and Use of the Document
The 2005 NETA Maintenance Testing Specifications are protected under the copyright laws of the United States, and all rights are reserved. Further, the Specifications may not be copied, modified, sold, or used except in accordance with such laws and as follows:

Purchasers may reproduce and use all or a portion of the Specifications after paying the charges as long as the 2005 NETA Maintenance Specifications are clearly and obviously identified in writing as the source of all such uses or reproductions.

NETA intends that Section 7.0 of the 2005 NETA Maintenance Testing Specifications be reproduced and used on a “cut and paste” basis for the particular type of equipment to be tested. For all uses, the following sections are incorporated by reference in each section of 7.0 as though set out in full; these sections must be included along with any portions of Section 7.0:

3.0 Qualifications of Testing Organization and Personnel
   3.1 Testing Organization
   3.2 Testing Personnel
4.0 Division of Responsibility
   4.1 The Owner’s Representative
   4.2 The Testing Organization
5.0 General
   5.1 Safety and Precaution
   5.2 Suitability of Test Equipment
   5.3 Test Instrument Calibration
   5.4 Test Report
Summary
The guidance of an experienced testing professional should be sought when making decisions concerning the extent of testing. It is necessary to make an informed judgment for each particular system regarding how extensive a procedure is justified. The approach taken in these specifications is to present a comprehensive series of tests applicable to most industrial and larger commercial systems. In smaller systems, some of the tests can be deleted. In other cases, a number of the tests indicated as optional should be performed.

The Association encourages comment from users of this document. Please contact the NETA office or your local NETA member firm.

Standards Review Council
InterNational Electrical Testing Association

Charles K. Blizard, Sr.
Timothy J. Cotter
Diane W. Hageman
Roderic L. Hageman
Mary R. Jordan
Ralph Patterson
Alan D. Peterson
Ron Widup
## CONTENTS (cont.)

1. **GENERAL SCOPE** ........................................................................................................................................... 1
2. **APPLICABLE REFERENCES** ......................................................................................................................... 2
3. **QUALIFICATIONS OF TESTING ORGANIZATION AND PERSONNEL** ............................................................. 11
4. **DIVISION OF RESPONSIBILITY** ..................................................................................................................... 12
5. **GENERAL** .................................................................................................................................................... 13
   5.1 Safety and Precautions ................................................................................................................................. 13
   5.2 Suitability of Test Equipment .................................................................................................................... 13
   5.3 Test Instrument Calibration ....................................................................................................................... 14
   5.4 Test Report ................................................................................................................................................. 15
6. **POWER SYSTEM STUDIES** ............................................................................................................................ 16
   6.1 Short-Circuit Studies .................................................................................................................................. 16
   6.2 Coordination Studies .................................................................................................................................... 17
   6.3 Arc-Flash Hazard Analysis ......................................................................................................................... 18
   6.4 Load-Flow Studies ...................................................................................................................................... 20
   6.5 Stability Studies ........................................................................................................................................ 21
   6.6 Switching-Transients Studies – Reserved .................................................................................................. 22
   6.7 Motor-Starting Studies – Reserved ........................................................................................................... 22
   6.8 Harmonic-Analysis Studies ....................................................................................................................... 23
   6.9 Ground-Mat Studies – Reserved ................................................................................................................ 24
   6.10 Cable-Ampacity Studies – Reserved ......................................................................................................... 24
   6.11 Reliability Studies – Reserved ................................................................................................................ 24
7. **INSPECTION AND TEST PROCEDURES** ......................................................................................................... 25
   7.1 Switchgear and Switchboard Assemblies .................................................................................................. 25
   7.2.1.1 Transformers, Dry-Type, Air-Cooled, Low-Voltage, Small ............................................................. 29
   7.2.1.2 Transformers, Dry-Type, Air-Cooled, Large .................................................................................... 31
   7.2.2 Transformers, Liquid-Filled .................................................................................................................. 35
   7.3.1 Cables, Low-Voltage, Low-Energy – Reserved .................................................................................... 39
   7.3.2 Cables, Low-Voltage, 600 Volt Maximum ............................................................................................ 40
   7.3.3 Cables, Medium- and High-Voltage ....................................................................................................... 42
   7.4 Metal-Enclosed Busways ............................................................................................................................. 45
   7.5.1.1 Switches, Air, Low-Voltage ................................................................................................................ 47
   7.5.1.2 Switches, Air, Medium-Voltage, Metal-Enclosed .......................................................................... 50
   7.5.1.3 Switches, Air, Medium- and High-Voltage, Open ........................................................................ 53
   7.5.2 Switches, Oil, Medium-Voltage ............................................................................................................. 56
   7.5.3 Switches, Vacuum, Medium-Voltage .................................................................................................. 59
   7.5.4 Switches, SF₆, Medium-Voltage ............................................................................................................ 63
   7.5.5 Switches, Cutouts .................................................................................................................................. 67
   7.6.1.1 Circuit Breakers, Air, Insulated-Case/Molded-Case .......................................................................... 69
   7.6.1.2 Circuit Breakers, Air, Low-Voltage Power ....................................................................................... 72
   7.6.1.3 Circuit Breakers, Air, Medium-Voltage .......................................................................................... 76
   7.6.2 Circuit Breakers, Oil, Medium- and High-Voltage .............................................................................. 80
   7.6.3 Circuit Breakers, Vacuum, Medium-Voltage ..................................................................................... 85
   7.6.4 Circuit Breakers, SF₆ ............................................................................................................................. 89
   7.7 Circuit Switchers ......................................................................................................................................... 93
   7.8 Network Protectors, 600 Volt Class ............................................................................................................ 96
   7.9.1 Protective Relays, Electromechanical and Solid-State ............................................................................. 100
   7.9.2 Protective Relays, Microprocessor-Based ............................................................................................. 107
### TABLES

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.1</td>
<td>Insulation Resistance Test Values</td>
<td>210</td>
</tr>
<tr>
<td>100.2</td>
<td>Switchgear Withstand Test Voltages</td>
<td>211</td>
</tr>
<tr>
<td>100.3</td>
<td>Dissipation Factor/Power Factor at 20°C</td>
<td>212</td>
</tr>
<tr>
<td>100.4</td>
<td>Suggested Limits for Service-Aged Insulating Fluids</td>
<td>213</td>
</tr>
<tr>
<td>100.5</td>
<td>Transformer Insulation Resistance</td>
<td>216</td>
</tr>
<tr>
<td>100.6</td>
<td>Medium-Voltage Cables, Maintenance Test Values</td>
<td>217</td>
</tr>
<tr>
<td>100.7</td>
<td>Molded-Case Circuit Breakers, Inverse Time Trip Test</td>
<td>219</td>
</tr>
<tr>
<td>100.8</td>
<td>Instantaneous Trip Tolerances for Field Testing of Circuit Breakers</td>
<td>220</td>
</tr>
<tr>
<td>100.9</td>
<td>Instrument Transformer Dielectric Tests, Field Maintenance</td>
<td>221</td>
</tr>
<tr>
<td>100.10</td>
<td>Maximum Allowable Vibration Amplitude</td>
<td>222</td>
</tr>
<tr>
<td>100.11</td>
<td>Periodic Electrical Test Values for Insulating Aerial Devices</td>
<td>223</td>
</tr>
<tr>
<td>100.12</td>
<td>US Standard Fasteners, Bolt Torque Values for Electrical Connections</td>
<td>224</td>
</tr>
<tr>
<td>100.13</td>
<td>SF₆ Gas Tests</td>
<td>226</td>
</tr>
<tr>
<td>100.14</td>
<td>Insulation Resistance Conversion Factors</td>
<td>227</td>
</tr>
<tr>
<td>100.15</td>
<td>High-Potential Test Voltage for Automatic Circuit Reclosers</td>
<td>229</td>
</tr>
<tr>
<td>100.16</td>
<td>High-Potential Test Voltage for Periodic Test of Line Sectionalizers</td>
<td>230</td>
</tr>
<tr>
<td>100.17</td>
<td>Metal-Enclosed Bus Dielectric Withstand Test Voltages</td>
<td>231</td>
</tr>
<tr>
<td>100.18</td>
<td>Thermographic Survey, Suggested Actions Based on Temperature Rise</td>
<td>232</td>
</tr>
<tr>
<td>100.19</td>
<td>Overpotential Test Voltages for Electrical Apparatus</td>
<td>233</td>
</tr>
<tr>
<td></td>
<td>Other than Inductive Equipment</td>
<td></td>
</tr>
<tr>
<td>100.20</td>
<td>Rated Control Voltages and Their Ranges for Circuit Breakers</td>
<td>234</td>
</tr>
<tr>
<td>100.21</td>
<td>Accuracy of IEC Class TP Current Transformers, Error Limit</td>
<td>237</td>
</tr>
<tr>
<td>100.22</td>
<td>Minimum Radii for Power Cable</td>
<td>238</td>
</tr>
</tbody>
</table>

### APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix A</td>
<td>Definitions</td>
<td>241</td>
</tr>
<tr>
<td>Appendix B</td>
<td>Frequency of Maintenance Tests</td>
<td>243</td>
</tr>
<tr>
<td>Appendix C</td>
<td>About the InterNational Electrical Testing Association</td>
<td>247</td>
</tr>
<tr>
<td>Appendix D</td>
<td>Form for Comments</td>
<td>249</td>
</tr>
<tr>
<td>Appendix E</td>
<td>Form for Proposals</td>
<td>250</td>
</tr>
<tr>
<td>Appendix F</td>
<td>NETA Affiliate and Publications Information</td>
<td>251</td>
</tr>
</tbody>
</table>
1. GENERAL SCOPE

1.1 Maintenance Testing Specifications

1. These specifications cover the suggested field tests and inspections that are available to assess the suitability for continued service and reliability of electrical power distribution equipment and systems.

2. The purpose of these specifications is to assure that tested electrical equipment and systems are operational and within applicable standards and manufacturer’s tolerances and that the equipment and systems are suitable for continued service.

3. The work specified in these specifications may involve hazardous voltages, materials, operations, and equipment. These specifications do not purport to address all of the safety problems associated with their use. It is the responsibility of the user to review all applicable regulatory limitations prior to the use of these specifications.