CABLE TESTING STANDARDS:
OVERVIEW OF THE
IEEE 400™ BUNDLE
Moderator

Ron Spataro
AVO Training Institute Marketing Manager
Q&A

Send us your questions and comments during the presentation.
CABLE TESTING
STANDARDS: OVERVIEW
IEEE 400™ BUNDLE
IEEE Cable Testing Standards

- Institute of Electrical and Electronic Engineers
  - IEEE-world’s largest technical professional organization
  - U. S. and global standards
  - Hundreds of standards including cable testing standards
  - Need for cable testing has existed the 1800’s
  - Guided IEEE 400 Series (Bundle) Standards
Need for Cable Testing Standards

Cable Outage Research U.S.

- Studies National Electric Energy Testing Research and Applications Center (NEETRAC)
- Georgia Institute of Technology
- Indicate significant concern for U.S. cable installations
- Service-aged and new cable installations subject to same workmanship issues
- 50% U.S. cable outages due to poor workmanship
U.S. Cable Failures

Causes of Cable Failure
- Inadequate cable prep
- Poor assembly techniques
- Not following instructions
- Lack of training and experience
- Inadequate cable installation
- Environment not controlled
Why Test?

- Outages and repairs are costly
- Negative effects on system reliability
- Need for proactive maintenance
- Find “bad actors” prior to failure
- Best return on cable investment
- Test after repairs
- Test new installations
Where Do You Start

• Identify status of existing cables
• Prove new cable installations
• Identify installation quality issues
• Baselines for future cable testing
• Basis for Condition Based Maintenance
• Solutions for complex cable problems
IEEE 400 Series (Bundle)

- Five major standards
- Guidelines for testing old and new cables
- Current tests being utilized industry
- “Living documents”
- Provides methods, parameters, some evaluation criteria
- Through examination specific to organizations needs
IEEE 400 Series (Bundle)

- **IEEE 400 - 2012 (Omnibus)**

- **IEEE 400.1 - 2007**
  - IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage.

- **IEEE 400.2 - 2013**

- **IEEE 400.3 - 2006**

- **IEEE 400.4 - 2015**
IEEE Cable Testing Standards

• Evolved with cable and testing technology
• Field Tests identified major categories
  – Installation
  – Acceptance
  – Maintenance
• Further divided depending on user needs
  – Withstand
  – Diagnostic
IEEE 400 - 2012 (Omnibus)

- The “omnibus” guide revised from 2001
- Overview of available test methods
- Description of test sources with discussion of tests
- Does not address test results or parameters
- Refers to “point” documents as definitive reference
IEEE 400 – 2012 (Omnibus)

- Includes safety awareness
- General discussions for field testing of cables
- Field testing methods
- Applicability testing methods & advantages/disadvantages
IEEE 400 – 2012 (Omnibus)

• Safety Awareness
  – Regulations and standards observed
  – Same factors as energized work
  – Unique issues to testing present
  – Work area protection and guarding
  – Voltage verification required
  – Grounding equipment required
  – Voltage clearances maintained
IEEE 400 – 2012 (Omnibus)

- Protective grounding
- Rated and tested
- PPE required

Grounding
- Work area protection/guarding
- Minimum Approach Distances
- Insulation required

M.A.D.
General discussions for field testing of cables

- Testing objectives.
- Cable systems to be tested.
- Operating conditions of cable and system components
- Suitable field tests.
- Documentation for analysis.
- Corrective actions on cable system.
Field Testing Methods (5)

1. Voltage Withstand
2. Dielectric Response
   - Dissipation Factor (tan delta)
   - Leakage current
   - Recovery Voltage
   - Polarization/Depolarization current
   - Dielectric spectroscopy
Field Testing Methods (continued)

3. Partial discharge
   – Electrical measurement
   – Acoustical measurement

4. Time-domain reflectometry (TDR)

5. Thermal infrared imaging
Field Testing Methods

1. Voltage Withstand

• Simple (non-monitored) withstand
  – Ability to hold voltage is recorded
  – Go/no-go test

• Monitored Withstand
  – Other attributes monitored during test
  – Dielectric response or PD
  – Temporal stability

IEEE 400 – 2012 (Omnibus)
Field Testing Methods

2. Dielectric Response (5 tests)
   I. Dissipation factor (tan delta)
   II. DC Leakage Current
   III. Recovery Voltage
   IV. Polarization/Depolarization Current
   V. Spectroscopy
Dielectric Response (Continued)

- Provides overall insulation diagnosis
- Can be made at different frequencies or in different time domain
- Analyze effects but not locate defects
- Commonly measured termination to termination
- Values primarily influenced by condition, age etc.
- Results can be compared & used for trending
Dielectric Response (Continued)

I. Dissipation factor (Tan Delta)
   - Loss factor increases as cable ages
   - Tan delta measurement used as a diagnostic
   - Ratio between loss current and charging current
   - Loss current increases as cable ages increasing tan delta angle
   - Absolute tan delta, tip-up and stability values are derived
Dielectric Response (Continued)

II. DC leakage current

- DC voltage lower than withstand applied
- Measures current flowing through insulation
- HVDC not recommended for aged extruded cables
- Measurements taken at steady state voltage
- Performed as a step test
- Cables discharged 4 times test duration after test
Dielectric Response (Continued)

III. Voltage recovery

– Charged with DC voltage for given time
– Discharged with ground resistor
– Open circuit voltage recorded versus time
– Can indicate moisture in PILC cables
– Uses to indicate water tree degradation
Dielectric Response (Continued)

IV. Polarization/depolarization

- Uses polarizing and depolarizing current per time
- Also used to calculate Polarization Index (PI)
- Can compare new and aged insulation
Dielectric Response (Continued)

V. Dielectric spectroscopy

- Displacement and loss currents measured at a range of frequencies
- Can calculate tan delta
- Can be used in time domain for tan delta vs, frequency
Field Testing Methods

3. Partial Discharge-Electrical Measurement
   - Locate potential weak spots
   - Partial discharges are initiated
   - Conducted at $U_o$ or higher voltages
   - Determine voltage level PD inception and PD extension
   - Above $U_o$ used to verify no PD at acceptance test level.
   - Accurate interpretation requires strong understanding of PD behavior
IEEE 400 – 2012 (Omnibus)

Partial Discharge Test

Inception/extension Voltage

PD Event Location
Field Testing Methods

3. Partial Discharge-Acoustic Measurement
   - PD site acts like acoustic wave source
   - Can be externally detected
   - Sensor normally has to make contact
Field Testing Methods

4. Time Domain Reflectometry

– Does not measure dielectric properties
– Used to characterize changes in impedance
– Locates discontinuities
– Shape of reflected pulse assists in identification
Field Testing Methods

5. Thermal Infrared Imaging

- Measure surface temperatures of accessories
- Detects connector high resistivity
- Unusual heating of an accessory
• Point standard for testing laminated insulated cables with HVDC
• Includes testing procedures
• Provides guidelines for test voltages
• Methods of evaluation
  – Current-time relationship
  – Resistance values
• Not recommend for service aged solid dielectric cables
• Point standard for VLF withstand tests
• Presents rational for VLF versus DC
• Test parameters for tan delta
• Test values in appendix
IEEE 400.3 - 2006
IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment

- Background information on partial discharge detection and location
- Interpretive guidance provided
- Technology has improved sensitivity of measurements
- Very good and very bad cables identified
- Remaining life cannot be predicted with great accuracy
IEEE 400.4 - 2015

• Provides for use of damped alternating current voltages for field testing
• Guidelines for evaluation of test results
• DAC applications advanced diagnostic testing
• Most common use partial discharge and dissipation factor

Simulated DAC Wave
Cable outages & repairs are costly
50% of U.S. cable outages due to poor workmanship
Need for testing new and service-aged cable systems
The “omnibus” IEEE 400™ 2012 standard provides guidelines
Specific testing requirements in the “point” standards
End user history and specific test data is key
Join Us For Our Next Webinar

- AVO Electrical Cable Webinar Series Part 2: Mark Franks
  “The Trillion Dollar Problem – Power Cable Outages And The Training Connection”

- Tuesday, June 13, 2017 at 1 PM CST

Register here:
https://attendee.gotowebinar.com/register/3740472969103358979
Electrical Cable Training

- **AVO Cable U** was designed as a technologically advanced “real world” place for every electrical cable installation, testing and diagnostic application.

- **Medium-Voltage Cable Technician Certification:**
  - Cable Splicing & Terminating, Medium-Voltage,
  - Cable Fault Location & Tracing, Medium-Voltage

- **Medium-Voltage Cable Diagnostics & Testing:**
  - Certification Cable Testing & Diagnostics, Medium-Voltage
After more than 50 years, AVO Training remains a global leader in safety and maintenance training for the electrical industry. We deliver an engaging, hands-on experience for our clients in a professional, real-world environment.

We strive to provide industry relevant courses in a practical and flexible learning environment through an ongoing commitment to quality service, integrity, instruction, and client satisfaction.

Our goal is to convey practical job skills and career development for our clients and students by saving lives through a world-class learning experience.