MOTOR WINDING INSULATION TESTING

AKA “Megger” Testing
Prepared by Jeff Timbas, PE
For Levee Safety Meeting
06 December, 2018

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US Army Corps of Engineers
PURPOSE:
TO FAMILIARIZE WITH MOTOR WINDING TESTING REQUIREMENTS AND PROCEDURES
AGENDA

- Why should we perform winding insulation testing
- What needs to be tested
- What are the standards for insulation testing
- USACE “Megger” procedure
- How is the testing data used
- What records need to be kept
- Poor result mitigation techniques
WHY PERFORM INSULATION RESISTANCE TESTING

- It’s the law
  - 33 CFR 208.10(f)(1)
    - Megger tests of all insulation shall be made whenever wiring has been subjected to undue dampness and otherwise at intervals not to exceed one year. A record shall be kept showing the results of such tests.

- Helps to plan for the future with respect to funding for rehabilitation/replacement of motors (trending graphs)
WHAT NEEDS TO BE TESTED

- Flood pump motors
  - Utilize the USACE distributed procedure
    - Titled “Electric Motor Testing Procedures”
- USACE has plans to develop and distribute testing procedures for:
  - Cabling
  - Switchgear
  - Transformers
STANDARDS GOVERNING TESTING

- Low voltage (0-1,000 volts)
  - IEEE 43 (2013) for motors
  - IEEE 400.1 (2007) for conductors
    - Standard was prepared for medium voltage, but the testing procedure for low voltage conductors is the same. Only differences are the test equipment rating and applied voltages
  - NETA MTS (2015) for switchgear
STANDARDS GOVERNING TESTING (CONT.)

- Medium voltage (1,000-72,000 volts)
  - IEEE 43 (2013) for motors
  - IEEE 400.1 (2007) for conductors
  - NETA MTS (2015) for switchgear
  - IEEE C57.152 (2013) for transformers
USACE TESTING PROCEDURE

MOTOR TESTING RECORD

Date

Apparatus
Description
Year of Mfr.
Insulation Class

Rated Voltage
Single or Three Phase

Rating
Horsepower or kW

Minimum Acceptable
Insulation Resistance
From: IEEE 43, Table 3 or Curve?

Hours Since Motor Shutdown

Test Conditions:
Ambient Temperature °F
Wet Bulb Temperature
Relative Humidity %

Dew Point Temperature °F

Weather

Winding Temperature
How Obtained

WINDING RESISTANCE

Instrument
Make and Model
Calibration
Date
Resistance
Range

Resistance (Ohms)

Reading
A-B
A-C
B-C

Corrected

With Cables
without Cables

INSULATION RESISTANCE & DIELECTRIC ABSORPTION RATIO/POLARIZATION INDEX

Instrument
Make and Model
Calibration
Date
Resistance
Applied

Range

Test Date:

MINUTES
0.25
0.5
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

Reading

Correction

Winding Grounding Time

Dielectric Absorption Ratio (R10/R1)

Polarization Index (R60/R15)

Remarks:

Tested by

US Army Corps of Engineers.
USACE TESTING PROCEDURE (CONT.)

- Primarily for non-submersible type pump motors
- Environmental Conditions
  - Temperature: Winding vs Dew Point
    - Dew point needs to be determined prior to testing
    - For valid results, winding temp has to be at least 5°C warmer than the dew point.
  - Weather – Rainy? Humid?
    - If environment is wet/humid, results may be skewed
      - Schedule tests around weather
  - Enter environmental conditions on Motor Testing Record sheet
USACE TESTING PROCEDURE (CONT.)

- Winding DC Resistance Test
  - Prep
    - Safety measures
    - Record operational status of equipment on Motor Testing Record sheet
    - Disconnect motor from power source (label both terminals and conductors to ensure same return setup)
    - Disconnect support equipment (PFCCs)
    - Short out and ground any resistance temperature detector (RTDs) or current transformer (CTs) wiring
    - Run test equipment diagnostics
USACE TESTING PROCEDURE (CONT.)

- Winding DC Resistance Test
  - Follow USACE procedure
  - Three sets of results total (A to B phase, B to C phase, C to A phase)
  - Correct values to 40°C using the formula in step 8.
  - Record initial and corrected values on Motor Testing Record sheet.
  - All values obtained from Winding DC Resistance Test should be below 1 Megohm and similar in value
USACE TESTING PROCEDURE (CONT.)

- Winding Insulation Test
  - Primarily for non-submersible type pump motors
- Prep
  - Determine testing voltages
  - Determine minimum acceptable resistance at 40°C
  - Short all three phases together at terminals
  - Use a multimeter to measure resistance between the leads and grounded motor frame. If the value returned is above the minimum, proceed with the testing.
- Winding Insulation Test

Testing Voltages
- Taken from IEEE 43 – Table 1

<table>
<thead>
<tr>
<th>Winding rated voltage (V)*</th>
<th>Insulation resistance test direct voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000</td>
<td>500</td>
</tr>
<tr>
<td>1000–2500</td>
<td>500–1000</td>
</tr>
<tr>
<td>2501–5000</td>
<td>1000–2500</td>
</tr>
<tr>
<td>5001–12 000</td>
<td>2500–5000</td>
</tr>
<tr>
<td>&gt;12 000</td>
<td>5000–10 000</td>
</tr>
</tbody>
</table>

*Rated line-to-line voltage for three-phase ac machines, line-to-ground voltage for single-phase machines, and rated direct voltage for dc machines or field windings.

Minimum Acceptable Resistance
- Taken from IEEE 43 – Table 4

<table>
<thead>
<tr>
<th>Minimum insulation resistance (megohms)</th>
<th>Test specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>$IR_{\text{min}} = kV + 1$</td>
<td>For most windings made before about 1970, all field windings, and others not described below</td>
</tr>
<tr>
<td>$IR_{\text{min}} = 100$</td>
<td>For most ac windings built after about 1970 (form wound coils)</td>
</tr>
<tr>
<td>$IR_{\text{min}} = 5$</td>
<td>For most machines with random-wound stator coils and form-wound coils rated below 1 kV and dc armatures</td>
</tr>
</tbody>
</table>
USACE TESTING PROCEDURE (CONT.)

- Winding Insulation Test
  - Follow USACE procedure
  - Correct values to 40°C using the formula in step 8.
  - Record initial and corrected values on Motor Testing Record sheet
- Helpful Ratios to calculate and record:
  - Dielectric Absorption Ratio (1 min/30 sec)
  - Polarization Index (10 min/1 min)
USACE TESTING PROCEDURE (CONT.)

- Post Test Efforts
  - Removing all shorting and grounding to RTDs/CTs
  - Reconnect all supporting equipment (PFCCs, surge arrestors, etc.)
  - Remove shorting of motor leads
  - Reconnect power supply to motor.
  - Verifying that equipment is operational after getting it to its pre-test state
TESTING RESULTS – WHAT DO THEY MEAN?

- 1 minute value comparison
- Polarization Index ranges
- What records should be kept
  - All Motor Testing Record sheets
  - USACE recommends plotting the 1 minute results annually
TESTING RESULTS – WHAT DO THEY MEAN? (CONT.)

![Graph showing insulation resistance over time from 1/1/2000 to 1/12/2000. The insulation resistance decreases as time progresses.](image-url)
SUBMERSIBLE PUMPS

- Testing values for submersible pumps
  - Typically lower due to nature of construction and installation
  - Important to trend data to see tapering effect
  - Chart below can be used as an unofficial check

<table>
<thead>
<tr>
<th>Condition of Motor &amp; Leads</th>
<th>Ohm Value</th>
<th>Megohm Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor out of wet well (without cap/cable attached)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A new motor</td>
<td>20,000,000 or more</td>
<td>&gt; 20.0</td>
</tr>
<tr>
<td>A used motor which can be reinstalled in wet well</td>
<td>10,000,000 or more</td>
<td>&gt; 10.0</td>
</tr>
<tr>
<td>Motor installed in wet well (cap/cable installed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A new motor</td>
<td>2,000,000 or more</td>
<td>&gt; 2.0</td>
</tr>
<tr>
<td>A used motor which can be reinstalled in wet well</td>
<td>500,000 or more</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>A motor which may have been damaged by lightening or may have damaged leads (Motor still ok to operate)</td>
<td>20,000 or more</td>
<td>&gt; 0.02</td>
</tr>
<tr>
<td>A motor which has been damaged by lightning or has damaged cable Motor may be operational, but should be pulled for repair</td>
<td>10,000 or more</td>
<td>&gt; 0.01</td>
</tr>
<tr>
<td>A motor that has failed or has severely damaged insulation.</td>
<td>Less Than 10,000</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>
MITIGATION TECHNIQUES

- Heaters
- Dehumidifiers
- Refurbishment
  - Rewind/re-insulate
  - Opportunity for refurbishment of other motor aspects
- Replacement

- Check O&M for potential capacity issues
  - Can project afford to lose a motor during an event?
  - Pump rentals?
SUMMARY

- Why testing is required
- Test prep
- Testing and interpreting results
- What info to keep
- Submersible pumps
- Mitigation Techniques
QUESTIONS?

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