Off-Line Electric Motor Testing Guidelines

**Purpose:**
The purpose of these guidelines is to provide standards for off-line motor testing for low and medium voltage electric motors. It is recommended that the recommended tests be performed annually on in-service and spare motors, and at acceptance of new/refurbished motors.

**Recommended Tests:**
The recommended off-line in-service motor tests are-
1. Stator winding resistive imbalance,
2. Stator winding insulation resistance (megger checks),
3. Polarization Index (PI),
4. Step Voltage test,
5. Surge test.

The recommended spare motor tests are-
1. Stator winding resistive imbalance,
2. Stator winding insulation resistance (megger checks),
3. Polarization Index (PI).
4. Step Voltage test
5. Surge test

The recommended new/refurbished motor tests are –
1. Stator winding resistive imbalance,
2. Stator winding insulation resistance (megger checks),
3. Polarization Index (PI),
4. Step Voltage test,
5. Surge test.

**Guidelines:**
Motor testing can be conducted at the controller cabinet or at the motor junction box. If the tests are performed at the controller cabinet, any abnormal readings should be confirmed at the motor to eliminate false readings due to faulty cabling between the controller and the motor.

1. Stator winding resistance imbalance
   a. Calculated as: \( \% \text{ imbalance} = \frac{\text{largest phase to phase } \Delta \text{ from average } \Omega}{\text{average } \Omega} \)
   b. Controller – 3% maximum imbalance, (Form Wound Motor)
   c. Motor Leads – 1% maximum imbalance. (Form Wound Motor)
   d. Controller – 4% maximum imbalance, (Random Wound Motor)
   e. Motor Leads – 2% maximum imbalance. (Random Wound Motor)

2. Stator winding insulation resistance –
   a. All winding insulation resistance readings should be corrected to 40°C. using the following equation:
   \[
   M\Omega \text{ corrected} = M\Omega \text{ uncorrected} \times (0.5)^{(\text{Temp}-40)/10}
   \]
b. Table 1 provides minimum applied dc voltages during megger testing. Higher voltages may be applied based on site-specific requirements and procedures.

Table 1 – Guidelines for dc voltages to be applied during insulation resistance test

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 (from IEEE Std 43-2000).

<table>
<thead>
<tr>
<th>Winding rated voltage (V) (^a)</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>5001-12000</td>
<td>2500-5000</td>
</tr>
<tr>
<td>&gt;12000</td>
<td>5000-10000</td>
</tr>
</tbody>
</table>

Table 2 provides minimum acceptable stator winding insulation resistance values. If the motor fails the megger check, clean and dry the motor as necessary based on standard motor inspections, then re-perform the test.

Table 2 – Recommended minimum insulation resistance values at 40ºC (all values in MΩ)

<table>
<thead>
<tr>
<th>Minimum insulation Resistance</th>
<th>Test specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR(_{1\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(_{1\text{min}})=100</td>
<td>For most dc armature and ac windings built after about 1970 (form-wound coils)</td>
</tr>
<tr>
<td>IR(_{1\text{min}})=5</td>
<td>For most machines with random-wound stator coils and form wound coils rated below 1 kV</td>
</tr>
</tbody>
</table>

NOTES
- IR\(_{1\text{min}}\) is the recommended minimum insulation resistance, in MΩ, at 40ºC of the entire machine winding
- KV is the rated machine terminal to terminal voltage, in rms kV.
- Table 2 from IEEE Std 43-2000.

3. Polarization Index –
   a. This test is performed on motors of 100 Hp or greater. On the motor tester, the PI minimum alarm should be set at 2.0 for class B, F and H insulation and 1.5 for class A insulation
   b. It is important to note that PI should NOT be used as the basis for any motor acceptance criteria. It should be used as a trending and diagnostic tool, along with other test results, including the PI curve generated by the AWA.
4. Step Voltage testing –
   a. Step Voltage testing should be performed on motors that meet the following criteria –
      i. Acceptable Stator winding insulation readings (MΩ Test).
      ii. Acceptable PI data, including the PI curve.
   b. As stated previously, this test is generally conducted at the controller. If the motor fails the test at the controller, then the motor should be tested at the motor junction box to confirm the readings.
   c. Set up

<table>
<thead>
<tr>
<th>Voltage Class</th>
<th>Voltage / Step</th>
<th>Hold Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>480</td>
<td>500</td>
<td>30 sec</td>
</tr>
<tr>
<td>2KV +</td>
<td>1000</td>
<td>30 - 60 sec</td>
</tr>
</tbody>
</table>

5. Surge testing –
   a. Surge testing should be performed on motors that meet the following criteria –
      i. Acceptable winding resistance readings.
      ii. Acceptable stator winding insulation readings.
      iii. Acceptable PI data, including the PI curve.
   b. Step surge testing is the preferred test.
   c. As stated previously, this test is generally conducted at the controller. If the motor fails the test at the controller, then the motor should be tested at the motor junction box to confirm the readings.
   d. Surge Testing with rotor removed (typically motor shop testing)
      i. Engage L-L EAR Ratio and set ratio to 2% (Form Wound Motor)
      ii. Engage L-L EAR Ratio and set ratio to 3% (Random Wound Motor)
      iii. Engage P-P EAR Ratio and set ratio to 10%
   e. Surge Testing with rotor installed (typically field testing)
      i. Engage P-P EAR Ratio and set ratio to 10%
      ii. Be sure to disengage L-L EAR when testing in the field.