Key Guidelines for Conductor Hardware & Accessories

National Seminar on
NEW GENERATION HIGH PERFORMANCE CONDUCTORS
High Performance Conductor Hardware & Accessories

1.1 Standards & Specific Guidelines
1.2 Critical Components in String Accessories
1.3 Critical functionalities of Key String Components
1.4 Different types of HPC and suitable Hardware & Accessories
1.5 Qualifying Type Test Requirements
1.6 References
1.1 Standards and Specific Guidelines

Reference Standards

- IEC 61284 - IEC 61854 - IEC 61897 | ANSI C 119.4 – ANSI C 119.7
- Customer Specification

Different tests and technical specifications dedicated for HPC

- Mechanical tests (HPC – Thermo Mechanical Tests)
- Electrical tests
- Vibration tests
Operating Temperatures

Conventional conductors (AAAC, AAC, AACSR, ACSR)

• Permanent service : about 75°C.
• 110°C. maximum

High Performance Conductors

• Permanent service : Conductor Specific
• Range : 150°C – 250 °C
• Overload / Relief circuit: 170 °C, 200 °C and more for some HPC
1.2 Critical Components of String Hardware / Accessories
1.2 Critical Components in HPC String Hardware / Accessories

- Dead-End Clamps / Strain Clamps
- Suspension Clamps
- Mid-span Joints | Sleeves
- Spacers | Spacer Dampers
- Vibration Dampers
- T-Connectors | Terminal Connectors
- Aircraft warning Devices
- Elastomeric Components

(AGSC | Bundle Spacers | Damping Elements)
1.3 Critical functionalities of String Hardware / Accessories
1.3 Critical functionalities of String Hardware / Accessories

General features:

- Designed for a specific size / type of HPC
- Designed to keep the fitting cool
- Materials selection to resist annealing or adverse aging @ High Temperature

General Design Requirements:

- Use of Thermally stable materials
- Minimize Hardware Operating temperature
- To be tested for continuous & maximum emergency operating temperature
- Use of materials compatible with the Conductor
1.3.1 Connectors

Current Carrying Devices | Provide Electrical Path | Support High Mechanical Loads

- Limited Tension Connectors (Repair Sleeves | T-Connectors)
- Full tension Connectors (Dead-Ends | Mid-Span)

Design Requirements:

- Suitable conductance
- Low resistance
- Adequate strength
- Low Operating Temperatures
- Least susceptibility to magnetic loss
1.3.2 Suspension Clamps

- Provide Conductor Support at Suspension Towers
- Withstand Vertical and Traverse loads
- Controlling bending stresses at Support point

Design Requirements:

- Designed for High Temperature Conductors
- Sufficient Holding Strength
- Reduced Static and Dynamic Stresses
  (Armor Rods with or without Elastomeric Components)
- Corona Control
- Low Magnetic Losses
1.3.3 Damping Devices

Vibration Dampers
Devices designed to prevent fatigue damage of the conductor due to *Aeolian* Vibrations

Design Requirements:
- Conductor Specific Design
- Ensure conductor outer strand protection
- Helically formed wire mounted or Elastomer cushion mounted
- Thermal Profile of the Damper to be monitored during testing at High Temp
- Material selected to prevent adverse ageing
1.3.4 Damping Devices

Spacer Dampers
Devices designed to counter wind induced oscillations and Aeolian Vibrations in Bundle Conductors

Design Requirements :
- Designed for High Temperature Operation
- Lower Thermal profile of the spacer damper
- Designed to withstand Short Circuit Loads
- Mounting via Helically formed wire or Elastomeric Clamps are some options
- Elastomeric Resilience must be sustained over product lifespan (HT)
1.4 Different Types of HPC and Suitable Accessories
**Different Types of HPC and Suitable Accessories**

### 1.4.1 ACSS, ACSS/TW: Aluminium Conductor Steel Supported

**General features:**
- Construction of Fittings similar to ACSR conductor
- Two stage compression Dead Ends
- Material grade selection must withstand high continuous operating temperatures without Annealing

![ACSS Diagram]

- **Annealed Al.**
- **Extra High Strength Steel Core**

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*2 Stage Compression Dead end*

*Vibration Damper & Suspension Clamp with Armour rod*
1.4.2 GTACSR, GZTACSR: GAP Conductor

General features:

- Special Dead Ends required
- Installation Procedure different from conventional conductors
- Aluminum Layer is compressed only after Steel core is under Tension
- Requires High Temperature Grease filling
1.4.3 (S)TACSR, (S)TACIR: Thermal Aluminum Conductor Steel / Invar Reinforced

General features:

- Construction of Fittings similar to ACSR conductor
- Fittings must be made to withstand Continuous High Temperatures
- Material selection must account for high continuous operating temperatures without Annealing or Aging

Different Types of HPC and Suitable Accessories
1.4.4 Aluminium Oxide / Polymer Matrix Core

- **Core**: Aluminium oxide fibers
  - Max temperature: 250°C
  - Core strength: ≈ 1300N/mm²

- **Core**: Polymer Matrix Core
  - Max temperature: 180°C
  - Core strength: ≈ 2100N/mm²

- Aluminium Zirconium
- Anneal aluminium Trapezoidal shape
Aluminium Oxide Fibre Core HPC

General features:
- Fittings similar to conventional ACSR conductor accessories, but with specific design requirement of HPC
- Materials selection is such that it resist annealing or adverse aging in the expected range of operating temperature
Polymer Matrix Core

**General features:**

- Solid Single Piece Core Construction
- Dead End Fitting Specific to PMC conductors
- Fittings similar to ACSR but designed for HT application
- Materials selection: To resist annealing or adverse aging at High Temperatures
1.5 Specific Qualifying Type Test Requirements
1.5.1 Specific Qualification Tests - Mechanical

Mechanical test at High Temperature

- Used to validate the Dead-ends joints, Midspan joint, Preformed repair rods etc…
- Exceeds 95% RBS at maximum conductor emergency operating temperature.
- No slippage.
### 1.5.2 Specific Qualification Tests - Electrical

**Thermal Aging cycles**
- Used to validate all fittings and accessories for installation directly on conductor

Option 1: - 100 Cycles → Permanent Overload (Emergency Temperature Rating + 60°C)
Option 2: - 500 Cycles → Maximum operating temperature rating / Client requirement

![Diagram of Heat cycle test at 250°C]

*Diagrammatic representation of heat cycle test sequence according to IEC 61284.*
1.5.3 Specific Qualification Tests - Electrical

It’s necessary to know the temperature of each component in order to validate its use

- Using of thermal sensors to recording the local T°C
  - The behavior of elastomeric parts is studied with special interest
1.5.4 Specific Qualification Tests - Vibration

The self damping test is valid for one given cable (type and section)

- Vibration behavior of the High Temperature cable with and without accessories.
The fatigue test allows to verify the life duration of conductor with specific accessories.

Validation of all accessories on a span length
### Specific Qualification Type Test Requirements

#### 1.5.6 Test Matrix [ Dead-End | Mid-Span Joints] *as per CIGRE Guide # 426 clause 5.1*

<table>
<thead>
<tr>
<th>Test</th>
<th>Standards</th>
<th>Modifications</th>
<th>Pass/Fail criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Terminations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dead-end, Joint Strengths</td>
<td>ANSI C119-section 7.3.4, IEC 61284-section 11.5.1</td>
<td>None, but option to use epoxy as one of terminations. Only test dead-end designs that are also an electrical junction.</td>
<td>Exceeds 95% RBS of conductor</td>
</tr>
<tr>
<td>Current Cycling</td>
<td>ANSI C119.4-section 6-modified, ANSI C119.7 (draft), IEC 61284-section 13-modified</td>
<td>Each cycle to conductor emergency temperature rating, plus a further 100 cycles to (emergency + 60°C)</td>
<td>Show resistance and temperature stability per standard</td>
</tr>
<tr>
<td>Sustained Load (room temperature)</td>
<td>ANSI C119.4-section 7.3.3</td>
<td>None but option to use epoxy as one of terminations</td>
<td>No slippage. Exceeds 95% RBS of conductor after sustained load test</td>
</tr>
<tr>
<td>Sustained Load (high temperature)</td>
<td>ANSI C119.4 - section 7.3.3- modify to higher temperature</td>
<td>As ANSI C119.4, but with 15%RBS at conductor emergency temperature</td>
<td>No slippage. Exceeds 95% RBS of conductor after sustained load</td>
</tr>
<tr>
<td>Thermal Profile</td>
<td>none</td>
<td>Pass current to heat conductor and hardware to maximum (emergency) operating temperature. Measure temperatures on hardware.</td>
<td>Temperature in hardware below specified maximum use temperature of materials used in hardware. Attachment point (to insulator) temperature less than maximum specified for the insulator</td>
</tr>
<tr>
<td>Corona</td>
<td>IEEE539/656, IEC 61284-section 14</td>
<td>None</td>
<td>Corona extinction voltage and maximum RIV shall meet required specification</td>
</tr>
</tbody>
</table>
### 1.5.7 Test Matrix [ Terminal Connectors] as per CIGRE Guide # 426 clause 5.1

<table>
<thead>
<tr>
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<th>Modifications</th>
<th>Pass/Fail criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Profile</td>
<td>none</td>
<td>Pass current to heat conductor and hardware to maximum (emergency) operating temperature. Measure temperatures on hardware.</td>
<td>Temperature in hardware below specified maximum use temperature of materials used in hardware.</td>
</tr>
<tr>
<td>Current Cycling</td>
<td>ANSI C119.4-section 6-modified, ANSI C119.7 (draft), IEC 61284-section 13-modified</td>
<td>Each cycle to conductor emergency temperature rating, plus a further 100 cycles to (emergency + 60°C)</td>
<td>Show resistance and temperature stability per standard</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>ANSI C119-section 7.3.4, IEC 61284-section 11.6.1</td>
<td>None. Measure slipping or failure load. This is typically a partial tension connector (low strength).</td>
<td>Meets partial-tension strength rating of the hardware</td>
</tr>
</tbody>
</table>
### Specific Qualification Type Test Requirements

#### 1.5.8 Test Matrix [Suspension Clamps] *as per CIGRE Guide # 426 clause 5.1*

<table>
<thead>
<tr>
<th>Test</th>
<th>Standards</th>
<th>Modifications</th>
<th>Pass/Fail criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeolian Vibration</td>
<td>IEEE 1138-annex B, IEC 60794-1-2-section 21</td>
<td>None</td>
<td>No broken or damaged strands. Optional tensile test-exceeds 95% RBS</td>
</tr>
<tr>
<td>Ice Galloping</td>
<td>IEEE 1138-annex C</td>
<td>8% RBS</td>
<td>No broken or damaged strands. Optional tensile test-exceed 95% RBS</td>
</tr>
<tr>
<td>Turning Angle</td>
<td>none</td>
<td>Hold a minimum of &gt;40% RBS (or maximum heavy load design value) through suspension with 30° turning angle</td>
<td>No broken or damaged strands. Optional tensile test-exceeds 95% RBS</td>
</tr>
<tr>
<td>Unbalanced Load</td>
<td>IEC 61284-section 11.4.2/3/4</td>
<td>Measure load to get slip of conductor in suspension</td>
<td>Meet slip load specification And no damage to conductor. Optional tensile test-exceeds 95% RBS</td>
</tr>
<tr>
<td>Thermal Profile</td>
<td>none</td>
<td>Pass current to heat conductor and hardware to maximum (emergency) operating temperature. Measure temperatures on hardware.</td>
<td>Temperature in hardware below specified maximum use temperature of materials used in hardware. Attachment point (to insulator) temperature less than maximum specified for the insulator</td>
</tr>
<tr>
<td>Corona Testing</td>
<td>IEEE 539/656, IEC 61284-section 14</td>
<td>None</td>
<td>Corona extinction voltage and maximum RIV shall meet required specification</td>
</tr>
</tbody>
</table>
Specific Qualification Type Test Requirements

### 1.5.9 Test Matrix [Vibration Dampers | Spacer Dampers] as per CIGRE Guide # 426 clause 5.1

<table>
<thead>
<tr>
<th>Test</th>
<th>Standards</th>
<th>Modifications</th>
<th>Pass/Fail criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damper Efficiency</td>
<td>IEEE 664, IEC 61897-section 7.11</td>
<td>None</td>
<td>Demonstrate damping efficiency exceeds minimum specification across the frequency range</td>
</tr>
<tr>
<td>Spacers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short Circuit bundle collapse test</td>
<td>none</td>
<td>Short circuit pulses to force conductor bundles to collapse and touch. Choose current and time interval to meet utility specification. Adjust tension to permit collapse condition.</td>
<td>No conductor and spacer damage after short circuit collapse.</td>
</tr>
<tr>
<td>Thermal Profile</td>
<td>none</td>
<td>Pass current to heat conductor and hardware to maximum (emergency) operating temperature. Measure temperatures on hardware.</td>
<td>Temperature in hardware below specified maximum use temperature of materials used in hardware.</td>
</tr>
</tbody>
</table>

Note: For Vibration Damper, test mentioned in the above matrix is in addition to the complete tests as per IEC 61897.

For Spacer Damper, tests mentioned in the above matrix is in addition to the complete tests as per IEC 61854 as well as performance test on a test line.
1.6 References

Guidelines

Test Standards
1. IEEE Std 539: Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines
4. IEC 61284: Overhead Line, Requirements and Tests for Fittings
5. IEC 61897: Overhead Lines – Requirements and tests for Stockbridge type Aeolian vibration dampers
6. IEC 61854: Overhead Line, Requirements and Tests for Spacers
7. IEC 62217: Polymeric insulators for indoor and outdoor use with a nominal voltage 1000 V – General definitions, test methods and acceptance criteria
8. IEC 60468: Method of measurement of resistivity of metallic materials
11. ANSI C 119.4: Connectors for Use Between Aluminum-to-Aluminum and Aluminum-to-Copper Conductors Designed for Normal Operation at or Below 93°C and Copper-to-Copper Conductors Designed for Normal Operation at or Below 100°C
Thank You