Understanding MV Cables Testing, applications, cable selection & standards

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Introduction

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Major Project & Engineering Support

• 19 years wire & cable experience, major industrial projects
• BSc. Eng. (University of Alberta)
• Employer – Texcan, Surrey BC – Wire and Cable distributor
• Previous employers – Cable manufacturers – in Application Engineering and Sales roles
  • Southwire
  •shawflex
  • Alcan Cable
• IEEE activity
  • ESTMP presentations
  • PCIC Vancouver Volunteer 2019
  • Presentations at IEEE Chapter meetings in Calgary, Edmonton, and Fort McMurray
• Regular cable technical newsletters
Agenda

- Medium voltage cables, 5KV to 35KV
  - Among the most complex cables, technically and commercially
  - Focus on industrial / commercial cables

- Applicable CSA Standards

- Available products
  - Differentiating between stocked options and customized made to order options

- Demonstrate construction and purpose of each layer

- Testing
Medium Voltage Cables CSA Standards

- CSA C68.10 Shielded Power Cable for Commercial and Industrial Applications, 5-46 KV
  - FT4 flame rated for exposed usage required by CE Code 2-130
  - HVTECK, HVTC, CSA MV105
- CSA C68.5 Primary Shielded & Concentric Neutral Cable for Distribution Utilities
  - Not flame rated or only FT1, might not be CSA rated.
  - UD /URD concentric neutral cables
- CSA C22.2 #131 Type Teck 90 Cable
  - Unshielded 5KV Teck90
  - At 5KV you can use either shielded C68.10 or unshielded C22.2 #131
- CSA C22.2 #96 Portable Power Cables
  - SHD-GC mining cables up to 35KV
Limited number of manufacturers making these products.
  • Prysmian / General cable merged
  • Aetna used to make short runs / reduced leadtimes but they went out of business Jan 2017

Reduced electrical distribution inventory
  • Less stock / available lengths might be a consideration

Minimum order quantities / leadtime considerations:
  • 1000m for 3 conductor products
  • 3000m for single conductor products
  • 12-20+ week leadtimes

If you have a smaller project or long lead times don’t work, your best CSA product bets are:
  • 3 conductor HVTECK – TRXLPE insulation / 133% insulation level
  • Single conductor CSA MV105 stocked in the US in large quantities
  • Concentric neutral cables in 15KV and 25KV in select sizes (might need to go up a gauge size or two)
• Built to CSA C68.10 – 5KV to 46KV Shielded
• 3c TRXLPE HVTECK 133% well stocked in 5KV and 15KV
• Single conductor HVTECK, EPR products, or 100% insulation levels are made to order
• Typical lead times for made to order is 12 to 20 weeks, 1000m MOQ for 3c, 3000m for 1c
UD / URD Concentric Neutral Cables

- C68.5 Utility Grade Cables, 15KV – 46KV
- Concentric neutral – Full Neutral, 1/3 CN, or reduced neutral
- Either no flame rating or only FT1, suitable for direct burial or conduit applications.
- Typically these are made to order cables or stocked by the Utility. Distribution stocks select gauge sizes.
- Minimum order quantity 3000m for made to order product. 14 – 24 week lead times
• MV105 is the US standard 5KV to 35KV cable, now CSA / UL dual listed

• It is well stocked in 5KV 133% and 15KV 133% in copper
  • Some sizes stocked in 5KV alum, 15KV alum, 25KV cu, 35KV cu

• Built to CSA C68.10 – FT4, TC (tray rated), direct burial, HL Class 1 Div 2 per CE Code Table 19

• 105C EPR insulation, 5mil 25% overlap copper tape shield, PVC jacket

• A great substitute if you can’t find an HVTECK or URD cable you are looking for.

• Note the copper tape shield is a shield only, need to run an additional bond (Table 16)
• 3c version of CSA MV105 built to CSA C68.10
• 100% or 133% insulation level, TRXLPE or EPR insulation
• Looks like UD cable except it is FT4 flame rated and can be installed exposed.
• Made to order product 12 to 20 weeks lead time, 1000m MOQ
Mining Cables

- CSA C22.2 #96 Portable Cords, 600V - 35KV
- For temporary applications and therefore can’t be run on cable tray. They are very rugged and flexible constructions.
- However the new C22.2 #230-17 Tray Cable standard allows SHD-GC cables to be TC-ER marked allowing them to now be installed on cable trays.
- 5KV and up are typically made to order but the minimum order quantities can be as low as 300m.
5KV Shielded vs Unshielded

- Built to 2 different CSA Standards – C68.10 and C22.2 #131
- In Canada most 5KV historically has been 3c unshielded Teck90
- In the US the NEC requires 5KV cables to be shielded
- Shield drains any leakage currently safely to ground
- Shielded cables can be properly acceptance / maintenance tested
  - Can do a proper DC Hi Pot or VLF test on a shielded cable, not on unshielded.
- Shield distributes electrical stresses evenly around the conductor extending insulation life
- Only 5KV shielded can now be called 100% or 133% insulation level
MV Power Cable Construction

- Conductor
- Conductor Shield
- Insulation
- Insulation Shield
- Metallic Shield
- Jacket
Class B stranding most common
Higher class high strand conductors for high flexibility

Conductor Stranding

Stranding Constructions

- Concentric Round (Bare Conductors)
- Compressed (3% reduction)
- Compact (10% reduction)
Copper vs. Aluminum Conductors

Copper is the industrial standard but there are places for aluminum.

Typically go up 2 gauge sizes for equal ampacity alum
Alum is 1/2 the weight and more flexible
Aluminum conductors are generally used by Utilities
Less expensive.
Stable pricing.
Reliable
Spec dual rated ALCU lugs
Insulation

A material that has a high resistance to the flow of current to prevent leakage from the conductor to ground.

2 Types of insulation in MV cables

- TRXLPE – tree retardant cross-linked polyethylene
- EPR – ethylene propylene rubber
Two Types of Thermoset MV Insulations

TRXLPE (Cross-Linked Polyethylene)
- Excellent electrical properties
- Temperature rating 90°C
- Physically tough insulation
- Stiff
- Slightly lower dielectric losses
- Most common Cdn industrial MV insulation

EPR (Ethylene Propylene Rubber)
- Excellent electrical properties
- Flexible; easier to work with
- Great low temp performance
- Higher temperature rating 105°C
- Tree retardant
- US standard not well stocked in Canada
### Operating Temperatures

<table>
<thead>
<tr>
<th>Material</th>
<th>Continuous</th>
<th>Emergency</th>
<th>Short Circuit</th>
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<tbody>
<tr>
<td><strong>EPR</strong> Thermoset Material</td>
<td>105°C</td>
<td>140°C</td>
<td>250°C</td>
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<tr>
<td><strong>TRXLP or XLP</strong> Thermoset Material</td>
<td>90°C</td>
<td>130°C</td>
<td>250°C</td>
</tr>
</tbody>
</table>
MIL Thickness – Power Cable Insulations CSA C68.10

Voltages are:
RMS Phase to Phase

Voltage can not exceed
5% continuous operation
10% emergency operation
Insulation Levels “Thickness”

**100%IL**: (Grounded Neutral)

- Cable in this category are used on electrical systems with relay protection such that *ground faults (cable failure) will be cleared within 1-minute*. A normal insulation thickness can be used for these cables because no exposure to over-voltages occurs during the failure.

**133%IL**: (Ungrounded Neutral)

- Cables in this category are used on electrical systems where a *ground fault (cable failure) cannot be cleared in 1-minute but the faulted cables will be de-energized within 1 hour*.
- When one phase fails, the two remaining phases continue to operate but with a higher than normal voltage applied across the insulation. *A greater insulation thickness is required on some cables to withstand this higher voltage.*
There are **two semi conductive shields** in a medium voltage cable working with a **metallic shield** designed to even out the voltage stress throughout the entire cable.

- **Conductor shield**\(^1\) on the inside of the insulation.
- **Insulation shield**\(^2\) on the outside of the insulation.
- **Metallic shield**\(^3\) over the insulation shield.
  - Can be copper tape or copper wires
Non-Shielded Cable

Electric/Magnetic fields exist outside the cable and are not equally distributed

Figure 1-2
Dielectric Field of Low-Voltage Nonshielded Cable In Contact with Electrical Ground
Electric/Magnetic fields contained within the cable and equally distributed.
Copper tape
- Takes all leakage current back to ground
- Various overlaps & intercalated options
- 100% coverage or gapped
- Can not be used as a bonding conductor
- Need to run a separate bonding conductor

Concentric neutrals
- Large copper wires (traditionally used by Utilities)
- 3 purposes: metallic component of insulation shield, fault current, and conductor for the neutral return current
- Can also have the copper wires sized only for shielding like a copper tape
Water Trees

Cable Failure
Jackets and Armour (or “Sheaths”)

The jacket and/or armor are the parts of the cable which supply all other properties other than electrical properties.

- Fire Retardancy
- Chemical resistance
- Water-Impervious
- Toughness
- Physical protection
Armour (If Required)

**Types of Armor**

- **AIA** (Aluminum Interlocked Armor)
- **GSIA** (Galvanized Steel Interlocked Armor)
- **CCA** (Continuous Corrugated Armor)

Provides physical and mechanical protection for the cable
Interlocked Armor
Interlocked armor is produced by taking a flat metal tape, preforming it into an approximated “S” shape, and then helically wrapping it around a cable core so that the formed edges lock together.

Continuous Corrugated Armor
Continuously corrugated armored cable is formed by a flat metal sheet that is longitudinally folded around the cable core, seam welded and then corrugated.
CEC Code Requirements – Flame Ratings

CE Code 2-130  Electrical wiring and cables installed in buildings shall meet the flame spread requirements of the National Building Code of Canada. (see Appendix B and G)

Appendix B clarifies:
• FT1 for combustible buildings
• FT4 for noncombustible buildings
• FT6 for plenums
Most Widely Used Jacket Materials

PE (Polyethylene)
- High Water Resistance
- Excellent Physical Properties
- Flammable
- UD/URD Cables

PVC (Polyvinyl Chloride)
- Good Chemical Resistance
- Flame Retardant
- Inexpensive
- Teck90 / HVTECK Cables

CPE (Chlorinated Polyethylene)
- Thermoset or Thermoplastic
- Tough and chemical resistant
- Flame Retardant
- Mining Cables

TPU (Thermoplastic Polyurethane)
- Excellent water submersion
- Very tough, stiff in low temperatures
- Mining Cables

Low Smoke Non Halogen
- Reduced Smoke Hazards
- Improved Flame Retardancy
- Lower coefficient of friction
- Pricey in Canada – tunnel / transit applications
## Factory Acceptance Test - CTR

### Cable Description:

- **Cable Description:** 1/C 500 KCMIL CL 115 EPR CPE JKT 5KV/133% 8KV/100% CT

### Specifications

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### Conductor

- **MIN Diameter (INCH):** 0.774, 0.776, 0.776, 0.776, 0.776, 0.776

### Conductor Shield

- **MIN Thickness (INCH):** 0.016, 0.023, 0.023, 0.023, 0.023, 0.023

### Insulation

- **MIN Diameter (INCH):** 1.035, 1.050, 1.050, 1.050, 1.050, 1.050
- **MIN Thickness (INCH):** 0.110, 0.117, 0.117, 0.117, 0.117, 0.117

### Insulation Shield

- **MIN Diameter (INCH):** 1.065, 1.150, 1.140, 1.140, 1.140, 1.140
- **MIN Thickness (INCH):** 0.052, 0.036, 0.036, 0.036, 0.036, 0.036

### Metallic Shield

- **MIN Thickness (INCH):** 1.104, 1.140, 1.140, 1.140, 1.140, 1.140
- **NOM Tape Overlap:** 22.5%, 25%, 25%, 25%, 25%, 25%

### Jacket

- **NOM Diameter (INCH):** 1.244, 1.400, 1.370, 1.365, 1.380, 1.340
- **MIN Thickness (INCH):** 0.070, 0.082, 0.082, 0.082, 0.082, 0.082

### Electrical Testing

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<th>1/C</th>
<th>1/C</th>
<th>1/C</th>
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<td>AC Withstand Time (Minutes)</td>
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<td>MAX Partial Discharge (pC)</td>
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<td>MIN Insulation Resistance (Meg Ohms'/1000')</td>
<td>3450</td>
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<td>MAX Conductor Resistance (Ohms'/1000')</td>
<td>0.0220</td>
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<td>0.0216</td>
<td>0.0216</td>
<td>0.0216</td>
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</tbody>
</table>

**Specifications**

- ICEA S-93-639
- NEMA PUB. NO. WC.74
- UL STANDARD 1072
Testing Overview

• Start with a Continuity and Megger Test (insulation resistance)
  – Refer to NETA 100.1 for test information

• DC Hipot test equipment is widely available, inexpensive, and easy to use
  – Refer to IEEE 400.1 for test information

• DC testing might not be effective in detecting certain types of insulation defects

• IEEE 400 doesn’t recommend DC Hipot tests for aged /underground extruded cables.

• VLF withstand testing is much more common now and recommended for field testing of aged or underground cables
  – Refer to IEEE 400.2 for test information
  – Can also do a Tan Delta test giving you information you can trend over time.
DC Installation – Hi Pot Testing

- DC installation testing is accomplished by employing high voltage, low current dc power to the cable. Installation testing is important in that it provides assurance that no damage has occurred during installation or in handling after leaving the factory. If the cable is installed by a contractor, the test can serve as an acceptance test and assure the owner that the cable has not been damaged and should perform satisfactorily.

### Recommended dc Test Voltages for Shielded Power Cable Systems

- **From 5 - 35KV**

<table>
<thead>
<tr>
<th>System Voltage (KV Phase to Phase)</th>
<th>Acceptance Test Voltage (KV dc, Cond-gnd)</th>
<th>Maintenance Test Voltage (KV dc, Cond-gnd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
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<tr>
<td>15</td>
<td>56</td>
<td>46</td>
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<tr>
<td>25</td>
<td>75</td>
<td>61</td>
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<td>28</td>
<td>85</td>
<td>68</td>
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<tr>
<td>35</td>
<td>100</td>
<td>75</td>
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</tbody>
</table>

Acceptance test voltage duration is normally 15 minutes. Maintenance test voltage duration is normally not less than 5 minutes or more than 15 minutes.
# High Potential Test Report

<table>
<thead>
<tr>
<th>DC Voltage Buildup</th>
<th>Leakage Current (μA)</th>
<th>Insulation Resistance (Megaohms)</th>
</tr>
</thead>
<tbody>
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<td>Time</td>
<td>KV</td>
<td>A</td>
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<td>1.40</td>
</tr>
<tr>
<td>30 sec</td>
<td>10</td>
<td>3.20</td>
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<tr>
<td>45 sec</td>
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<tr>
<td>1 min</td>
<td>20</td>
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<tr>
<td>2 min</td>
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<td>3 min</td>
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<td>4 min</td>
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<td>9.00</td>
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<td>5 min</td>
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<td>15 min</td>
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</table>

## COMMENTS AND REMARKS:

[Graph showing leakage current over time]

- The leakage current during the test shows a significant increase at certain intervals.
- The insulation resistance remains consistent throughout the test.
- The test was conducted under controlled conditions with no external disturbances.
IEEE 400.2 VLF Testing

IEEE Std 400.2-2013
IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

also recommended to retest with VLF-TD, VLF-DTD, VLF-TDTS, or VLF-PD after repair to assess the workmanship of the repair. Monitoring cannot be used to reduce the testing time for retests as the cable system has already been shown to be potentially weak by the prior failure.

Table 3—VLF withstand test voltages for sinusoidal and cosine-rectangular waveforms (see Note 1)

<table>
<thead>
<tr>
<th>Waveform</th>
<th>Installation (phase to phase) [kV]</th>
<th>Acceptance (phase to ground) [kV rms]</th>
<th>Acceptance (phase to ground) [kV peak]</th>
<th>Maintenance2 (phase to ground) [kV rms]</th>
<th>Maintenance2 (phase to ground) [kV peak]</th>
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What to do when you see an anomaly?

• If a cable does not pass the test it may still be good.
• Dirty cable end and high humidity can have significant effects on tests
  – Ensure the cable ends are clean and dry and retest
• Ensure the cable isolated from other components
  – The issue could be with the terminations or other equipment
• Ensure the cable length is within the test sets limitations
Contact Info

Blair Sackney

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- Cell: 604-209-4259
- LinkedIn: https://www.linkedin.com/in/blair-sackney-texcan/