Design and Testing of a High Voltage Feedthrough for Extending IEC Operations to 300 Kilovolts

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• Previous HV Feedthrough Design
• 300 kV Feedthrough
  – Design
  – Testing
• Glass Stalk Testing
Previous Feedthrough Design
Previous Feedthrough Design: HELIOS

- 200 kV design
- 200 kV cable coupled to molybdenum stalk conductor via banana-style connector
- Stalk held by Swagelok-style, nylon ferrule compression fitting
- Vegetable based oil filled, PVC jacket increase voltage standoff
Previous Feedthrough Design: Issues

- Most common failures:
  - Pin-hole type failure near vacuum sealing compression nut
  - Over tightening of ferrule can fracture boron nitride (BN) stalk
  - Oil leak if ferrule is not tight enough

Swagelok style oil to vacuum seal

Nylon Ferrule

Pin Hole Failure

BN Stalk fracture
**300 kV Feedthrough: Quartz Design**

- Removes all conductive material close to stalk
- O-ring seal against quartz bowl replaces metal compression nut
- Macor ceramic plate protects quartz from high-energy particles
- Two tier PVC allows for servicing cable connector without breaking vacuum
- 300 kV cable compatible

**HELIOS 300 kV Quartz Feedthrough**

Grooves increase path length to ground
Comparison of 200 kV and 300 kV designs

ANSYS Maxwell simulations of electric field strengths inside the high-voltage feedthrough designs at an applied voltage of 250 kV (G.E. Becerra, PhD Thesis, 2014)
300 kV Feedthrough: Quartz Design Issues

- Brittle quartz → Shear stress induced crack
- No redundancy in vacuum seal
300 kV Feedthrough: Blue Nylon

- MC901 cast unfilled nylon 6 (blue nylon) base replaces quartz bowl
- Features good mechanical and dielectric strength (2MV/m), vacuum compatible, excellent wear resistance
- Double o-ring fitting for radial sealing against stalk

Fully assembled blue nylon base HV feedthrough
300 kV Feedthrough: Stalk Design

Grooves add:
- Increased path length to ground
- Maintains breaks in metal surface coating from sputtering

4.7 mm diameter molybdenum rod and centering nut vacuum epoxied into stalk top

BN collar shields moly rod from fast ion bombardment

PYRE-ML coating prevents oil permeation

Cathode connector

Boron Nitride insulator

*dimensions in mm
300 kV Feedthrough: In Air Testing

- Corona formation on old banana style connector ~85 kV
- Brass ball used to make electrical connection between cable and moly rod
- Up to 105 kV before corona breakdown
300 kV Feedthrough: Testing, Issues (1)

- Helium testing showed leaks at o-ring to PYRE-ML seal due to **poor surface coating**

- **Holes** in PYRE-ML if mishandled

Adapted feedthrough design installed on HOMER
300 kV Feedthrough: Testing, Issues (2)

- Metal Coating
  - Exposed moly rod during high power runs resulted in conductive coating along stalk and ceramic shield surface from ion sputtering
  - Arcing between stalk and ceramic plate
300 kV Feedthrough: Design corrections

- Vacuum Leaks
  - Top of stalk coated and sealed to macor plate using vacuum epoxy eliminates oil permeation
  - Face seal o-ring provides oil to vacuum barrier

- Surface Sputtering
  - Stalk grooves: 0.075 inch deep, 0.050 inch wide
  - Grooves added to ceramic shield plate
  - Increased lifetime of stalk at higher power runs

Improved HV feedthrough performance from 110 kV to 165 kV thus far…
Borosilicate Glass Stalk Testing

- **Advantages:**
  - Much less expensive than BN stalk
  - Ease of manufacturing
  - Excellent vacuum properties

- **Disadvantages:**
  - Brittle → cracks
  - Melting
Questions?