Study Committee A3

Transmission & Distribution Equipment

Paper 10657_2022

Pressurized air insulated cables: A novel, compact GIL design for 12 kV- 420 kV: Design, Simulation, and Test results

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Motivation

- SF6 in High-Voltage equipment needs to be replaced.
- Alternative gas mixtures are suboptimal for large gas compartments in Gas-Insulated lines.
- Pressurized air is the only reasonable and viable choice as an insulation gas.
- A new GIL design based on pressurized air is required.

Method/Approach

- A basic dimensioning using pressurized air at <=10 bar operating pressure for insulation of coaxial GIL conductor arrangements is provided.
- A new, boltless flange design for enclosure tubes has been developed and optimized for this application
- A detailed technical comparison of the new flange design with bolted flanges and welded flanges is provided showing superior characteristics.
- A set of components using this flange to enable various applications is proposed. Scaling allows products from 12 kV up to 420 kV.
- Results from bursting tests and high-voltage and high current testing are provided for the 145 kV application.
- Application and installation examples including dimensions are provided.

Objects of investigation

- “Pressurized air cables” are essentially gas-insulated lines which use pressurized air for insulation and included flexible components which allow applications similar to traditional high-voltage cables.
- Pressurized air cables have been developed, produced, tested and optimized for 52 kV and 145 kV rated voltage. Results are provided in this paper.
- Installation examples have been demonstrated.

Experimental setup & test results

- Bursting pressure tests for all enclosures have been conducted according to SVTI pressure vessel code and withstand > 50 bar.
- High-voltage AC and BIL testing have been successfully performed on 52 kV and 145 kV products acc. to IEC 62271-204 and matched simulation results.
- High current testing up to 2500 A has been performed on 52 kV and 145 kV product and confirm enclosure temperatures < 65 °C.

Discussion

- Dielectric and mechanical dimensioning result in flange diameters similar to SF6-insulated busbars by using air up to 10 bar and the new flange design.
- AC and BIL requirements by IEC standards can be met. Weakest points are the triplepoints between spacer, air and conductors.
- The large conductor cross sections allow high continuous currents and low losses during operation. Reduced losses benefit thermal stability, compact trenches and economic viability over lifetime.

Conclusion

- Pressurized air cables for 52 kV and 145 kV have been developed and type tested according to IEC62271-204
- The proposed new flange design is superior compared to bolted flanges and welded flanges.
- New flange enables quick assembly and disassembly, a larger insulation gap, better dielectric shape and fewer manufacturing steps.
- Pressurized air cables with the proposed roller design enable compact installations. Demonstration examples worked as intended.
- Prototypes for 245 kV have been developed. Scaling up to 420 kV is feasible

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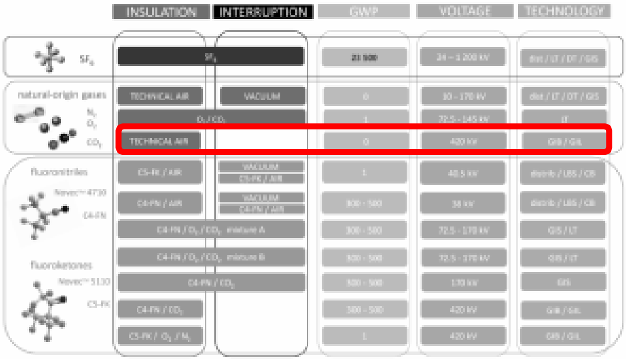
Selection of insulation gas

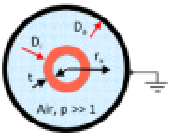
Pressurized air pressurized technical air has been chosen as insulation gas for pressurized air cables – providing a dielectric breakdown strength for dimensioning according to Eq.1:

$$E_{bd} = 24 \frac{kV}{cm\ bar} \cdot p^{0.92} \qquad \text{Eq. 1}$$



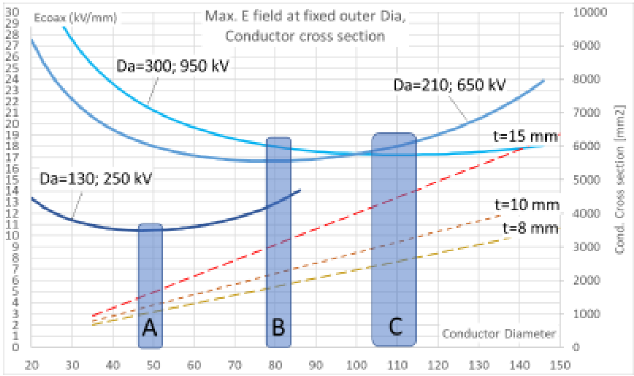
Basic dimensioning

Single-phase arrangement of a high-voltage conductor centered in a metallic enclosure



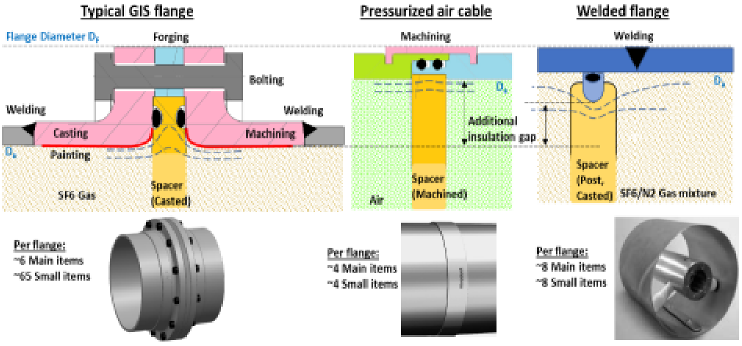
$$E_{coax}(r_x) = \frac{U}{r_x \cdot ln\frac{D_a}{D_i}}$$

$$A_{Cond} = \frac{\pi}{4}(D_i^2 - (D_i - t)^2)$$



Comparison of flange designs

Bolted vs. Welded vs. new ring flange design



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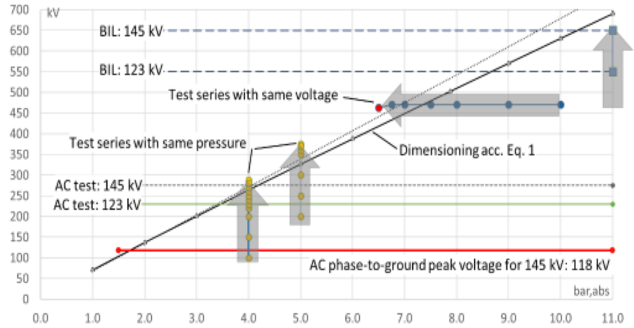
Dielectric test results

AC and BIL tests at various pressures

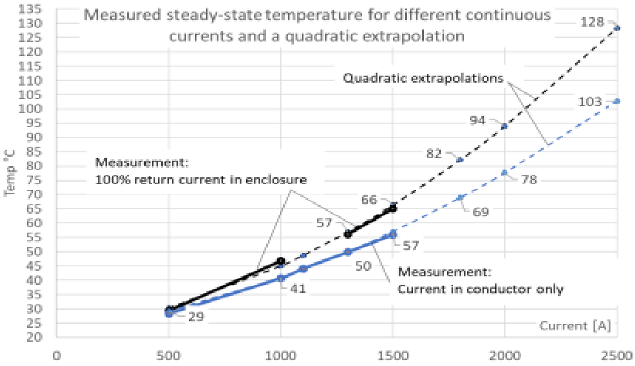
- Good match with simulation results
- Large pressure margin for operation



High current test results

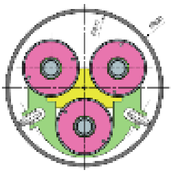
High current tests with and without enclosure current

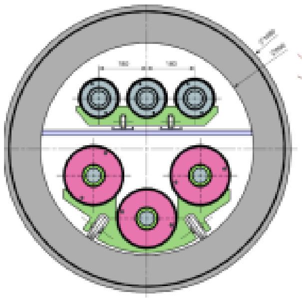
- Conductor temp. up to 105 °C
- Enclosure temp. up to 65°C.
- Thermal time constant ~2hrs.

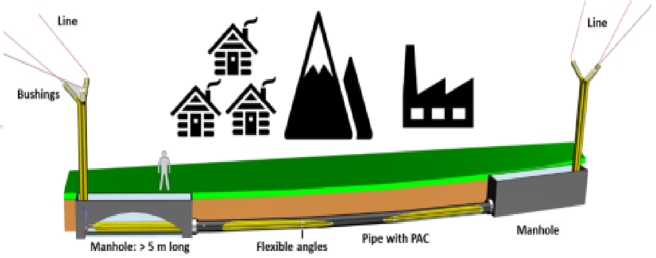


Installation examples

- Underground section of HV line
- Dimension examples for installation in pipe or microtunnel







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