Comparing temperature rise measurement and calculations for 24 kV, 3000 A pressurized air cables in various arrangements

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ABSTRACT

Pressurized air cables (=PAC) are a new technology for medium- and high voltage electric energy transmission. Using pressurized air as the main insulation medium in a coaxial conductor arrangement requires larger insulation gaps and rigid aluminum enclosure tubes which must fulfil pressure vessel requirements. Due to the larger diameter of conductors and enclosures – and corresponding large cross sections – PAC are specifically advantageous for high current applications with rated currents > 1000 A.

To confirm application options for a pressurized air cable specified 24 kV, 2000-3000 A, 50 Hz, temperature rise tests were performed in a single-phase arrangement with straight tubes and bushings. The tests confirmed a maximum conductor temperature below 105 °C as is required by IEC 62271-204 standard.

PAC can be installed in trenches as well as in protective tubes or microtunnels using a roller system. In these arrangements, the conductor and enclosure temperature is strongly affected by heat dissipation of all 3 phases and the thermal properties of the surrounding air, pipe, concrete, and soil. To check these influences, calculations according to IEC 60287 were carried out for a side-by-side arrangement in a microtunnel and a side-by-side arrangement in air for comparison.

It is concluded that pressurized air cables are a valid option for high continuous current applications in various arrangements. Placement in a pipe or microtunnel reduces the thermal limit current, which is strongly dependend on air flow in the tunnel. The rigid enclosure tubes offer additional advantages compared to XLPE cables such as lower outside magnetic field and fire protection due to purely metallic enclosure.

KEYWORDS

Pressurized Air Cable; Thermal design; Temperature rise test; Thermal simulation.

INTRODUCTION

Pressurized air insulated cables (=PAC) are based on a coaxial arrangement of a HV conductor inside a grounded, conducting enclosure – like gas-insulated lines (GIL). The basic properties of GIL and the product design and applications are well known [1] and products are tested according to international standard [2]. GIL applications were enabled by the excellent dielectric strength of pure Sulphur hexafluoride (SF6) gas and fluorinated gas mixtures, resulting in compact insulation gaps when using a standard GIS flange design [3]. However, as SF6 is the most potent greenhouse gas, the application of GIL type of products is limited to GIS busbars and exit busducts in connection with gas-insulated switchgear today and will be banned for future new installations.

The proposed new design of pressurized air insulated cables has overcome the known GIL limitations by using **pressurized air** for insulation instead of SF6, by using a **new flange design** for quick and gas-tight assembly, added a **double-sealing system** and by adding **flexible components** to make it "cable-like" for installation [4].

They are named "pressurized air insulated cables (PAC)" as this best describes the functionality and refers to pressurized air as main insulation medium.

A comparison of a PAC for 24-36 kV with two typical XLPE cables is shown in Fig. 1. PAC have larger diameters than XLPE cables for all rated current values due to the larger insulation gap required for pressurized air. Using up to 10 bar of air pressure, the maximum electric field stress in a PAC is limited to ~20 kV/mm [2] whereas XLPE allows much higher stress values on the conductor.

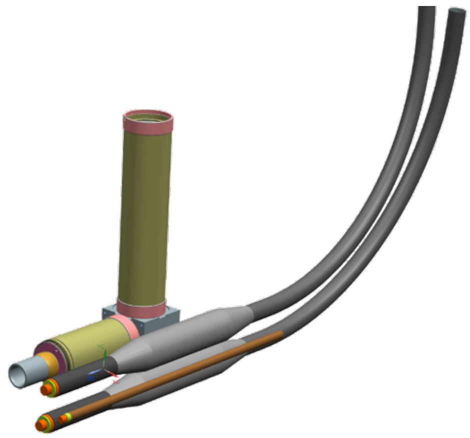

Fig. 1: Comparison: MV PAC (back) with XLPE cables

The larger enclosure diameter of PAC requires a larger diameter of the conductor to be near the dielectric optimum of D_{encl}/D_{cond} = e = 2.71. This leads to key differences between PAC and XLPE cables as presented in Tab. 1.

Parameter	PAC	XLPE
Enclosure diameter	>= 150 mm	40-100 mm (depends on rated current)
Conductor diameter	>80 mm	As small as possible
Conductor cross section	> 2200 mm^2	Engineered for rated current: ~1A/mm^2
Conductor material	Aluminium	Aluminium, Copper
Enclosure	1ph, rigid, 8 mm thick aluminum tube (pressure vessel)	Several layers for protection & shielding
Connections	Proprietary boltless flanges every 5 m	Cable joints

Tab. 1: Differences between PAC and XLPE cables

These basic design differences lead to conductor resistances for different cable types as shown in Fig. 2 – showing the reduction of conductor resistance with increasing conductor cross section (CCS).