Thermal-electrical aging of selected polymeric LVAC cables under DC voltage stress

Karsten **FUCHS**, Frank **BERGER**, Dominik **SCHAFFRINNA**, René **APEL**, Technische Universität Ilmenau, Germany, karsten.fuchs@tu-ilmenau.de, frank.berger@tu-ilmenau.de; rene.apel@tu-ilmenau.de

Guido **EGE**, Werner **KOERNER**; U.I. Lapp GmbH Stuttgart, Germany, guido.ege@lappgroup.com, werner.koerner@ lappgroup.com.de

ABSTRACT

In the context of the energy revolution (Energiewende) and the associated challenges, there are concepts for new network structures and developments for new HVDC cables. Besides the implementation of DC high-voltage networks, efforts are also being made to set up LVDC networks in computer centers, production lines, cooling systems, LED systems etc.

Basically, different concepts are distinguished for LVDC networks. The advantages of LVDC networks with a central converter for supplying and generating the DC bus are a simplified structure, because power electronics in the form of the aforementioned power supplies (reactive power compensation) for the connected devices are no longer required. In addition, the efficiency increases because only one central converter causes conversion losses. At the same time, the costs for equipment are reduced and the design becomes more compact.

However, the challenges in implementing LVDC networks involve the development and definition of safety concepts with suitable DC power switches, control mechanisms for voltage maintenance and suitable polymer DC low-voltage cables, since insulating materials behave fundamentally differently under alternating and direct voltage loads.

The aim of this contribution is to measure an accelerated thermal-electrical ageing of selected low-voltage cables. Over a period of 2,500 hours, the test specimens are stressed by direct current in a heated water tank. On the basis of the results, initial knowledge of the failure behaviour and the changed dielectric strength should be obtained.

KEYWORDS

Extruded LVAC cables, LVDC grids, DC stress, Cable insulation, thermal-electrical ageing, mechanical stress

INTRODUCTION

Besides building energy-efficient HVDC lines within the energy revolution (*Energiewende* in Germany), there are also concepts for establishing new LVDC grids in industrial production, data and computing centres as well as for LED lighting systems. [1]

To realize LVDC grids, it is differentiated between diverse concepts. DC grids with only one central power inverter cause simplified network structures and configurations since every lossy power inverter / switching power supply reduces the efficiency factor of the complete network. Furthermore, reactive power compensation is no longer required. However, suitable safety concepts by means of DC circuit breakers, control mechanism for voltage stability as well as resistant polymeric LVDC cables or wires are needed. It has to be estimated, if connectors and equipment for safety concepts, which are designed for AC voltage applications, are suitable under DC voltage stress. [2]

It is well-known, that the inner conductor of a LVDC cable or wire is less stressed since direct current causes no skin effect, a homogeneous current density distribution as well as less thermal losses in comparison to an AC wire [3]. However, the ageing behaviour of polymeric insulation materials under thermal, mechanical and DC stress is not sufficiently researched. Previous studies (e.g. [4], [5], [6]) only considered ageing phenomena of LVAC cables or conductors under certain conditions. Reliable statements concerning the expected life time of LVDC cables or wires cannot be made so far.

The paper focuses on the determination of the thermal, electrical and mechanical ageing behaviour of selected polymeric LVAC wires under DC voltage stress of U_{DC} = 1 kV. They were accelerated aged over 2,500 h in a heated water tank with a temperature of 80 °C. To determine the influence of mechanical stress, the mechanical bending radius was considered.

The aim of this article is to determine the failure behaviour of conductors with several insulation materials under thermal, mechanical and DC voltage stress over 2,500 h. For comparison, thermal-electrical ageing tests under AC voltage stress were done (without considering mechanical stress).

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Definition and Ageing mechanisms

According to DIN EN 50035-1 [7], *ageing* is defined as a whole of all irreversible chemical and physical processes that occur over the operating time in an insulation material. These processes cause always modifications and degradations of material properties.

If cables or conductors are exposed to an oxygen-containing atmosphere, a combination of different stresses always occurs in the insulation materials [8]. In principle, several ageing mechanisms can be divided into electrical and non-electrical mechanisms [8]. **Table 1** shows the effects caused by stress of electric fields, temperature, chemicals and radiation.

Unlike fixed cables, flexible cables are exposed to various mechanical stresses:

- Tension/Pressure: static or dynamic
- Bending: static, dynamic or continuous
- Torsion: simple, bending and torsion [9].