DIELECTRIC AND LIFE CYCLE BEHAVIOUR OF A CRYOGENIC INSULATION SYSTEM

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1. INTRODUCTION

Since the discovery of high temperature superconductors (HTS) in 1986 several applications for power equipment were developed. The critical temperature of the used ceramic HTS (up to 110 K) lays over the boiling point of liquid nitrogen (77 K), which is used for cooling down to the operating temperature and as insulating medium. Because of this different specifications compared to conventional insulation systems the dielectric and life cycle behaviour of a cryogenic insulation system was analysed [1].

In the test arrangement a cryogenic insulation system was constructed, where a combination of solid, liquid and gaseous materials were used. As representative for gaseous and liquid insulation medium Nitrogen was applied and for solid a polymer material. The solid medium has to show excellent electrical, mechanical and chemical properties at cryogenic temperatures. For this test arrangement PET was used because it has the same structure as Mylar, which is an often used polymer for cryogenic insulation systems.

In the first test series the breakdown voltage was measured and analysed with statistical methods [2]. To minimize the standard deviation of the breakdown voltages the N_2 gas was filled in the system between the high voltage electrode and the solid insulation medium, which was placed within the grounded electrode. The test voltage was an AC step voltage with 5 kV steps up to the breakdown.

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The statistic analysis of the measuring results showed a two parametric weibull distribution over this test arrangement.

In the second test series a life time curve of this insulation system should be determined. For this reason the thermal long time stability was very important. This demand could be fulfilled by measuring in a thermal insulated chamber with constant climate. The life time curve should be constructed by applying characteristic loads on the system.

2. LIFE TIME OF INSULATION SYSTEMS

The life time of insulation systems is dependant of load, which can be described by its quality and quantity. The quality can be expressed by the aging factors due to electrical, mechanical, thermal, chemical or their individual combination as multi stress load. The stress quantity can be described as critical magnitude for electrical field, mechanical stress, temperature etc. The aging behaviour of technical equipment can be characterized in the bath tube curve which is illustrated in **Figure 1.**

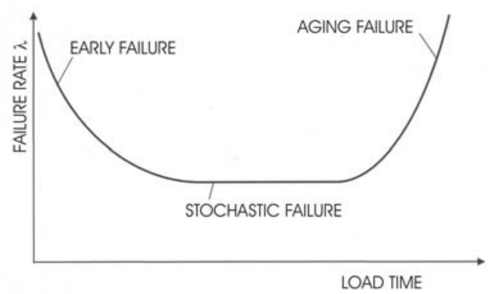

Figure 1. Bath tube curve of technical equipment

Looking at the aging behaviour of insulation systems the early failures and stochastic failures are not of interest. These failure types can be easily excluded taking a look to the Weibullexponent of the breakdown distribution. An exponent of 1 describes stochastic and an exponent smaller than 1 the early failures.

The aging behaviour can generally be expressed in the form of the exponential equation, which is linear in doubled logarithmic description. For electrical stress the aging behaviour can be described in the mathematic form of equation (1), with E… electric field, c_D … constant, t_D … load time, r … life time exponent.

$$E = c_D * t_D^{-1/r} \qquad (1)$$

3. TEST VESSEL AND MEASURING CIRCUIT

The life time tests were done in a cryogenic test vessel with cylinder concentric electrodes. The test object was a polymer insulating material, PET. PET has a very similar structure to Mylar, which is an often used insulation material for cryogenic insulation systems. The test vessel was installed in a laboratory where constant thermal and humid conditions were guaranteed, that there was no influence to the quality of LN_2. This was very important because former investigations showed a big influence to breakdown behaviour in dependence of ice particles in LN_2.

The test vessel and test circuit is shown in **Figure 2.** The test voltage was generated with an AC transformer and applied to the centre electrode. The dielectrical behaviour was observed with partial discharge measuring system, the applied voltage and load time was recorded with PC system. Total three measuring series with over 90 test objects were done.

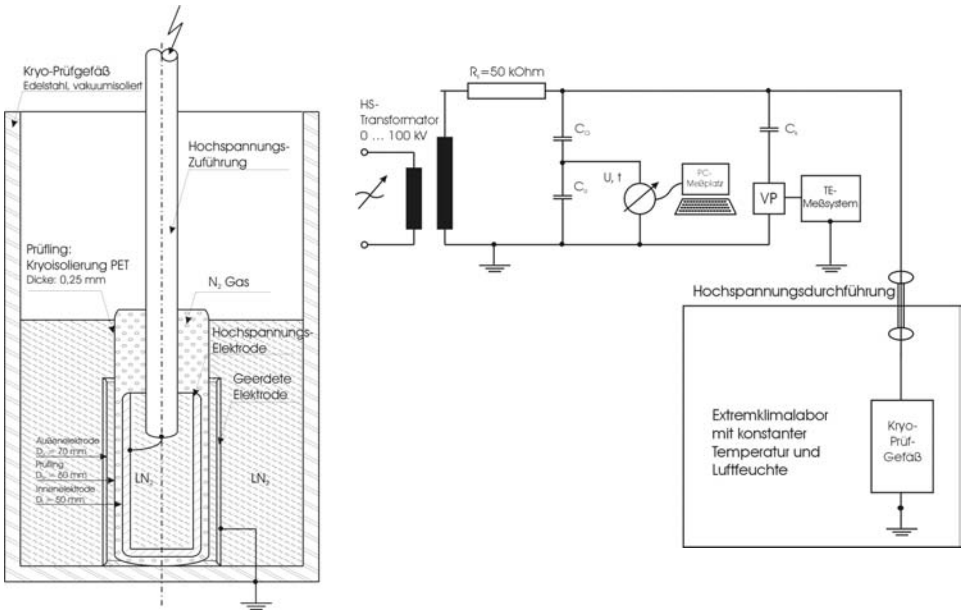

Figure 2. Cryogenic test vessel with electrical insulation system in cylinder concentric arrangement and measuring circuit for life time tests

4. RESULTS

Starting with voltage rise test the kind of breakdown distribution and the load parameter for constant voltage test could be determined. Evaluating the measuring results with the two parametric Weibull distribution the exponents were greater than 1, which confirmed the correct selection of the test voltages. The life time curve for the polymer insulation system could be constructed from the Weibull diagram. In **Figure 3** the evaluated test results and the life time behaviour is shown. [3]

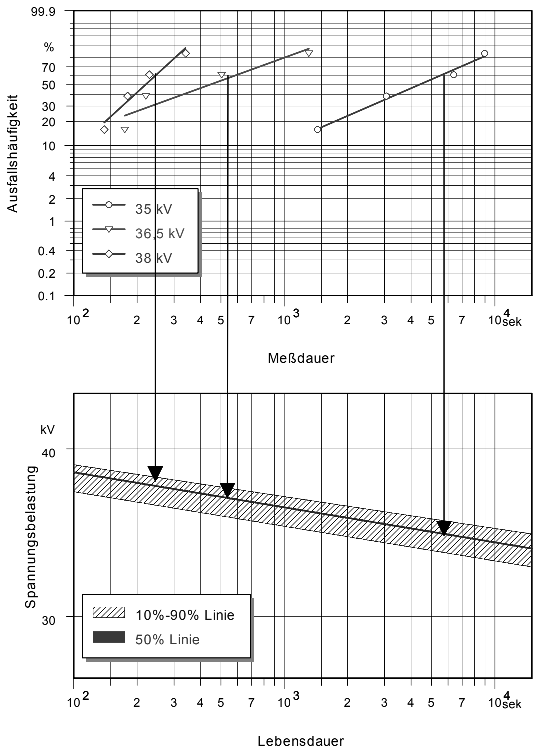

Figure 3. Test results of breakdown tests and life time curve of a cryogenic polymer insulation system.

The parameters of the life time curve were determined and can be expressed as equation (2):

$$U = 43{,}0 * t_D^{-1/40} \quad (2)$$

5. CONCLUSIONS

Comparing the life time exponent of this system with known values of PPLP, which is used as LN_2 impregnated insulant for cryogenic cables, the exponent is in the expected area. Life time exponents of cryogenic systems are higher because thermal aging can be excluded [4]. This means an important advantage to conventional insulation systems, because the life time exponent is more than doubled. The higher exponent of impregnated systems can be explained because of the trend to self healing effect. In the case of partial discharge the liquid medium fills the void [5]. The self healing effect can be influenced by increasing the pressure of the insulating liquid.

6. REFERENCES

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