Flashover behavior of different types of insulators under positive fast transient impulse voltage at different climatic conditions

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This paper deals with the influence of temperature and humidity on flashover behaviour of different insulating materials under positive lightning impulse, voltage stress. Five types of insulators are used for the flashover tests. A composite insulator, porcelain insulators, a semiconductor glazed insulator and an air gap. The flashover distances of all insulators are about the same, for ease comparison. The temperature is varied between 10°C and 40°C, the relative humidity ranges between 10% and 90 % in each temperature step. The tests are performed on a clean test samples, in an environmental chamber. The influence of the relative and absolute humidity on the flashover voltage is evaluated. A comparison of the flashover data of different insulator types is given. For the influence of the absolute humidity on the flashover voltage a temperature-pressure correction factor is calculated.

يقدم هذا البحث دراسة معملية لتأثير العوامل الجوية من درجة الحرارة والرطوبة على تحديد جهود التفريغ الهالى (Flashover) لعدد من العوازل الكهربية نتيجة تعرضها لموجة صاعقة كهربية موجبة. تم إجراء الاختبارات على خمس أنواع من العوازل الكهربية. وقد أجريت التجارب على العوازل الكهربية في حجرة خاصة , ويتم التحكم في درجة الحرارة والرطوبة داخل الحجرة. والنتائج المقدمة في هذا البحث تمثل درجات حرارة تتراوح بين ١٠ و ٤٠ درجة مئوية وكذلك الرطوبة النسبية تراوحت بين ١٠% و ٩٠% . وتمت المقارنة بين الأنواع المختلفة للعوازل الكهربية المستخدمة في البحث.

Keywords: Flashover voltage, Insulators, Temperature, Humidity

1. Introduction

Composite insulators become more common because of their outstanding surface characteristics in polluted areas [1,2]. Also, glazed porcelain with a semiconductor layer, gives good flashover characteristics under sever conditions [3].

Link and George [4, 5] have examined the effect of the relative humidity on the flashover voltage under AC stress, on cylindrical insulator without sheds. For glass samples a decrease in flashover voltage was observed at about 60% relative humidity. For silicon rubber the decrease is at about 80% relative humidity [6, 7].

In this work, the tests are carried out under fast transient impulse voltage stress.

2. Experimental set-up

Fig. 1 shows the test set-up. Marx generator is used for Lighting impulse generation (5μs / 50 μs) . The test samples are located in an environmental chamber. The chamber temperature can be controlled between -20 °C and +60 °C, with accuracy ±1 °C, maximum humidity is 95%.. The chamber volume is $41m^3$. The climatic conditions are measured with a psychrometer. The voltage is measured with damped capacitor divider with parallel resistor (accuracy ± 5V). The data are measured by a digital impulse analysing system (Haefely DIAS 730). All tests are carried out five times and consistent results are obtained.

Fig. 2 shows, the test samples. The flashover distance of all insulators is about 280 mm.

3. Tests

The test voltage is applied in steps. In each step the samples are stressed with 70 impulses. The ratio between the number of flashover to the total number of impulses gives the probability of flashover.

Fig. 3 shows the flashover probability and the corresponding voltage. A linear regression line is calculated from the data.

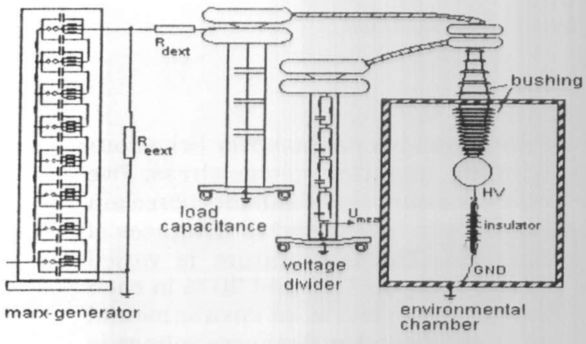

Fig. 1. Experimental set-up.

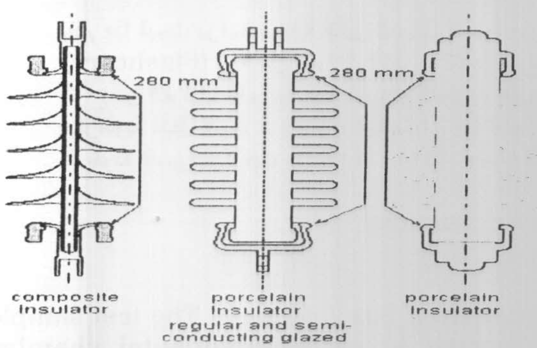

Fig. 2. Test samples.

4. Test results

4.1. Influence of relative humidity on the flashover voltage

Figs. 4-7 show the dependence of the 50% flashover on the relative humidity. The composite insulator and porcelain insulators behave in the same manner. The flashover voltage increases with rising relative humidity.

The semiconductor glazed insulator shows less sensitivity to the change in relative humidity, a smaller rise of flashover voltage with relative humidity fig. 7.

Fig. 8 presents the flashover voltage for the composite, the porcelain and the semiconductor glazed insulators, also that of the air gap at a temperature of 30 °C. The behaviour of all insulators is very similar, except that for semiconductor glazed insulator. At a relative humidity of 10% and a temperature of 30 °C the flashover voltage of glazed insulators is about 26% higher than that of the other insulators. At 90 % relative humidity the flashover is 4% higher. At a temperature of 40 °C same behaviour is observed, fig. 9.

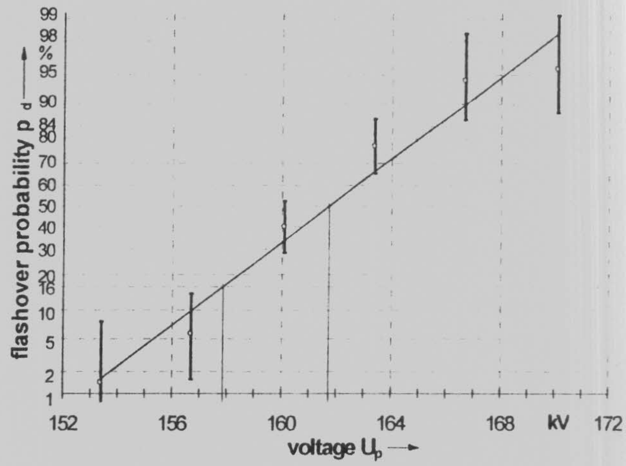

Fig 3. Probability paper with measured data and linear regression line, Under positive voltage polarity, for all samples, under different climatic conditions.

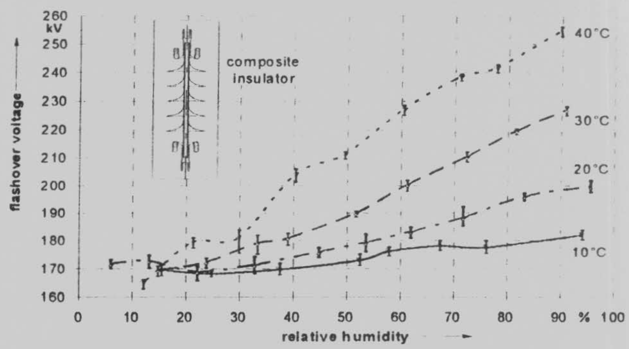

Fig. 4. Dependence of the flashover voltage (positive) on the relative humidity at different temperatures for a composite insulator.

3.2. Influence of the absolute humidity on the flashover voltage

Fig. 10 shows the influence of the absolute humidity on the 50% flashover voltage of the porcelain insulator.

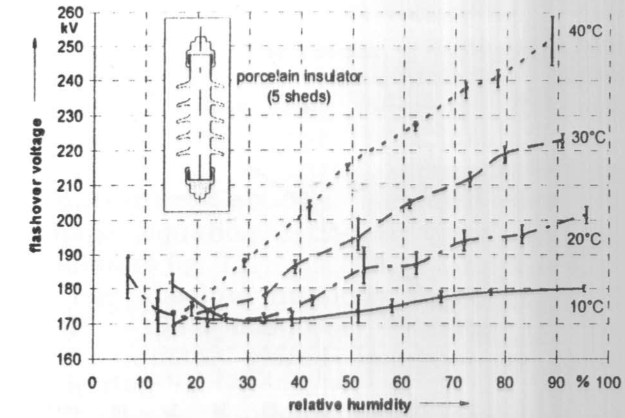

Fig. 5. Dependence of the flashover voltage (positive) on the relative humidity at different temperatures for a porcelain insulator with five sheds

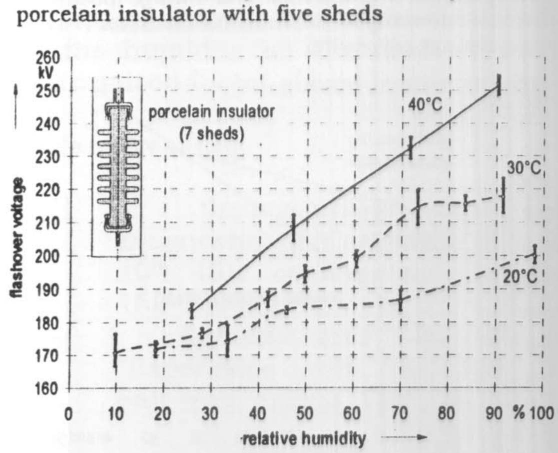

Fig. 6. Dependence of the flashover voltage (positive) on the relative humidity at different temperatures for a porcelain insulator with seven sheds.

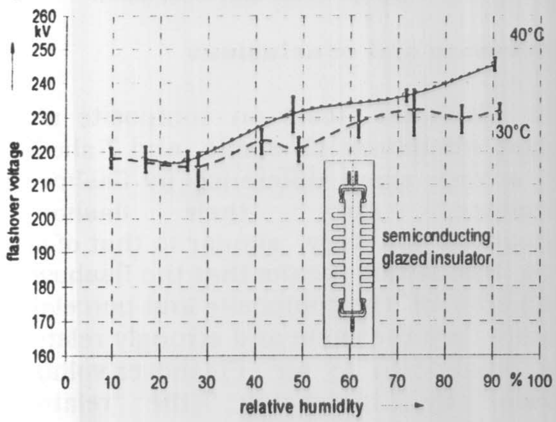

Fig. 7. Dependence of the flashover voltage (positive) on the relative humidity at different temperatures for a semiconductor glazed porcelain insulator with seven sheds

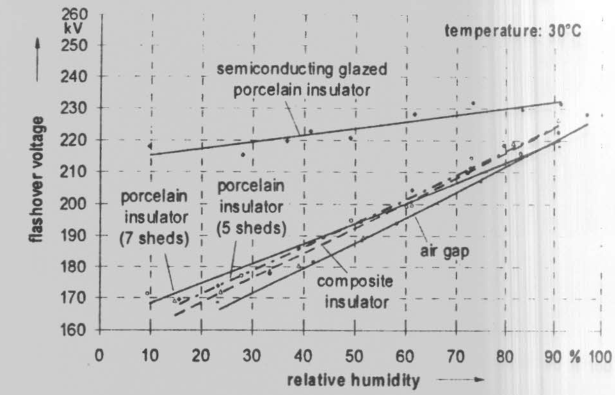

Fig. 8. Dependence of the flashover voltage (positive) on the relative humidity for different insulator types at a temperature of 30°C

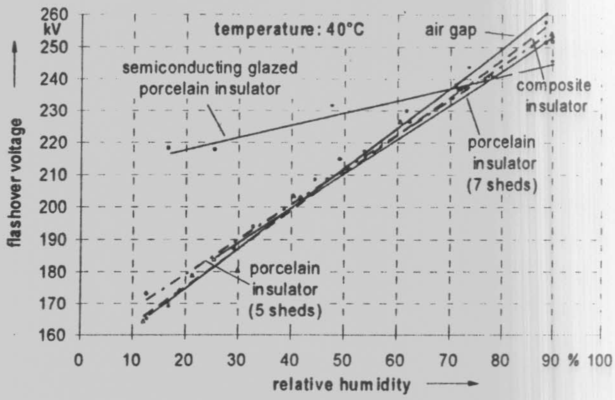

Fig. 9. Dependence of the flashover voltage (positive) on the relative humidity for different insulator types at a temperature of 40°C.

An increase of the flashover voltage with the increase of absolute humidity is observed .The flashover decreases with rising temperature at a constant absolute humidity. The influence of humidity is about the same for all measured temperatures. The flashover behaviour of the composite and porcelain insulator is equivalent.

Fig 11 shows that, the semiconductor glazed insulator gives less sensitivity to the change in the absolute humidity.

The temperature and pressure dependence of the flashover voltage is corrected with the following eq. [8,9]:

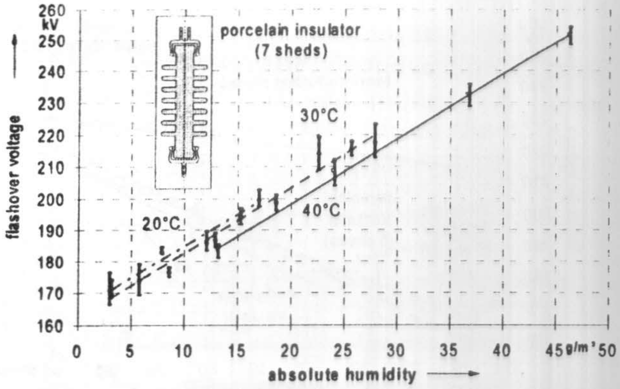

Fig. 10. Dependence of the flashover voltage (positive) on the absolute humidity for a porcelain insulator with seven sheds

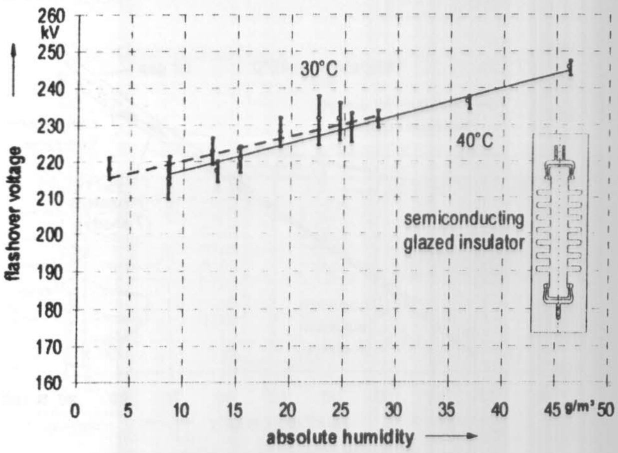

Fig. 11. Dependence of the flashover voltage (positive) on the absolute humidity for a semiconductor glazed porcelain insulator.

$$U_{dcorr} := \left(\frac{P_o}{P_{st}}\right)\cdot\left[\frac{(273.15+T_{st})}{273.15+T_o}\right]^n \cdot U_{dmeas}$$

P_o= 101.3 kPa
P_{st} is the actual ambient pressure
T_o = 20 °C
T_s is the ambient temperature
U_{dcorr} is the corrected flashover voltage
U_{dmeas} is the measured voltage

The exponent (n) of the temperature correction is determined from the measured results. For porcelain insulator (n=0.65), for composite insulator (n=0.7) and for semiconducting glazed insulator (n=0.3) .

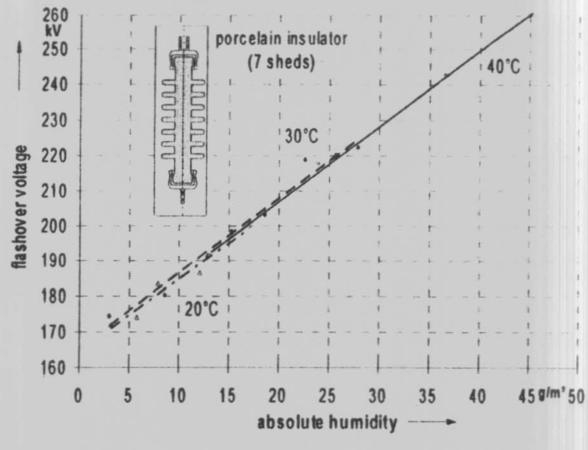

Fig. 12:Dependence of the flashover voltage (positive) on the absolute humidity for a porcelain insulator (7 sheds) with temperature correction

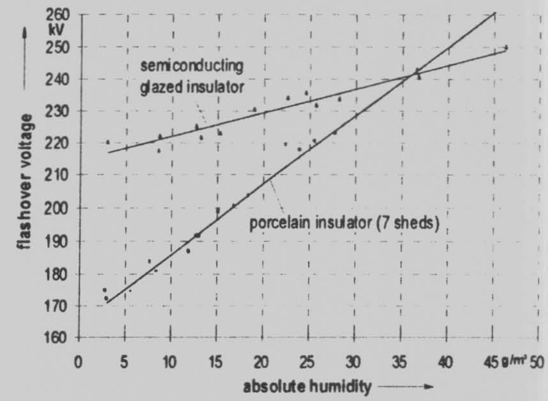

Fig. 13:Dependence of the flashover voltage (positive) on the absolute humidity for a semiconductor glazed and a porcelain insulator (temperature corrected data).

4. Discussion and conclusions

The flashover tests on composite and porcelain insulators (5 sheds and 7 sheds) show a very small difference in flashover performance. Also, their flashover performances are very similar to that of air gap, fig. 8,9. Which means that the flashover mechanisms of the composite and porcelain insulators are the same and strongly related to the breakdown in air. Flashover voltage increases by increasing the relative humidity. Humidity covers the insulator with insulating layer in the absence of contamination inside the environmental chamber.

For the semiconductor glazed insulator, there is a less influence of temperature and humidity on the flashover voltage fig. 7, than that on the other tested insulators. Which means that the semiconductor glazed insulator has a different flashover performance than other tested insulators.

There is a little influence of the temperature on the corrected flashover voltage (equation 1) for all types of tested insulators fig. 12.

For absolute humidity range up to 35 g/m^3, the flashover voltage of the semiconductor glazed insulator is higher than that of porcelain insulators. However, for absolute humidity higher than 35 g/m^3, porcelain insulator shows a higher flashover voltage with respect to semiconductor glazed insulator; this is due to the small influence of the humidity on the flashover voltage of the semiconductor glazed insulator, fig. 13.

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