PRELIMINARY RESEARCH OF TEMPERATURE EFFECT ON SURFACE LEAKAGE CURRENT OF INSULATORS

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Abstract: Preventing pollution flashover is one of the major concerns for power utilities. It is widely accepted that the surrounding environment has a huge impact on the pollution flashover voltage. Environment factors not only influence insulators' flashover voltages but also leakage current of the insulators surface. Temperature and humidity are the two most important factors. The previous researches were mainly focused on the characteristics of leakage current, as well as the correlation between the humidity and flashover voltages. Little effort was given to the effects of temperature on the flashover voltages. In this paper, the effects of humidity and temperature were both considered at the same time. The effects of temperature on wetting process and leakage current were introduced. The preliminary results show that the difference between insulators' temperature and environment's dew point directly affect the strength of leakage current. Despite the low relative humidity of environment, leakage current pulse would occur when insulators' surface temperature is much lower than the environment temperature.

1 INTRODUCTION

The dirty layer on the insulators has a huge impact on the Flashover voltage, mainly due to the content of soluble salt in the pollution and the wetting level of the dirty. Wetting process is affected mainly by four factors, including condensation, collision of the water droplets with the insulator surface, the hygroscopic behaviour of the insulator surface deposit, and a chemical diffusion which develops between the salt solution on the insulator surface and the water molecules of the fog [1]. Therefore the damp of contamination layer is mainly determined by the meteorological condition of environment. Temperature and humidity are two important meteorological factors. They play significant role in wetting process. Past research only focused on the effect of relative humidity and cared little about temperature. However, researches show that humidity correlated with temperature. The relative humidity changes with environment temperature if the water content in the air is unchanged. Thus, both temperature and humidity should be cared when discussing about wetting process.

Leakage current can be used to judge the pollution degree and the damp level of the dirty on insulators [2-9]. With the change of damp degree, the characteristic parameters of leakage current will change accordingly. The purpose of this paper is to introduce the effect of temperature difference between insulators and fog chamber environment on wetting process. In this paper, leakage current is used to describe this effect in a series of experiments. Research results show that temperature difference affect insulators' damp in short-term wetting process. In discussing wetting process should pay attention to the environment dew point. The effect of temperature difference will be more evident when insulators' temperature below the dew point of inside circumstance of the fog chamber. The temperature difference between insulators and the dew point of ambient determines the strength of discharge on the surface of insulators.

2 DEW POINT INTRODUCTION

In the course of studying temperature's effect on the damp process, what we cared is the temperature difference between insulators and environment. We focused on insulators' temperature below the ambient temperature. If such temperature difference is much enough, condensation will appear on the insulator. Condensation which relates to the dew point very closely is the change of the state of matter from gaseous to liquid

Water vapour pressure changes with the water content in the air. The content of water vapour will reach to saturation when the pressure reaches to the limitation. If over the limitation, part of the water vapour will changes from gas to liquid. The limitation pressure is defined as saturation vapour pressure. For air, the lower temperature is the smaller value of the saturation vapour pressure will be. For gas which contains certain vapour, the saturation vapour pressure will decline if the air pressure is constant during decline the air temperature. Dew point is the temperature in which the saturation vapour pressure equals with the current vapour pressure. This means that the dew point must be equals with the current temperature when the current vapour pressure reaches to the limitation, and the dew point must be lower than the current environment temperature if the current vapour pressure does not reach to the limitation.

3 TEST METHORDS AND EQUIMPENTS INTRODUCTION

3.1 Test samples and equipments

Porcelain suspension insulators XP-70 were chosen in the experiments. The real figure and parameters of XP-70 are presented in Figure 1 and Table1. According to the standard IEC60507, solid-layer method was taken in the artificial pollution tests [10]. Kaolin composition was chosen as artificial pollution. During the whole course of experiments， salt deposit density (SDD) and non-soluble deposit density (NSDD) were chosen as 0.1mg/cm^2 and 1.0mg/cm^2.

Figure 1: Porcelain insulators XP-70

Table 1: Parameters of insulators XP-70

Model	Diam. (mm)	Leakage distance (mm)	Surface area (cm^2)	Form factor
XP-70	255	290	1489	0.736

Insulators were suspended in a humidity and temperature controllable mini fog chamber which is column in shape with the height in 120 cm, diameter in 84 cm accordingly. The fog chamber can simulate the environment conditions by control the temperature and humidity inside the chamber. The relative humidity can be adjusted from the atmospheric humidity to 99% with less than 3% fluctuation. The temperature can be modulated from the room temperature to 50℃ with variation in 1℃. Control effect of temperature and humidity in the fog chamber are presented in Figure 2.

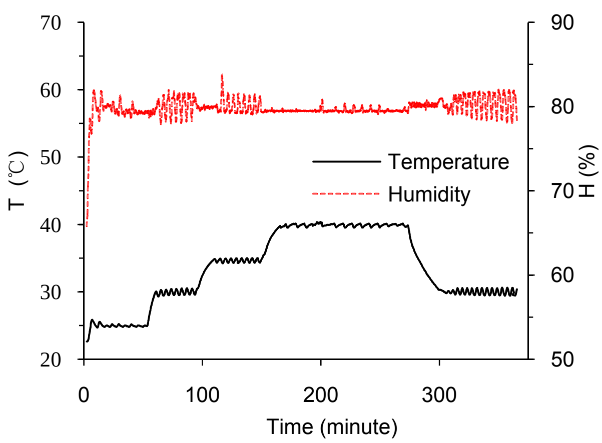


Figure 2: Control effect of temperature and humidity in the mini fog chamber. During this period, relative humidity (RH) remained unchanged while changed the temperature (T) from 25℃ to 30℃, to 35℃, to40℃, and at last down to 30℃. Every stage maintained more than 30 minutes

3.2 Test procedure

The purpose of the experiments is to reflect the effect of temperature difference between the insulator and inner environment temperature of fog chamber on wetting. One insulator was selected every time. Before the insulator was suspended in the fog chamber, the humidity and temperature in the fog chamber were adjusted to the aimed values and in a stable state with small fluctuations. The insulator's temperature was set by an electrical thermostat before putting into the fog chamber. Temperature difference can be described by $\triangle t$ in (1)

$$\triangle t = T_{in} - T_f \quad (1)$$

where: T_{in} = the temperature of the insulator at the moment of it was put into the fog chamber in Centigrade (℃)
T_f = the aimed temperature value in the fog chamber in Centigrade (℃).
$\triangle t$ = temperature difference in Centigrade (℃)

In the 110kV transmission, each insulator averagely bears about 8kV operating voltage. We simulated this situation in the tests. Once the insulator was set in the fog chamber，the insulator would subject to the 8kV testing voltage. A leakage current measuring and monitoring system would start to record the characteristic parameters of the leakage current after the testing voltage was raised to 8kV [11]. During the course of experiments, the trend curves of leakage current were saved automatically by the monitoring system. The curve was extracted from measurement data, which was taken every 0.5 second. Each dot in the curve stands for the maximum value of leakage current in every 0.5 second. During each experiment, the temperature and humidity in the fog chamber were controlled to maintain unchanged. $\triangle t$, T_f and the RH might be different between two trials. If the contamination layer was damp enough, the trend curve would have many discharge pulses. Leakage current pulse was used to describe the role of temperature difference on wetting process.

4 EFFECT OF TEMPERATURE DIFFERENCE ON LEAKAGE CURRENT

Experiments results show that if there had no temperature difference, even if the RH was very high, the contamination layer would be damped very slow. Typical trend curve of leakage current in the situation of no temperature difference is presented in Figure 3.

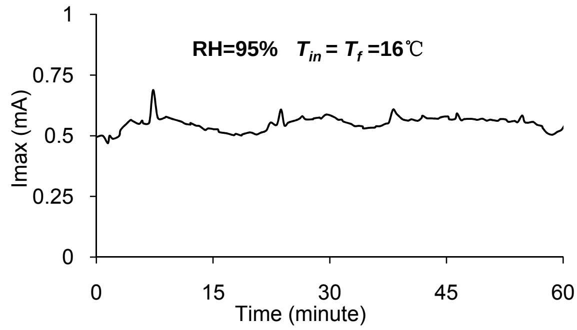
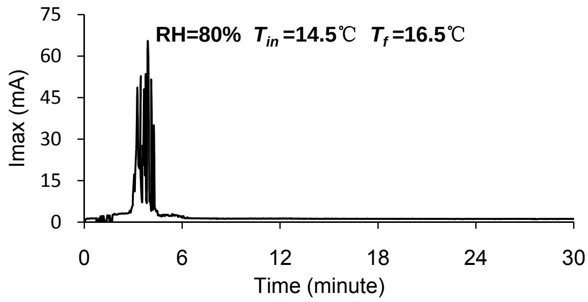
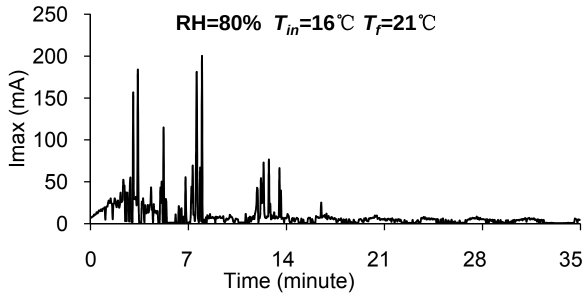


Figure 3: Typical trend curve of leakage current when △*t*=0. T_{in} = T_f = 16℃*,* and maintained the wetting process about one hour. Nearly no discharge surges appeared during the whole course.

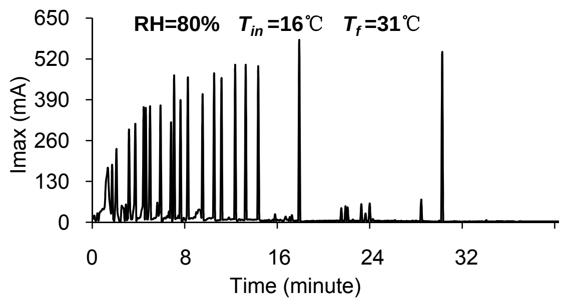
However, if temperature difference existed at the moment when the insulator was put into the fog chamber, the insulator would become damp immediately. Many evident discharge surges appeared in the trend curve of leakage current at the same time. Even if in the situation that the RH was a little low, discharge phenomenon on the insulator still can be observed. Leakage current curves in the cases of existed temperature difference are shown in Figure 4.



(a) T_{in}=14.5℃, T_f=16.5℃, △*t*=−2℃



(b) T_{in}=16℃, T_f=21℃, △*t*=−5℃



(c) T_{in}=16℃*,* T_f =31℃*,* △*t*=−15℃

Figure 4: Leakage current trend curves with different value of temperature difference.

When the initial temperature of insulate was much lower than the air temperature in the fog chamber, discharge phenomenon was very strong and this phenomenon might maintain a long time.

Although temperature difference might cause the contamination layer to be damped in a short-term, it does not mean that large discharge pulses could appear in the leakage trend curve in any cases. A series of trials' results have proved that dew point of the air inside the fog chamber play very important role in the effect of temperature difference on wetting. Dew point of the air inside the fog chamber can be calculated by the formula (2) and (3):

$$H = \frac{\lg(\mathrm{RH})-2}{0.4343} + \frac{17.62\times T_{in}}{243.12+T_{in}} \quad (2)$$

$$D_P = \frac{243.12\times H}{17.62-H} \quad (3)$$

Where: D_P = Dew point in Centigrade (℃).

If RH=80%, T_{in} =20℃, bring 80 and 20 into the above formulas, will get the D_P =16.44℃

Results of whether exist large discharge pulses during wetting in different cases are shown in the Table 2.

Table 2: Test results of temperature difference

(a)

RH (%)	T_f (℃)	D_P (℃)	T_{in} (℃)	Have pulses? (Yes/No)
80	17	13.52	16	No
80	18	14.5	16	No
80	19	15.47	16	No
80	21	17.4	16	Yes
80	24	20.3	16	Yes
90	17	15.35	16	No
90	18	16.33	16	No
90	19	17.32	16	Yes

(b)

RH (%)	T_f (℃)	D_P (℃)	T_{in} (℃)	Have pulses? (Yes/No)
80	21	17.4	16	Yes
75	21	16.4	16	Yes
70	21	15.32	16	No
65	21	14.17	16	No

Table 2 shows that the impulses tend to appear when the initial temperature of the insulator (T_{in}) lower than the dew point of the air in the fog chamber (D_P). Define △*t'* as the temperature difference between T_{in} and D_P. △*t'*= T_{in}−D_P. Test results suggest that the maximum value of leakage current was changed with △*t'*. The smaller the △*t'* was, the more likely to have a higher maximum value of the leakage current. This trend is shown in

Figure 5. (The maximum value of the leakage current is referring to the maximum number in the trend curve and is defined as I_h)

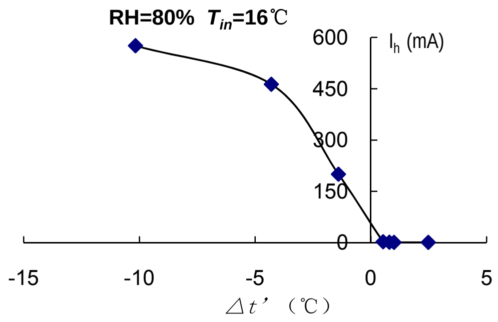
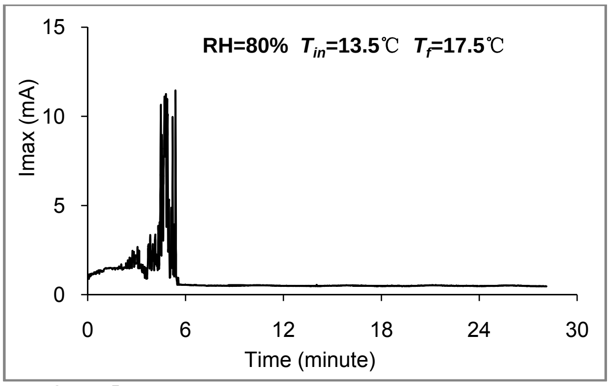


Figure 5: Relationship between I_h and $\triangle t'$

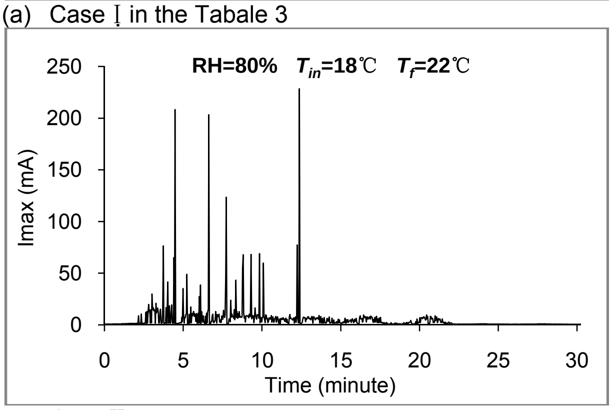
The number of surges and the value of I_h increased when $\triangle t'$ changed from positive to negative number. However, two insulators with initial temperatures close to the dew point of air might have different discharge phenomena. Two examples are presented in Table 3 and Figure 6.

Table 3: Initial conditions of experiments

case	RH (%)	T_f (℃)	D_P (℃)	T_{in} (℃)	$\triangle t'$ (℃)
I	80	17.5	14	13.5	-0.5
II	80	22	18.39	18	-0.39



(a) Case I in the Tabale 3



(b) Case II in the Tabale 3

Figure 6: Leakage current trend curves have similar $\triangle t'$ with different initial temperatures

When initial temperature of insulators were different, even with the similar $\triangle t'$, discharge phenomenon distinction might appear because of the different conditions of air inside the fog chamber. When temperature inside the fog chamber was raised, the dew point would rise. If wanted the insulators which had the higher initial temperature to have an equal value of $\triangle t'$ with the insulators which had the lower initial temperature, the temperature inside the fog chamber should be raised. Despite the RH in the fog chamber was same in the two cases, absolute humidity must be higher in the situation of higher temperature. The preliminary research indicates that two insulators had the similar $\Delta t'$, the intensity of discharge would be stronger on the insulator which had the higher temperature.

5 CONCLUSION

From the experiments results, it is easy to get some conclusions as below:

(1) In the situation that there were no temperature difference between insulators and the air inside the fog chamber, if the RH of the air inside the fog chamber did not reach to 100%, the effect of humidity on contamination layer wetting was very slight in short-term. During the damp process, the average value of the leakage current was very small. Nearly no discharge pulses appeared in the trend curves of leak current.

(2) The dirty layer could be wetted immediately if there were temperature difference between insulators and air. Temperature difference affcted the wetting process of dirty layer. Discharge pulses likely to appear in the case of existing temperature difference.

(3) Discharge phenomena were easily observed when the insulators' surface temperature approximately equaled to the dew point of environment . Two insulators with different initial temperatures might suffer different discharge strength even their surface temperature were both near to the dew point of air. According to the results of trials, insulators with higher temperature had the stronger discharge phenomenon on the surface.

(4) Dischrge sound on the insulators of transmission line can be heard usually even the humidity is not very high in most cases. These discharges might be caused by temperature difference. Dew point relates with humidity and temperature. As there are temperature difference between insulators and air, local small-scale close to the insulators might have different dew point with the overall atmosphere. If the local small-scale air's dew point is higher than the overal atmosphere, the insulators are more likely to be wetted. Discharges will be more easier to occur in the above hypothesis situation. However, this hypothesis needs to be verified.

Temperature and humidity as the two most importan environmental factors, playing important roles in the process of insulators' wetting. A lot of research needs to be done on the link between humidity and temperature. The effct of temperature and humidity on characteristics of pollution flashover shoul be further researched.

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