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초고압 SF_6가스중의 선구방전기구

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Precursor Discharge Mechanism under EHV in SF_6 Gas

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Abstract

The axial discharge at switching operations of EHV SF_6 disconnector can lead to the breakdown to the enclosure. Precursor in periphery zone leads to formation of leader over some time delay. Injected charge value depends on electric field and gap geometry. The calculation method for parameters of SF_6 insulation for DS in EHV-GIS is suggested by using the new criterion of leader inception in connection with periphery field nearby the boundary of streamer zone.

1. Introduction

The axial discharge at switching operations of SF_6 disconnector rated at 500kV and above can lead to the breakdown to the enclosure. The insulation decrease may be caused by leader discharge features, radial field component as well as very fast transient overvoltage with high amplitude. The various leader discharge meachnisms are possible in SF_6 gaps: precursor mechanism, stem mechanism, high frequency heating mechanism and so on. As a rule, for disconnector insulation the precursor mechanism is most possible for positive voltage. The SF_6 insulation at positive impulse is most interesting for the disconnector design taking into account very fast transient overvoltages[1-3]. The mentioned mechanism is based on the physical model where the streamers inject the charge in the gap at some voltage. This charge enhances the initial electric field and the electric field will be increased. When the injected charge would exceed some critical value the ionized zone will be formed in the periphery zone named "precursor". This precursor leads to formation of leader over some time delay. The value of injected charge depends on electric field and gap geometry.

However, the precursor mechanism model allows to find the discharge inception voltage to the earthed enclosure using another method for the development of real disconnector design.

2. Physical Basis of Precursor Discharge Mechanism

A new method is based on the periphery field nearby the boundary of streamer zone for precursor formation. At the moment of the precursor formation, the input of energy into the streamer zone may be found as $W = W1 + W2$ where $W1$ and $W2$ are input energies in the streamer zone and in the precursor zone.

The input of energy per unit of length in the streamer zone may be estimated as follows:

$W1 = Ec\int_{o}^{\infty} i(t)\, dt = E_{cr.o}Q$ where the streamer channel field Ec equals $Ecr.o$.

On the other hands, the energy input in the precursor zone may be found as follows:

$$W2 = \int\int Ec(t,x)\; Q(t,x)\; dxdt$$

where x is coordinate of the precursor zone.

The field distribution in the nonuniform gaps is shown in Fig.1. The energy losses nearby precursor zone are small. This means that positive ions move in the low field very slowly. As a result the energy concentration in the precursor zone must be increased.

The energy criterion of the precursor inception may be shown as $W2 = Wo + \Delta W$

where $W2$: the total energy carried to precursor zone Wo: the lost energy in the internal collisions of ions and electrons according to streamer processes ΔW: additional energy which leads to change the parameters highly inside precursor zone.

Therefore $\Delta W = W2 - Wo = f(E, Ns, P)$.

The energy ΔW depends on the maximal field and difference of charge flow at the boundary of the precursor zone. Actually the precursor model is connected with increasing of electric field far from electrode. The electric field on the boundary of streamer zone will be increased up to $E_{cr}.o$. The electric field

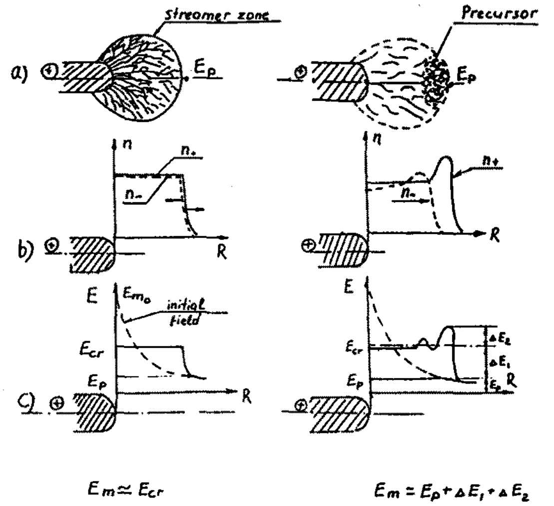


Fig.1 Illustration of physical basic of approach

a)Patterns of discharge

b)Distribution of ion density

c)Field distribution for streamer corona and formation of precursor

becomes higher to cause the intensive processes of ionization. Thus the establishment of precursor and the following leader development depend on some maximal critical field in the gap. In this case the maximal stress in the periphery region $E_{m}p$ at the moment of precursor formation can be found as follows

$$E_{m.p.cr} = E_{p.cr} + \Delta E_1 + \Delta E_2$$

where $E_{p.cr}$ is the initial field stress at the distance what equals size of critical zone and ΔE_1 *and* ΔE_2 are field enhancements because of injected charge and charge dipole formation. If the periphery field is high the positive ions move quickly. In case of low periphery field the ions move slowly. It leads to the increase of positive ion density in the precursor zone and to decrease of charge flow at the precursor zone boundary. It is shown that the streamer development is practically impossible at lower field than 35-45kV/cm · atm. The streamer development decreases significantly in the field of about 45-60kV/cm · atm and practically constant in the field less than 40-45kV/cm · atm.

On the other hands, the leader inception voltage of gas gaps with microirregularities and relevant methods of its calculation leads to results shown in the Fig.2(curve1). The last curve shows that the background field at the leader inception depends on the product of gas pressure and microirregularity height significantly.

The field distributions nearby microirregularities at experiments of Fig.2 are shown in Fig.3. It is clear that the field of 0.6-0.7 mm distance from microirregulartity

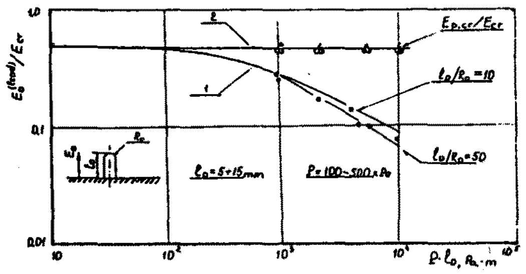
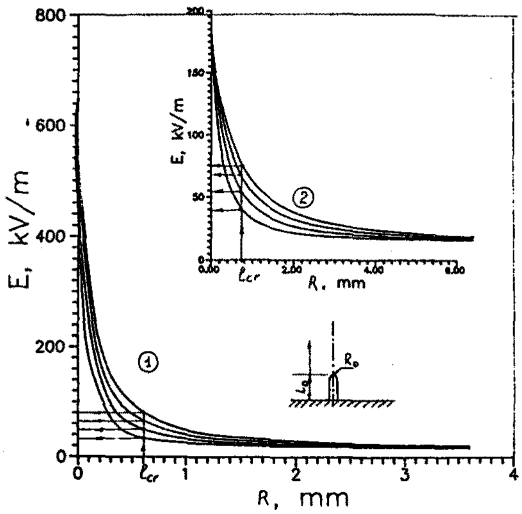


Fig.2 Dependences of background field on the product of gas pressure and height of microirregularity



1) R/L₀ = 50 Lo = 5, 7.5, 10, 12.5

2) R/L₀ = 10 Lo = 5, 7.5, 10, 12.5

Fig.3 Normalized field distribution for microirregularity

tip is 44-45kV/cm · atm. It is concluded that if the geometric parameters of microirregularity are known and the initial field at the distance of 0.6mm doesn't exceed the value of 45kV/cm the development of leader discharge is impossible.

3. Pratical Calculation for EHV-DS design

The main problem in DS insulation is to exclude the discharge to the earthed enclosure. Nowadays it is more correct to choose the minimal leader inception voltage like precursor inception voltage. Secondly it is clear that the initial field has to provide the development of axial discharge. The field distributions before and after axial discharge are shown in Fig.4. The axial channel could be considered as microirregularity. If the electric field in such gap at the distance from discharge channel of about 0.6mm would be less than 45kV/mm · atm the prevention of radial leader inception will be fulfilled. It seems that the critical distance value

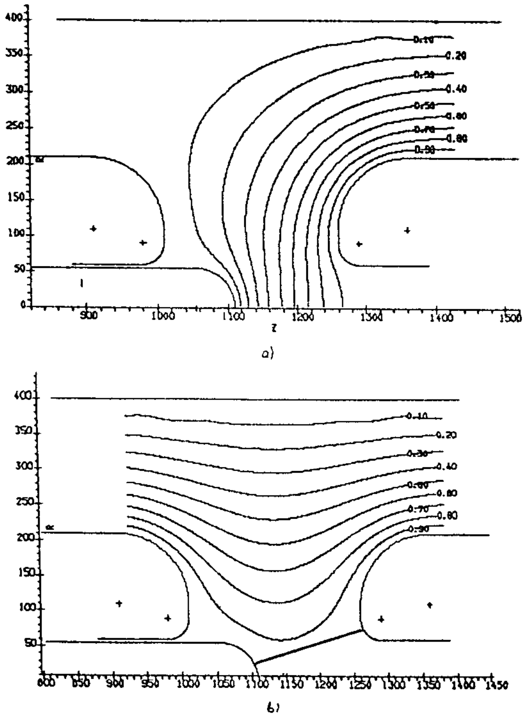


Fig.4 Field distribution of disconnector before axial discharge(a) and after it(b)

of about 0.6mm may be increased a little.

The field distribution nearby leader channel for case of completed axial discharge in disconnector at channel radius of 10-500 µm is shown in Fig.5. To exclude the radial leader inception it is necessary to increase the electrode diameter or to decrease the distance between electrodes. Therefore, the calculation of disconncector insulation has to be conducted in two main steps: first it is necessary to optimize it in static regime and second to take into account the axial discharge according to mentioned consideration and to make some correction of the design.

4. Conclusions

The positive precursor inception voltage depends on the periphery field. The critical periphery field at initial precursor formation is independent of the field form, and the product value of gas pressure and microirregularity at the gas pressure of 0.1-0.4Mpa. The critical periphery field is about 45kV/cm · atm at distance of precursor formation of 0.6-0.7 mm. The field calculation for electrode system and axial discharge channel as microirregularity lead to choose the disconnector design correctly. This work was done as joint research project between KERI and VEI of Russia.

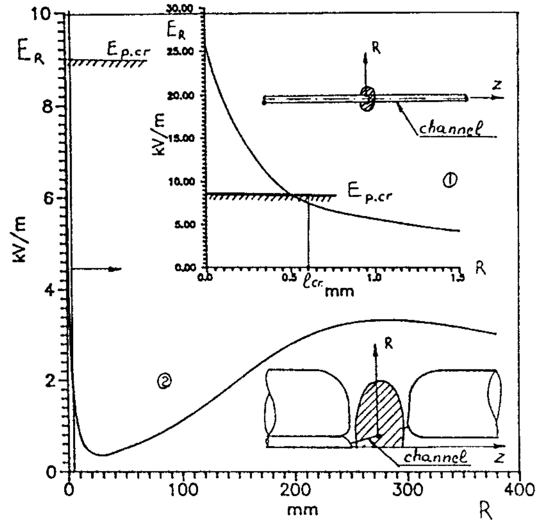


Fig.5 Radial field distribution in possible radial discharge

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