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Revision, preview and assignment

Revision: 4.4-4.7

Preview: 5.1-5.4

Homework: 4-15, 4-17, 4-20, 4-21, 4-27, 3 extra exercises (on the Online Learning Platform)

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Specific Topics:
Insulation Structure of High-Voltage Bushings and High-Voltage Current Transformers

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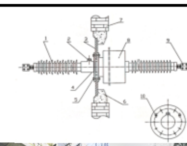
Contents

1 Basic concepts of bushings



1.1 Definition of Bushings

A bushing is an insulating device used to introduce a live conductor into electrical equipment or through a wall.

1.2 Classification of Bushings

The former is called electrical equipment bushing, and the latter is called wall-penetrating bushing.

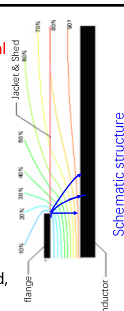
1.3 Structure of Bushings

The structure of a bushing typically consists of three parts:

- Insulator, is a cylindrical pipe (jacket & shed)
- Conductor (conductor rod/coil), passes through the axis of the insulator
- Metal flange, with an annular shape, to fix the bushing on the wall or tank of the equipment, located outside the insulator and serves for grounding.

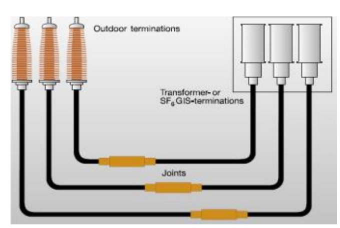
1.4 Characteristics of Bushings

- ➢ Bushing is an insulating structure with a strong vertical electric field component.
- ✓ The electric field is high at the edge of metal flange, making it easy to corona and flashover along the surface of insulating material.
- ✓ The radial electric field between the flange and the conductor rod is also high, leading to insulation breakdown.
- ➢ For bushings with a voltage rating of 35kV and below, a single solid layer insulating material is commonly used.
- ➢ However, for higher voltage applications, multiple layer insulating materials may be employed, or measures are taken to achieve an uniform electric field, promoting uniformity in both axial (tangential) and radial electric field components.



2 Applications of bushings

2.1 Terminations and joints in cable systems



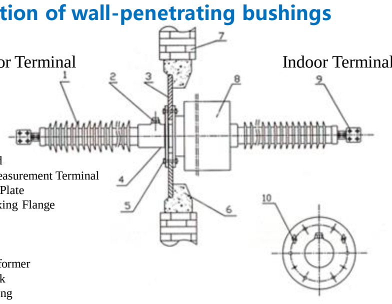
Power cable accessories—terminations

2.2 Bushings for oil-immersed power equipment

- **Equipment:** Transformers, reactors, current transformers, voltage transformers, capacitors……
- **Dielectrics:** Besides **oil-immersed**, there are also bushings used for **dry-type and gas-insulated** applications.

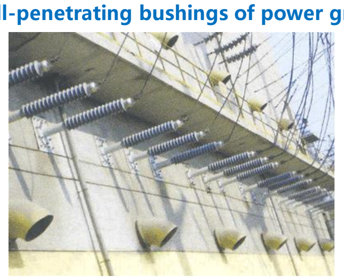
2.3 Wall-penetrating bushings

Installation of wall-penetrating bushings



1. Assistant Shed
2. Grounding Measurement Terminal
3. Wall Bushing Plate
4. Connection/fixing Flange
5. Fixing Bolts
6. Concrete
7. Interval Wall
8. Current Transformer
9. Terminal Block
10. Suspension Ring

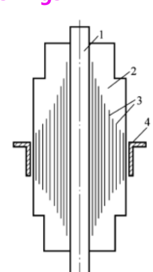
Wall-penetrating bushings of power grid



3 Electric field control structures in bushings

3.1 Capacitive screens

1. Conductor rod/coil
2. Lamination paper layers (oil immersed and/or epoxy impregnation)
3. Voltage uniformization screen (metal foil screen)
4. Connection/fixing Flange

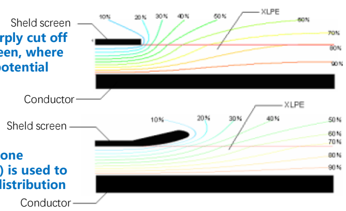


To control the electric field distribution between each gap of the two nearby foils.
Finally, the exponential distribution of the electric field changes to an uniform distribution by the controlled capacitances.

3.2 Electric stress control in prefabricated cable terminations

Geometrical shapes method:

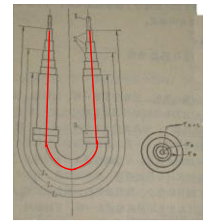
- ✓ Field distortion by the sharply cut off semi-conductor shield screen, where are concentration of equipotential curves
- ✓ A trumpet-shaped stress cone (electric field control cone) is used to uniform the electric field distribution



4 High-voltage current transformers

4.1 Measurement problems of current in HV circuits

- **High voltage isolation**
- **Sudden short-circuit large current**
- **Use current transformers**
- ➢ The primary winding of the current transformer is connected in series with the high-voltage wire carrying the measured current and is at high potential.
- ➢ The secondary winding is connected to measuring instruments.
- ➢ The insulation layer between the primary and secondary windings must withstand long-term operating voltage and short-term overvoltage.



1- primary winding 2-capacitive screen
3- secondary winding and iron core

4.2 Current transformer structure

- Voltage uniform ring
- Primary winding
- Capacitive screen (voltage sharing)
- Secondary winding
- Bushings (with flanges)
- Enclosure
- Low-voltage terminal outlets
- Suspension ring with garter belts

4.3 Structure, principles and photos of current transformer

- **Schematic of capacitive-type current transformer:**
  Reference: Yan Zhang, Zhu Deheng. "High Voltage Insulation." Tsinghua University Press, March 2002, p.237, Figure 8-9.
- **Structure and function of bushings:**
  Reference: "High Voltage Engineering," p.85, Figure 3-4 Various Common Insulators (Including Sleeves and Wall-Penetrating Bushings); p. 86, Figure 3-5 Electric Displacement Lines; p. 89, Figures 3-9 and 3-10 Electric Field Distribution and Equivalent Circuit of Wall-Penetrating Bushings.
- **Capacitive screen structure:**
  Reference: "High Voltage Engineering," p.93.
- **Field strength control cone** (Stress Cone) in Cable Terminations and Connectors:
  Reference: "High Voltage Engineering," p.131.

Searching for these items by yourself!

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Specific Topics: Insulation Structure of High-Voltage Bushings and High-Voltage Current Transformers

THE END!

THAKS!

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High Voltage Engineering

Electrical Properties of Liquid and Solid Dielectrics (3)

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Chapter 4 Electrical properties of liquid and solid dielectrics

4.3.1 Breakdown theory of liquid dielectrics

➢ **Overview**

- **Electrical strength**: Generally higher than gases (air) and has good heat dissipation properties.
- **Current status of breakdown theory**: Far behind gas, lack of perfection.
- **Classification of breakdown mechanism**
  - ◆ The breakdown mechanism of pure liquid dielectrics
    - ◻ Electric breakdown theory
    - ◻ Bubble breakdown theory
  - ◆ (Not pure) breakdown mechanism of liquid dielectrics for engineering applications

4.3.1 Breakdown theory of liquid dielectrics

1. Electric breakdown theory of pure liquid dielectrics

- **Breakdown theory**: Electrons generated in the liquid due to factors such as high field emission are accelerated in the electric field and undergo collision ionization with liquid molecules.
- **Breakdown characteristics**: Similar to the discharge process in long air gaps.

4.3.1 Breakdown theory of liquid dielectrics

2. Bubble breakdown theory of pure liquid dielectrics

- **Causes of Gas Generation in Liquid Dielectrics**

① Electron current heats the liquid, releasing gas.
② Electron collision with liquid molecules.
③ Electrostatic repulsion
  - Microbubbles on the electrode surface accumulate charges.
  - When electrostatic repulsion exceeds the liquid surface tension, the bubble becomes bigger.

④ Corona discharge at electrode bumps induces liquid vaporization.

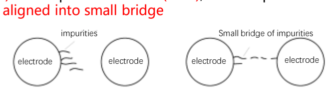
- **Breakdown theory**
  - In series-connected dielectrics, the distribution of electric field is inversely proportional to the dielectric constant. As the dielectric constant of bubbles ($\varepsilon_r = 1$) is lower than that of the liquid (ε_r), bubbles have higher electric field.
  - Since gas has lower electrical strength than liquid, bubbles ionize first. Once ionized bubbles accumulate in the electric field and form a gas channel, breakdown occurs within this channel.

4.3.1 Breakdown theory of liquid dielectrics

3. Small bridge (suspension) breakdown theory of impure liquid dielectrics

✓ **Impurities in oil:** moisture, detached fibers from solid insulation materials (such as paper, cloth), and aging decomposition of the liquid itself.

✓ **Formation of small bridge:** impurities orient in the electric field, and gradually arrange themselves into "small bridge" along the direction of the electric field/force lines. Due to the significantly higher dielectric constants of water (81) and fibers (6-7) as compared to the oil (~2.8), these impurities are easily polarized and aligned into small bridge

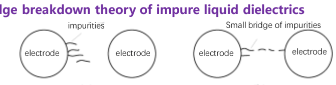


"Small Bridge" not formed "Small Bridge" Formed

Schematic diagram for the orientation of wet fibers between electrodes

4.3.1 Breakdown theory of liquid dielectrics

3. Small bridge breakdown theory of impure liquid dielectrics



"Small Bridge" not formed "Small Bridge" Formed

Schematic diagram for the orientation of wet fibers between electrodes

✓ **Small Bridge Heating:** Fibers and moisture forming the small bridge have high electrical conductivity, leading to an increase in leakage current and intense heating of the small bridge.

✓ **Small Bridge Penetration:** As a result of heating, localized boiling and vaporization of oil and water occur, ultimately leading to breakdown along this vapor bridge.

Impurities in oil - Polarization forming a small bridge - Small bridge heating - Vaporization - Penetration of vapor bridge

Special topic: Small bridge breakdown test of liquid dielectrics

✓ **Characteristics of Small Bridge Breakdown**

- **Significant influence of impurities**
- **Closely connected to the thermal process**
- **Related to the shape of electrodes and uniformity of the electric field; difficult to form a small bridge when the electric field is extremely non-uniform due to disturbances**
- **Difficult to form small bridge in long gaps, but the distortion of the electric field by small bridge leads to a reduction in breakdown voltage**
- **Formation of small bridge is influenced by applied pressure, time, and voltage type; longer applied voltage time more easily form a small bridge**
- **Insufficient time to form the small bridge under impulse voltage**
- **Large dispersion in breakdown voltage for engineering liquid dielectrics: the formation of impurity small bridges is statistical**

Overall, the breakdown theory of liquid dielectrics is still not mature. Theoretically, small bridge breakdown can explain some breakdown patterns, but in practical engineering, it primarily relies on experimental data.

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The causes of small bridge breakdown

- A Polarization, heating
- B Vaporization, gas production
- C Oil disturbance
- D Fast changes of pulse voltage

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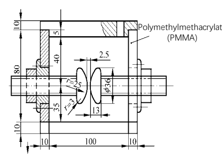
4.3.2 Factors affecting the breakdown voltage of the liquid dielectrics



Standard oil cup for test of liquid dielectric breakdown voltage

✓ Standard oil cup: GB / T 507

✓ Characterization of oil quality

By power frequency breakdown voltage, not by breakdown field strength

✓ Electrode: spherical or hemispherical

✓ Gap: 2.5 mm

✓ Breakdown voltage: only characterize the quality, not the calculation basis

Transformer oil: greater than 25 kV~40 kV

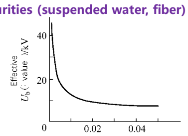
Capacitor oil and cable oil: greater than 50 kV~60 kV

UHV transformer oil: greater than 70kV

In engineering, the breakdown performance of liquid dielectrics is not characterized by electrical strength. The performance is characterized by the quality.

4.3.2 Factors affecting the breakdown voltage of the liquid dielectrics

1. Impurities (suspended water, fiber)



The Relationship between AC Breakdown Voltage and Water Content in Transformer Oil

No impact on withstand voltage | Great impact on withstand voltage

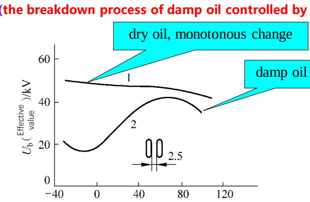
✓ **Impact:** A water content of a few parts per million (ppm) significantly reduce U_{break}.

✓ **Role of Oil Purity**

- Higher purity: The more uniform the electric field, the higher the DC and power frequency breakdown voltage.
- Lower-quality: The aggregation and arrangement of impurities distorts the electric field, and the uniformity of the electric field does not significantly increase the U_{break}.

4.3.2 Factors affecting the breakdown voltage of the liquid dielectrics

2. Temperature (the breakdown process of damp oil controlled by temperature)

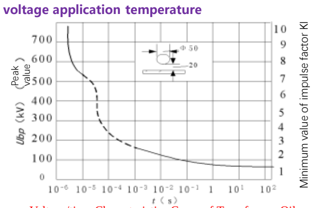


Relationship between power frequency breakdown voltage and temperature of transformer oil in standard oil cup

1-dry oil; 2-damp oil

4.3.2 Factors affecting the breakdown voltage of the liquid dielectrics

3. Duration of voltage application temperature



Voltage/time Characteristics Curve of Transformer Oil in Slightly Non-uniform Electric Field

✓ Under impulse voltage: Small bridge do not have time to form, and an uniform electric field can increase the breakdown voltage.

4.3.2 Factors affecting the breakdown voltage of the liquid dielectrics

4. The uniformity degree of electric field

✓ **Dispersion of breakdown voltage of liquid dielectrics**

- Related to the uniformity of the electric field. As the non-uniformity of the electric field increases, the dispersion of the breakdown voltage decreases.
- The dispersion of AC breakdown voltage in an extremely non-uniform electric field often does not exceed 5%.
- However, in an uniform electric field, it can reach 30 to 40%.

4.3.2 Factors affecting the breakdown voltage of the liquid dielectrics

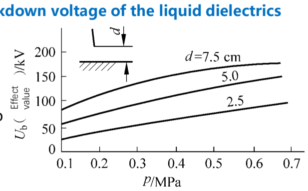
5. Pressure

✓ **Effect of dielectric quality**

- For engineering liquid dielectrics, the breakdown is affected by the pressure due to the presence of air bubbles
- no obvious effect for very pure liquid

✓ **Under impulse voltage**

- no impact



Relationship between power frequency breakdown voltage and pressure of transformer oil (engineering dielectric)

4.3.3 Methods for increasing breakdown voltage of liquid dielectrics

➢ **Countermeasures**

- Make the electric field as uniform as possible under impulse voltage.
- Improve the quality of insulating oil when voltage is applied for a long time.

1. Enhance and maintain oil quality

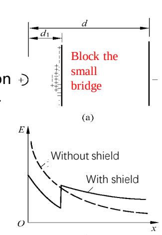
- paper filtration, heat vacuum spray oil filter machines.
- adsorbent filters: natural hydrated aluminum silicate, silica gel, activated alumina, soda fluorite. Maintain quality during operation

4.3.3 Methods for increasing breakdown voltage of liquid dielectrics

➢ **Countermeasures**

Block the small bridge

2. Covering layer: A solid insulation layer closely adhering to the metal electrode (<1 mm).
3. Insulation layer: A thicker insulation layer coated on the electrode surface (around several tens of mm).
4. Barrier: A solid insulation plate placed between electrodes (can also uniform the electric field)
5. Improve electric field distribution: when surface discharge or sliding spark discharge happen

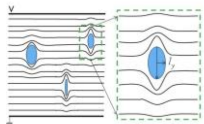


Chapter 4 Electrical properties of liquid and solid dielectrics

4.4 Breakdown of solid dielectrics

Electrical strength characteristics of three-state dielectrics

- **General principles of dielectric breakdown (weak point breakdown)**
  - Dielectric breakdown always occurs at the electrical weak points, e.g., dielectric defects or point with strong electric field.
  - Defects can refer to impurities and structural irregularities in dielectric materials, which usually lead to electric field enhancement or non-uniformity.
- **Breakdown characteristics of three-state dielectrics**
  - Generally, among the three states, solid insulators have the highest density and also the highest electrical strength.
  - The breakdown processes in solid dielectrics are rather complex, not well understood!
  - Unlike gas or liquid dielectrics, the solid dielectric is not self-healing after the occurrence of breakdown events.



Dielectric defect and field distortion

- **Electrical strength of three-state dielectrics**
- Gas (air): 3 kV/mm ~ 4 kV/mm

Sulfur hexafluoride
Freon
Carbon Tetrachloride

- Relative electrical strength of other gases (compared to air)

Gas type	N_2	SF_6	CCl_2F_2	CCl_4
Electrical strength	1	2.3～2.5	2.4～2.6	6.3
liquefaction T (1 atm, ℃)	-195.8	-63.8	-28	76

- Liquid: 10kV/mm ~ 20 kV/mm
- Solid: 10s kV/mm ~ 100s kV/mm.

The electric strength of solid is the strongest!

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Which gas is suitable as a electrical insulation medium for sealed gas-insulated electrical equipment (e.g., GIS)?

A CCl_4

B CCl_2F_2

C SF_6

D N_2

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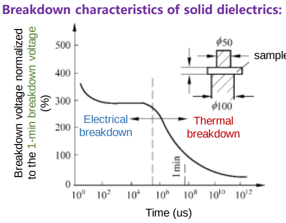
4.4.1 Breakdown process of solid dielectrics

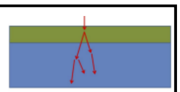
1. Breakdown characteristics of solid dielectrics: electrical, thermal, aging effects



Breakdown voltage (oil-Immersed paperboard) scaling with the voltage duration

- ✓ Electrical breakdown
  time scale: < 0.2 s
- ✓ Thermal breakdown
  time scale: > 0.2 s
- ✓ Electrochemical breakdown (aging effects)
  time scale: tens of hours

4.4.1 Breakdown processes of solid dielectrics



2. Electrical breakdown

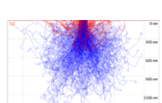
✓ **Establishment of the electrical breakdown theory:**

The breakdown theory is based on the collisional ionization in solid dielectrics. A small number of charge carrier (free electrons) exist in solid dielectrics, which undergo ionization collisions with atoms (lattice nodes) under the electric field, lead to the electrical breakdown.

✓ **Electron energy balance equation with respect to electrical breakdown:**

$$A(E,\alpha,T_0)=B(\alpha,T_0)$$

$A(E,\alpha,T_0)$: Electron energy gain per unit time under the electric field;
$B(\alpha,T_0)$: Electron energy loss per unit time due to collisions;
E: Electric field;
α: Factor denotes the electron state;
T_0: Lattice temperature.



4.4.1 Breakdown process of solid dielectrics

2. Electrical breakdown

✓ **Classification of electric breakdown theories:** **two interpretations of collision ionization**

$$A(E,\alpha,T_0)=B(\alpha,T_0)$$

Intrinsic breakdown theory:

Within a certain electric field, the energy balance equation holds as expressed;
however, for higher electric fields, destructions of the dielectric material can occur, determining the breakdown threshold.

Electron avalanche breakdown theory:

When the electron energy balance is broken, electrons are accelerated, which collide with the crystal lattice and cause ionization; then new electrons collide with atoms, forming an electron avalanche;
Under a stronger electric field, the electron energy can rise abruptly, resulting in the destruction of the dielectric structure, which is called electron avalanche breakdown theory.

4.4.1 Breakdown process of solid dielectrics

2. Electrical breakdown

✓ **Characteristics and Influential Factors of Electrical Breakdown**

- **Voltage duration:** a shorter duration of applied voltage usually results in a higher breakdown voltage.
- **Electric field uniformity:** local strong field has a significant impact on breakdown.
- **Dielectric properties:** if there are gas voids or defects in the dielectrics, the electric field will be distorted and the local enhancement of the electric field can reduce the breakdown voltage of the dielectrics.
- **Cumulative effects:**
  - ➢ Under highly non-uniform electric field or impulse voltage condition, the dielectric may experience a partial breakdown many times.
  - ➢ The breakdown voltage of dielectrics would decrease as the number of the externally applied voltage impulse increases.

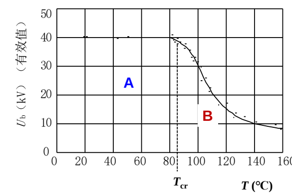
✓ **Note: irrelevant factors!** Once the electrical breakdown occurs, the breakdown voltage does not depend on the dielectric temperature, cooling condition, voltage frequency, etc.

4.4.1 Breakdown process of solid dielectrics

3. Thermal breakdown (Breakdown voltage is a function of dielectric temperature)

✓ **Range A -** Electric breakdown: U_b is not affected by T

✓ **Range B -** Thermal breakdown: U_b decreases as T increases



Breakdown voltage scaling with the dielectric (ceramic) temperature under AC voltage conditions

4.4.1 Breakdown process of solid dielectrics

3. Thermal breakdown

✓ **Physical processes during thermal breakdown:**

- Due to the dielectric loss, solid dielectrics under electric field are gradually heated up. Then, an increase in temperature leads to a decrease in the resistance of solid dielectric and the conducting current increases. Therefore, the dielectric loss and heat generation will be further enhanced.
- As the temperature of the dielectric continues increases, a continuous process of heat dissipation also occurs, which transports the dielectric heat through electrodes to the environments or surroundings. The heat accumulation and heat dissipation compete with each other.
- If, under a specific condition, the heat generation exceeds the heat dissipation, the temperature of the dielectrics will keep rising. This could cause the decomposition and carbonization of the dielectric, which ultimately leads to the thermal breakdown.

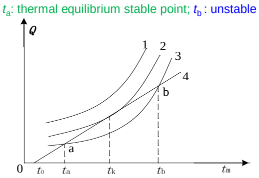
4.4.1 Breakdown process of solid dielectrics

3. Thermal breakdown

✓ **Analysis of the Thermal Breakdown Process:**

- The heating curves 1, 2, and 3 correspond to voltages $U_1 > U_2 > U_3$
- Line 4: heat dissipation Q as a function of the material temperature t_m

✓ t_a: thermal equilibrium stable point; t_b: unstable point



Heat generation and heat dissipation scaling with the material temperature under different external voltages

- **Question: will the thermal breakdown voltage can be increased by using thicker dielectrics?**
- **Not a good idea!** When the thermal breakdown occurs, using a thicker insulator often cannot improve the breakdown voltage since the heat dissipation might not be effective. Also, it is more expensive!

4.4.1 Breakdown process of solid dielectrics

4. Electrochemical breakdown (electrical aging)

✓ **Basic concept:** For dielectrics placed in electric field for a long-term, their physical and chemical properties gradually deteriorate **irreversibly**, eventually resulting in a breakdown.

✓ **Four types of electro (chemical) aging:**

a) **Conductivity aging (water treeing)**
b) **Ionization aging (electrical treeing)**
c) **Electrolytic aging:** happen in ionic inorganic insulation materials under DC voltage
d) **Surface tracking and corrosion:** insulation damage phenomenon on the surface of organic dielectrics (special aging)

◻ **Tree aging** is a widespread form of insulation failure of organic solid dielectrics. The electric field threshold for the water treeing is much lower than the electrical treeing.

Tracking and erosion resistance

?

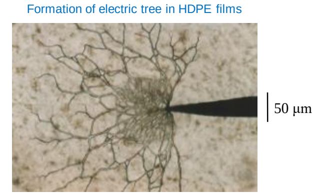
Electro-chemical aging

4.4.1 Breakdown process of solid dielectrics

4. Electrochemical breakdown (electrical aging)

Electric tree in dielectrics

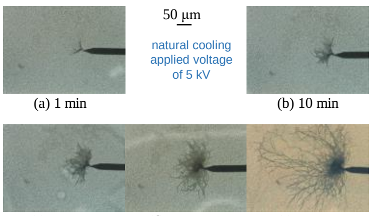
Formation of electric tree in HDPE films



4.4.1 Breakdown process of solid dielectrics

4. Electrochemical breakdown (electrical aging)

➢ Development of electrical tree in HDPE films



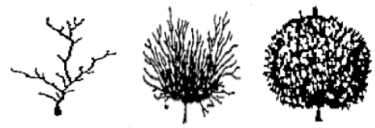
(a) 1 min (b) 10 min

(c) 40 min (d) 70 min (e) 75 min

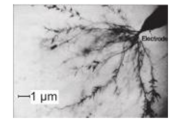
4.4.1 Breakdown process of solid dielectrics

4. Electrochemical breakdown (electrical aging)

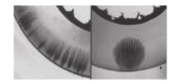
➢ Typical shape of electrical tree (IEEE)



Tree-like Bush-like chestnut-like



Electrical tree



Water tree

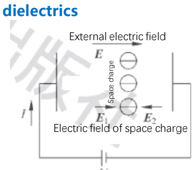
4.4.2 Main factors affecting the breakdown voltage of solid dielectrics

1. Voltage duration: $t_d \uparrow \Rightarrow U_b \downarrow$
2. Dielectric temperature: $T_m \uparrow \Rightarrow U_b \downarrow$
3. Electric field uniformity: field nonuniformity $\uparrow \Rightarrow U_b \downarrow$
4. Voltage waveforms: impulse>ac, dc>ac>high frequency
5. Partial discharges: partial discharge$\uparrow \Rightarrow U_b \downarrow$
6. Cumulative effects (unique properties of solids): partial destruction $\uparrow \Rightarrow U_b \downarrow$
7. Moisture Ingress: conductivity, water treeing $\uparrow \Rightarrow U_b \downarrow$
8. Mechanical Load: cracking, gas voids, mechanical defects $\Rightarrow U_b \downarrow$

Others, secondary effects include material uniformity, impurities, space charge, etc.

Chapter 4 Electrical properties of liquid and solid dielectrics

4.5 Space charge in dielectrics



Schematic Diagram of Space Charge Distribution in Dielectrics and Its Influence on Electric Field Distribution

Space charge distorts the internal electric field distribution in the dielectric, leading to a degradation in insulation properties.

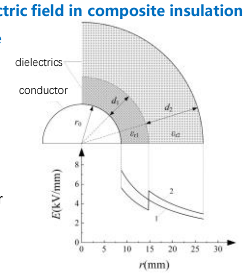
Chapter 4 Electrical properties of liquid and solid dielectrics

4.6.1 Distribution and adjustment of electric field in composite insulation

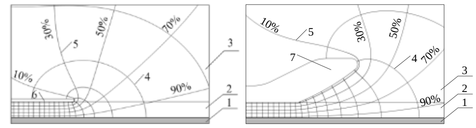
- Electric field distribution and control of simple geometric structures under AC voltage

✓ Using an uniform dielectric, the inner insulation must withstand much higher field strengths than that of the outer insulation. The higher the rated voltage, the thicker the insulation layer, the greater the difference.

✓ If graded insulation is used, the inner layer is made of high-density insulation paper, and ε_{r1} is larger, and the outer layer is made of thicker paper with lower density, and ε_{r2} is smaller. Thus the electric field distribution of every insulation layer is optimized, the field becomes more uniform.



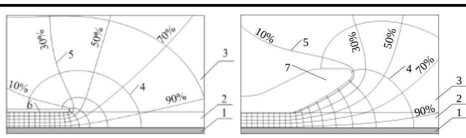
Electric field distribution in a cable



- Electric field distribution and adjustment of the electric field control cone (also called stress cone) under AC voltage

✓ The electric field at the break of the shield screen
  - There are electric field components perpendicular and along the axial/length direction of the cable
  - The electric field component along the length of the cable is concentrated at the break of the shield layer and reaches its maximum, can easily cause insulation breakdown.

✓ In Section 3.3.4, the use of capacitive screens has been introduced.



- Electric field distribution and adjustment of the electric field control cone (also called stress cone) under AC voltage

✓ electric field control cone
  - In practical applications, cable accessories with voltage levels of larger than 110 kV use electric field control cone to improve the electric field distribution of the insulation shield layer at the cable connection.
  - It extends the cutoff of the insulation shield layer to form a trumpet shape on the zero potential surface, improving the electric field distribution of the insulation layer.

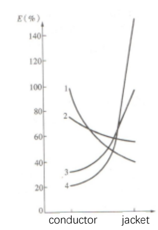
- Electric field distribution in combined insulation under DC voltage

✓ Unlike AC, the electric field distribution is determined by resistivity under DC voltage.

✓ The electric field distribution is affected by the temperature difference between the core and sheath.

✓ Also affected by space charge.

✓ If graded insulation is used, the inner layer is made of low resistivity dielectric and the outer layer is made of high resistivity dielectric.



Steady-state electric field distribution in DC cables under different temperature differences between inside and outside of the insulation layer

1-The wire core temperature is equal to the sheath temperature; 2-The wire core temperature is 5°C higher than the sheath temperature; 3-The wire core temperature is 25°C higher than the sheath temperature; 4-The wire core temperature is 50°C higher than the sheath temperature

Chapter 4 Electrical properties of liquid and solid dielectrics

4.7 Other properties of dielectrics

1. Thermal properties
2. Mechanical properties
3. Moisture absorption properties
4. Chemical properties and antibiological properties

Defects in any kind of the above properties will eventually lead to a significant decrease in electrical properties, and may even fail to serve as an insulating dielectric.

4.7 Other properties of dielectrics

1. Thermal properties

I. Heat resistance

Heat resistance: Maximum allowable temperature to ensure reliable and safe operation of dielectrics

a) Short term heat resistance: The temperature at which dielectric sustains short-term exposure without damage at elevated temperatures.

b) Thermal deterioration and long-term heat resistance
- Thermal degradation: The irreversible change in insulation performance that occurs after long-term exposure to slightly elevated temperatures.
- Lifetime: The time under certain temperature conditions during which the dielectric does not experience thermal damage.
- Long-term heat resistance: The maximum allowable temperature at which the dielectric does not undergo thermal damage over a given lifetime.

4.7 Other properties of dielectrics

1. Thermal Performance

II. Thermal rating (GB 11021)

The degree of thermal aging of the dielectrics mainly depends on the temperature and the time. For this reason, the IEC divides thermal rating according to the maximum continuous operating temperature of the material, such as

Y	A	E	B	F	H	N	R	XXX
90	105	120	130	155	180	200	220	≥ 250℃

a) Temperature rules: A Class exceeds the specified temperature by 8℃, B Class by 10℃, and H Class by 12℃, with a lifetime approximately halved.

b) Economic efficiency and lifetime under operating load
- Optimal economic design of equipment operating load can be based on the insulation thermal rating .
- The lifetime of power equipment is typically defined as 20-25 years.

4.7 Other properties of dielectrics

1. Thermal properties

III. Cold resistance

- Cold resistance is the lowest permissible temperature at which insulation material ensures safe operation at low temperatures.
- Otherwise, solids may become brittle and crack, liquids may solidify, and gases may liquefy.
- Transformer oils coded 10, 25, 40: Solidification temperatures are -10, -25, -40℃, respectively.

投票 最多可选2项 设置

What do you think is a reasonable economic operating life for electrical equipment?

A 25 years

B 50 years

C 100 years

D 30 years

提交

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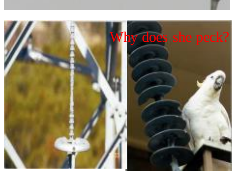
4.7 Other properties of dielectrics

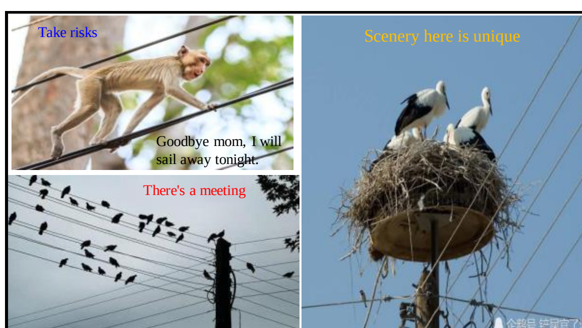
2. Mechanical properties

Three types: brittleness, plasticity, and elasticity.

3. Moisture absorption properties
- Use materials with low moisture absorption and strong hydrophobic properties in humid regions.
- Generally, non-polar dielectrics have low moisture absorption, while polar dielectrics exhibit higher moisture absorption.

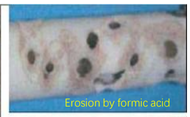
4. Chemical and antibiological properties
- Chemical properties, the chemical stability of materials, such as resistance to corrosive gases, liquid solvents, etc.
- Antibiological properties, ability to resist mold, insects, biological contamination, and withstand attacks and damage from organism. This is particularly crucial in humid and warm regions.





Is it easy for me to eat?

Attacks from rats, termites, etc.



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Brief summary

- ✓ Breakdown of liquid dielectrics
- ✓ Small bridge breakdown in liquid dielectrics
- ✓ Electric breakdown theory of solid dielectrics
- ✓ Thermal breakdown theory of solid dielectrics
- ✓ Electrochemical breakdown theory of solid dielectrics
- ✓ Factors affecting electrical properties such as breakdown voltage of solid dielectrics
- ✓ Space charge in dielectrics
- ✓ Treeing
- ✓ Electric field distribution and control of the combined insulation
- ✓ Thermal rating and cold resistance of materials
- ✓ Concepts of insulation life and economic operation
- ✓ Antibiological

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Electrical Properties of Liquid and Solid Dielectrics (3)

THAKS!

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