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Revision, preview and assignment

Revision: 5.1-5.4

Preview: 5.5-5.7, 6.1, 6.2

Homework: 5-6, 5-8, 5-10, 5-11, 5-12

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清華大学 Tsinghua University

Hybrid: Online teaching live + offline
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High Voltage Engineering-Lecture 9

Insulation Test and Diagnosis (1)

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Specific Topics:

Study on the Measurement of Space Charge Distribution in Solid Dielectrics using the Pulse Electro-acoustic (PEA) Method

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Development of PEA space-charge measurement system

PEA: Pulse Electro-Acoustic Method (abbreviate, PEA)

- **Proposed by Professor Tatsuo Takada from Musashi Institute of Technology in Japan in the 1980s, after two decades of improvement, it has become one of the widely used methods for measuring space charge globally.**

- **Basic Principle:** Utilizing electric pulses to generate mechanical stress at the location of spatial charges in the dielectric. This stress is then converted into an electrical signal by a sensor. Through processing this electrical signal, information about the spatial charge distribution is obtained.

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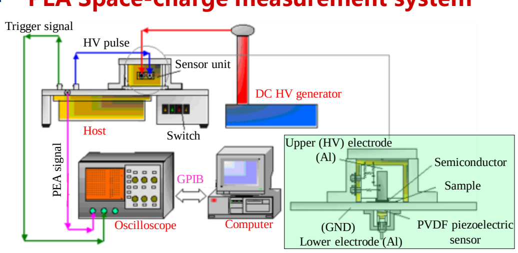
PEA Space-charge measurement system



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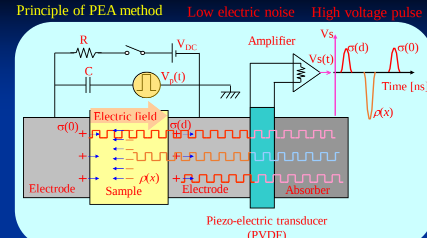

Apply to lab experiment

Un-uniform soldered dot may produce electric noise which greatly influence the measuring process, so as to lead to failure of measurement

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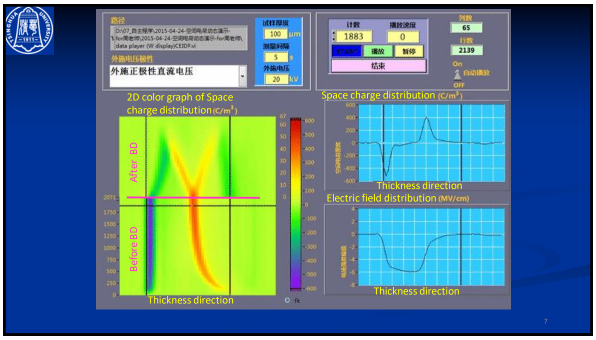

Thank you!

In the early stages of this research, collaborated with Professor Takada from Japan. The program received funding from various sources, including the National Natural Science Foundation of China for Key programs, General programs, and others.

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High Voltage Engineering-Lecture 9

Insulation Test and Diagnosis (1)

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Core concepts of this chapter

Insulation test and monitoring, insulation diagnosis

Voltage withstand test, non-destructive measurement

Insulation resistance, leakage current, tanδ, Schering bridge

Partial discharge, gas chromatography

Supplementary:

Preventive test, 1min power frequency voltage withstand test

External applied voltage withstand test

Induction voltage withstand test

Chapter 5 Insulation test and diagnosis

- 5.1 Basic concepts of insulation test and diagnosis
- 5.2 Measurement of insulation resistance and leakage current
- 5.3 Measurement of dielectric loss tangent
- 5.4 Measurement of partial discharge
- 5.5 Chromatographic analysis of dissolved gases in insulating oil
- 5.6 Voltage withstand test
- 5.7 Characteristics of voltage withstand test and preventive test methods
- 5.8 Insulation on-line test (self-study)

5.1 Basic concepts of insulation test and diagnosis

- **Insulation test and diagnostic techniques**
- **Equipment Faults**
  - ✓ Due to various factors such as electrical, thermal, mechanical, bad environmental conditions, the insulation of equipment undergoes gradual deterioration, leading to defects and eventual failure, resulting in power supply interruptions.
- **Test and Diagnosis (health checkup)**
  - ✓ The technology involves insulation tests and measurements of various performances to know and assess the insulation status of electrical equipment during operation, which enables early detection of faults.
- **Insulation Preventive Test, insulation experiments and tests to judge insulation state**
- **Classification of the techniques**
  - ✓ Based on the **impact on equipment**: Non-destructive, destructive
  - ✓ Based on the **operating state of equipment**: Online, offline

- **Non-destructive test (insulation characteristic test)**
  - **Concept**
    Insulation is tested at low voltage or through methods that do not damage the insulation
  - **Types**
    - ✓ insulation resistance test, dielectric loss tangent test, partial discharge test, gas chromatographic analysis of insulating oil, etc
- **Destructive test (voltage withstand test)**
  - **Concept**
    Insulation is tested at voltage higher than the normal operating voltage
    - ✓ **Characteristic:** strict test can ensure a certain insulation level or margin
    - ✓ **Drawback:** may cause some damage to the insulation
  - **Types**
    - ✓ AC voltage withstand test, DC voltage withstand test
    - ✓ lightning impulse voltage withstand test, switching impulse voltage withstand test

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投票 最多可选1项 设置

Which test do you think should be done first, the destructive test or the non-destructive test?

- A The destructive test first
- B The non-destructive test first
- C Both tests are ok
- D It depends on the situation

提交

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5.1 Basic concepts of insulation test and diagnosis

- **Offline**
  - **Concept**
    - ✓ equipment which is taken out of the operating state for the test
  - **Characteristics**
    - ✓ Usually applied periodically and intermittently, with the test cycle specified by the preventive test regulations for electrical equipment (DL/T 596).
    - ✓ Both destructive and non-destructive tests can be employed, complementing each other. Non-destructive tests first and then voltage withstand tests.
  - **Drawbacks:**
    - ✓ The judgement for the withstand level is relatively indirect, especially for periodic offline tests, more difficult to accurately judge the insulation level.

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5.1 Basic concepts of insulation test and diagnosis

- **Online**
  - **Concept**
    - ✓ The tested equipment is in operating
    - ✓ Monitor the insulation status continuously or periodically
  - **Characteristics**
    - ✓ Usually automatic
    - ✓ Only non-destructive test methods
    - ✓ Continuous monitoring can not only measure the numerical value of the insulation properties, but also can analyze the trend of performance over time, significantly improving judgment accuracy.

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5.1 Basic concepts of insulation test and diagnosis

- **Three basic procedures of insulation test and diagnosis**
  - **Sensors and measurement methods**
    Correctly select sensors and methods to monitor various characteristics and collect parameters.
  - **Data processing**
    Analyze and process the original messy information, remove interference, and extract the most sensitive and effective characteristic parameters that reflect the insulation status.
  - **Insulation diagnosis**
    - ✓ Based on the extracted characteristic parameters, knowledge of insulation aging processes, and operational experience, referring to relevant regulations to identify and judge the insulation status of operating equipment.
    - ✓ Predict the development trend of insulation status to provide early warning for faults and provide technical basis for decision-making of next maintenance.

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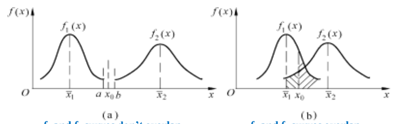
- **Insulation diagnosis rules**
  - **Diagnosis Classification:** logical diagnosis, fuzzy diagnosis, statistical diagnosis
  - **Logical diagnosis (binary logic)**
    - ✓ **Feature judged as** "yes/no". If the feature parameter is greater than a given threshold, then the feature is "yes", otherwise it is "no".
    - ✓ **State judged as** "yes/no, good/bad". Both of the two judgements are described by binary logical quantities.
    - ✓ **Characteristics:** Clear and simple, widely applicable, but oversimplifies problems, leading to lower diagnostic accuracy.
  - **Fuzzy diagnosis**
    - ✓ **Multi-value Logic:** Features and states of the tested object are described by multi-value logic feature functions. Then classified into a certain category according to the parameters.
      - a feature may be "very strong", "strong", "" general "," "weak", "very weak"
      - a fault may be "very serious", "serious", "general", "slight", "no", etc.
    - ✓ **Characteristics:** if Use continuous feature functions, we may obtain more accurate judgments.

- **Statistical diagnosis**
  - ✓ Consider the uncertainty in the distribution of characteristic parameters, that is statistical.
  - ✓ For similar equipment in the same state, their characteristic parameters may vary, following certain statistical distribution patterns. Use these patterns for insulation diagnosis.

In the **figure** below, $f_1(x)$ and $f_2(x)$ represent probability density curves for a certain parameter x of good and damaged insulation, respectively.



f_1 and f_2 curves don't overlap f_1 and f_2 curves overlap

The accuracy of insulation diagnosis increases with the addition of more types of characteristic parameters.

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Chapter 5 Insulation test and diagnosis

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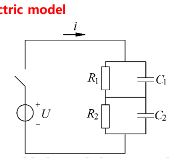
5.2.1 Principles of measuring insulation resistance and absorptance

- **Current-time characteristics of double-layer dielectric model**

  - **Absorption current**

$$i(t) = A + B\exp(-t/\tau)$$



Double layer dielectric model

✓**In the formula**

$$\tau = R_1R_2(C_1+C_2)/(R_1+R_2)$$
$$A=[U/(R_1+R_2)]$$
$$B=U(R_1C_1-R_2C_2)^2/[(C_1+C_2)^2(R_1+R_2)R_1R_2]$$

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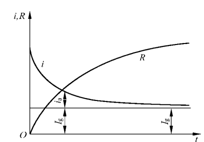

Absorption and leakage current and insulation resistance curves

$$\boxed{i(t) = A + B\exp(-t/\tau)}$$

- **Insulation resistance:** the U/i value measured under DC voltage
- **Engineering application:** U/i of the dielectric absorption process is also called insulation resistance

- **Absorptance ratio K:** the ratio of insulation resistance $R_{60''}$ and $R_{15''}$

$$K = R_{60''}/R_{15''}$$

- **Polarization Index P:** the ratio of insulation resistance $R_{10'}$ and $R_{1'}$

$$P = R_{10'}/R_{1'}$$

- *Note:* $R_{15''}$, $R_{60''}$, $R_{1'}$ and $R_{10'}$ are the resistance measured after applying voltage for 15 seconds, 60 seconds, 1 minute and 10 minutes.

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单选题 1分   设置

Which of the following insulation is good insulation?

A The absorptance ratio is close to 1, and the polarization index is close to 1

B The absorptance ratio is much greater than 1, and the polarization index is much greater than 1

C The absorptance ratio is much greater than 1, and the polarization index is close to 1

D The absorptance ratio is close to 1, and the polarization index is much greater than 1

提交

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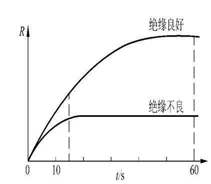
- **Insulation diagnosis based on insulation resistance**
  - If there is a concentrated conductive channel inside the insulation, or the insulation is severely affected by moisture,
    - the resistances R_1 and R_2 will be significantly reduced,
    - the leakage current will be greatly increased,
    - time constant τ will decrease greatly, and the absorption current will decay rapidly.
  - Even if the insulation partly gets damp, as long as one of the values of R_1 and R_2 decreases,
    - the τ value will be greatly reduced,
    - the absorption current will still decay rapidly,
    - still cause the absorptance ratio K or the polarization index P to decrease.
  - When K=1 or approaches 1, the equipment essentially loses its insulation capability.



Insulation resistance variation curve under different insulation states

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● **Criteria for judging the insulation state of equipment**

➢ **Judgment basis:** Power industry standard DL/T596 "Preventive Test Procedures for Electric Power Equipment"

➢ **Judgment criteria**

✓ **Power transformer and large generator with asphalt dipping and rolled mica insulation:**

- The K value shall not be less than 1.3
- The P value shall not be less than 1.5

✓ **Large generator with epoxy powder mica insulation:**

- The K value shall not be less than 1.6
- The P shall not be less than 2.0

➢ **Suggestion:** It is recommended to measure the P value for generator capacity of 200MW or above.

5.2.2 Method for measuring insulation resistance and absorptance

● **Measurement instrument:** generally use megohmmeter with high sensitivity

● **Megohmmeter Voltage Options:** 500V, 1000V, 2500V, 5000V, etc.

● **Types of Megohmmeters (meggers)**

➢ Tramegger: still commonly used on-site with hand-cranked DC generator

➢ Transistor megohmmeter: using battery power supply, transistor oscillator generates alternating voltage, and output DC voltage after transformer boost and double voltage rectification

● **Megohmmeter selection,** based on the equipment's voltage level

➢ 1000V megohehmmeter for rated voltage of 3kV and below

➢ 2500V for those above 3kV

Measure the insulation resistance of cables with megger

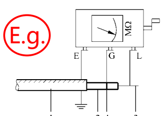
➢ Speed: 120 r/min

➢ Time to get data: 15 s and 60 s

➢ Drawback: manpower is hard to maintain for a long time

➢ Solution: use transistor megohmmeter

E.g.



Wiring diagram for measuring cable insulation resistance with megger
1-Lead sheath 2-Insulation
3-Conductor 4-Shield

● Pay attention to temperature

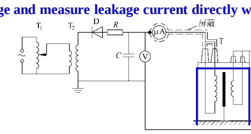
➢ Insulation resistance will change due to factors such as temperature

➢ Record ambient temperature and the temperature of the insulator (equipment) when measuring

➢ Pay attention to longitudinal and horizontal comparisons

5.2.2 Leakage current measurement

●Apply DC voltage and measure leakage current directly with a microampere meter



Wiring diagram for measuring main insulation leakage current of power transformer
T1 - Voltage regulator; T2 - High voltage test transformer; D - High voltage silicon stack
R——Protective resistor; C——Filter capacitor; T——Tested transformer

Winding nominal voltage /kV	3	6~10	20~35	66~330	500
DC Test Voltage /kV	5	10	20	40	60

The test voltage applied is higher than the voltage used in the insulation resistance test: it better reflects the actual status of the insulation.

Chapter 5 Insulation test and diagnosis

● **Test radio materials:**

Commonly use the method of applying high frequency voltage, but the voltage amplitude is not high.

● **In the field of electrical engineering:**

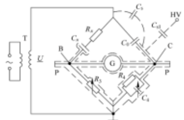
There are many instruments and methods for measuring $\tan\delta$ (Schering bridge and current comparison type bridge , etc.)

● **Online monitoring:**

Use microcomputers for $\tan\delta$ measurement.

5.3.1 Basic principles of Schering bridge

- **High Voltage Arm:**
  - ✓ The test sample is denoted as Z_1.
  - ✓ The lossless standard capacitor C_0 is represented by impedance Z_2.
- **Low Voltage Arm:**
  - ✓ Inside the bridge box
  - ✓ Adjustable non-inductive resistor R_3 is denoted as Z_3.
  - ✓ Non-inductive resistor R_4 and adjustable capacitor C_4 are in parallel, represented by Z_4.
- **Protection:** Discharge tube P
- **Bridge Balance:** Galvanometer G, zero-detection
- **Shield**
  - ✓ Eliminate the effects of stray capacitance
  - ✓ Anti-electromagnetic interference.



Circuit of Schering bridge

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主观题 10分 设置

How to manufacture a non-inductive resistor using resistive wire?

正常使用主观题需2.0以上版本雨课堂

作答

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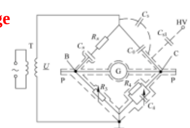
- **Balance Condition of Schering bridge**
  - ✓ $Z_1/Z_3 = Z_2/Z_4$
- **Series equivalent circuit**
  - ✓ $\tan\delta=\omega R_4 C_4$
  - ✓ $Cx = R_4C_0/R_3$
- **Parallel equivalent circuit**
  - ✓ $\tan\delta=\omega R_4 C_4$
  - ✓ $Cx = R_4C_0/[R_3(1+\tan^2\delta)]$
- **Cx are equal in both circuits**
  $\tan^2\delta$ is extremely small

Therefore, Cx are equal in both circuits



Circuit of Schering bridge

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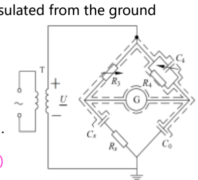
5.3.2 Reverse connection of Schering bridge

- **In laboratory**
  - ✓ Test materials and small equipment, which can be insulated from the ground
- **In field experiments**
  - ✓ Many test specimens with one end grounded, such as underground cables or large electrical equipment placed on the ground
  - ✓ It is impossible to disconnect the specimens with ground, the grounding point of the low voltage arm mentioned has to be changed and connected to HV .
  - ✓ This creates reverse-connection of Schering bridge. (the human body is directly exposed to high voltage)



Reverse wiring of Schering bridge

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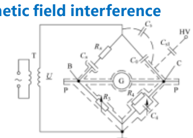
5.3.3 Measurement under external electromagnetic field interference

1. **Under external electric field interference**

- **On-site specimens:** difficult to achieve shielding, so the interference is serious
- **Measure twice:** eliminate or reduce the influence
  - ✓ First time, adjust the bridge to balance and measure $\tan\delta_1$ and Cx'.
  - ✓ Next, the test transformer's primary power supply leads are reversed, changing the phase of the test voltage by 180°.
  - ✓ Then measure the second value $\tan\delta_2$ and Cx''.
  - ✓ Accurate $\tan\delta$ and Cx values can be calculated

$\tan\delta=(Cx'\tan\delta_1 + Cx''\tan\delta_2)/(Cx' + Cx'')$

$Cx=(Cx' + Cx'')/2$



Circuit of Schering bridge

- **Strong electric field interference**
  - ✓ $-\delta$ may appear
  - ✓ To balance the bridge, C_4 must be disconnected from R_4 and connected in parallel with R_3.

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5.3.3 Measurement under external electromagnetic field interference

1. **Under external magnetic field interference**

- **Sources:** Bus reactors, communication filters and other equipment with large magnetic flux leakage near the field test can cause induced electromotive force and induced circulating current in the bridge circuit.
- **Loop magnetic interference:** Since the impedance of the specimens and standard capacitor is very large at power frequency, the error caused is not large.
- **Galvanometer:** well shielded, but also susceptible to interference
- **Measure twice:** swap the wiring at both ends of the galvanometer

✓**Normal wired:** $\tan\delta_1=\omega(C_4+\triangle C_4)R_4$, $C_{x_1}=C_0R_4/(R_3+\triangle R_3)$

✓**Reverse wired:** $\tan\delta_2=\omega(C_4-\triangle C_4)R_4$, $C_{x_2}=C_0R_4/(R_3-\triangle R_3)$

✓**No interference:** $tg\delta=\omega C_4R_4$, $C_x=C_0R_4/R_3$

Thus, $\tan\delta=(\tan\delta_1+\tan\delta_2)/2$

$C_x=2C_{x_1}C_{x_2}/(C_{x_1}+C_{x_2})$

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Chapter 5 Insulation test and diagnosis

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5.4.1 Basic concepts of partial discharge

- **Partial Discharge, PD**

The phenomenon of partial breakdown and discharge extinguished repeatedly occurs due to weaknesses in the insulation of electrical equipment uder a certain external applied voltage.




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Do you agree that corona discharge is also a partial discharge phenomenon?

- A Agree
- B Disagree

提交

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- **Harm of partial discharge**

➢ Partial discharge occurs within one or several small gaps or bubbles inside the insulation, where the electric field is large.

➢ The discharge energy is very small , thus it does not affect the short-term insulation strength of electrical equipment.

➢ Partial discharge phenomenon exists for a long time in electrical equipment under operating voltage.

- The weak discharge energy and undesirable effects produced by partial discharge, such as the production of undesirable compounds, will slowly damage the insulation.
- Over a long period, the entire insulation may eventually be broken down, causing sudden failure of electrical equipment.

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5.4.2 Methods for measuring partial discharge

- **The phenomenon of partial discharge inside dielectrics**

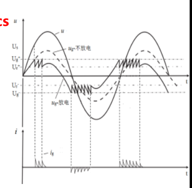
➢ **Electromagnetic phenomena**
- ✓ the generation of electric pulse
- ✓ the increase of dielectric loss
- ✓ electromagnetic wave radiation

➢ **Non-electrical phenomena**
- ✓ light, heat, noise, gas pressure changes
- ✓ chemical changes, etc.

- **Detection of a partial discharge**

➢ Both electromagnetic and non-electric phenomena can be used to determine the presence of partial discharge.

➢ The detection methods derived from these phenomena can be classified into electric and non-electric categories.



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5.4.2 Methods for measuring partial discharge

- **Several common methods of measuring partial discharge**

1. **Pulse current method**
   - Measures the pulse current generated by PD to determine the degree of PD.
   - Quantitative indicators can be obtained, and have been stipulated in the procedures.
2. **Ultrasonic detection method**
   - An ultrasonic detector composed of piezoelectric elements and preamplifier is placed on the outer wall of the electrical equipment.
   - Detect ultrasonic waves caused by PD, providing information on the occurrence, approximate intensity, and location of PD.
3. **Gas chromatography analysis of insulating oil**
   - Determine the presence of hidden defects within electrical equipment by analyzing the gas composition in oil samples.

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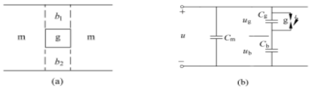
5.4.3 Pulse current method for parital discharge

●Three-capacitor model for PD

➢ **Concept: Use three capacitors to represent the mechanism of partial discharge when there are defects inside the dielectric.**



Dielectric profile with gap　　Equivalent circuit

Three-capacitor model of air gap discharge inside the dielectric.

Model parameters

- ✓ C_g: Capacitance of gap
- ✓ C_b: Capacitance of the dielectric in series with C_g
- ✓ C_m: Capacitance of the remaining majority of the insulation

➢ Gaps are very small, then

- C_g much larger than C_b
- C_m significantly larger than C_g

➢ When AC voltage u is applied between the electrodes, the voltage on C_g is u_g

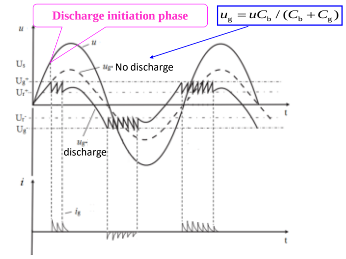
u_g is in reverse ratio to the capacitance

$$\boxed{u_g = uC_b/(C_b + C_g)}$$

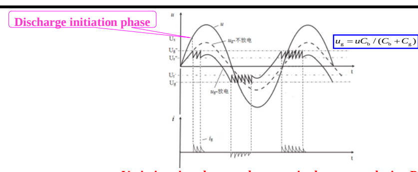
●PD processes

➢ Gas gap discharge → Discharge extinction → Residual voltage→Repeat of discharge and extinction

➢ Along with the sound, light and electrical signals, the dielectric is decomposed and various gases are produced.



Variations in voltage and current in the gas gap during PD



Variations in voltage and current in the gas gap during PD

- **Characteristic Parameters of PD**
- ➢ **Repetition rate of PD N: the number of pulses generated in one second, can be obtained experimentally**

  Calculation N: Assuming the number of discharges in each half-cycle is n, then $N = 2fn = 100n$
- ➢ **Discharge Charge (charge of PD)**
  - ✓ **Real charge**
  - ✓ **Apparent charge**

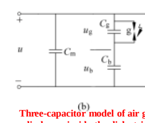
➢ **Calculation the charge of PD**

✓ **Total Discharge Capacitance:** When Cg discharges, the total discharge capacitance Cg' should be

$$C_g' = C_g + [C_m C_b/(C_m + C_b)]$$

✓ **Real charge $\triangle q_r$:** the voltage change across C_g' is (U_g - U_r), thus the charge in a single pulse $\triangle q_r$ should be

$$\boxed{\Delta q_r = (U_g - U_r)[C_g + C_m C_b/(C_m + C_b)]}$$



Three-capacitor model of air gap discharge inside the dielectric.

- **While $C_m >> C_b$, $C_g >> C_b$, $U_r = 0$, $\triangle q_r \approx U_g C_g$**
- **Δq_r can't be measured:** all parameters in the formula cannot be measured in actual tests.
- **It is necessary to seek other parameters that can reflect PD to measure**
- The externally applied voltage acts on C_m, when the voltage on C_g changes (U_g-U_r), the change in the externally applied voltage (that is, the voltage on the capacitor C_m) should be $\triangle U$.

$$\Delta U = C_b(U_g - U_r)/(C_m + C_b)$$

- Obtain the voltage change on C_m from $\triangle q_r$ and $\triangle U$　$\Delta U = C_b \cdot \Delta q_r/(C_g C_m + C_g C_b + C_m C_b)$
- ✓ **The charge change in C_m (Apparent charge)**　$\Delta q = \Delta U\{C_m + [C_b C_q/(C_b + C_q)]\}$
- **Substitute $\triangle U$ into $\triangle q$, we can get**　$\Delta q = \Delta q_r \cdot C_b/(C_g + C_b)$

$\triangle q$ is much smaller than $\triangle q_r$

➢ **Real discharge**

✓ **Concept:** $\triangle q_r$ is the actual discharge that occurs at the defect.

✓ **Characteristic: Unmeasurable**

➢ **Apparent discharge**

✓ **Concept:** $\triangle q$ reflects the discharge occurring at the defect indirectly from the external perspective.

✓ **Characteristic**

- All the quantities in the expression can be measured, and $\triangle q$ can also be measured.
- It is an important parameter in partial discharge tests.
- In international and national standards, the allowable values of apparent discharge $\triangle q$ of various high-voltage equipment are stipulated.
- From the relationship between $\triangle q$ and $\triangle q_r$,we know that $\triangle q$ is is much smaller than $\triangle q_r$

✓ **Unit:** pC

➢ **Discharge energy**

Basic parameters for PD, not only apparent discharge $\triangle q$, but also the energy of a single pulse discharge W.

$$W = \frac{\Delta q_r(U_g - U_r)}{2} = \frac{\Delta q(C_g + C_b)(U_g - U_r)}{2C_b}$$

➢ **discharge inception voltage (U_s)**

When the externally applied voltage rises from zero to U_s, the voltage across C_g is U_g, i.e.,

$$U_g = \frac{U_s C_b}{(C_g + C_b)} \Rightarrow W = \frac{\Delta q \cdot U_s(U_g - U_r)}{2U_g}$$

✓ **If $U_r \approx 0$, then**　$W \approx \frac{\Delta q \cdot U_s}{2}$

投票 最多可选1项 设置

Partial discharge levels increase with increasing voltage.

- A Agree
- B Disagree

提交

➢Alternative Parameters of Partial Discharge

In order to characterize the average comprehensive effects of PD over a certain period, various cumulative parameters have been proposed, including:

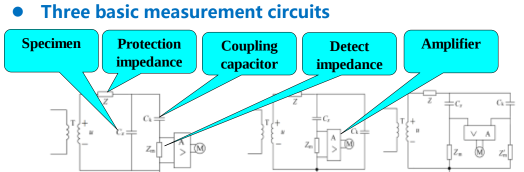
- ✓**Average discharge current**
- ✓**Discharge power**
- ✓**Discharge initiation voltage**
- ✓**Discharge extinction voltage, etc.**

➢ Main factors Influencing PD

- ✓ **Voltage Amplitude (Higher voltage leads to increased PD levels and greater dielectric loss).**
- ✓ **Voltage waveform and frequency.**
- ✓ **Duration of voltage application.**
- ✓ **Environmental Factors,** such as Temperature, Humidity, and Atmospheric Pressure, etc.

5.4.4 Basic circuits and detect impedances for pulse current method

- **Three basic measurement circuits**



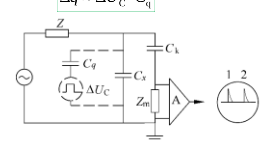
Circuit with test specimen in parallel with detection impedance after C_k | Circuit with test specimen and detection impedance serially connected | Bridge balancing circuit

5.4.5 Instruments and Calibration for the pulse current method

●Concept of calibration

- The partial discharge pulse value is determined through experiments
- The PD measuring instrument is experimentally calibrated.

$$\Delta q \approx \Delta U_C \cdot C_q$$



Direct Calibration Circuit for PD Test

5.4.6 Other technical issues of PD measurement

1. Anti-interference measures

➢ **Impact of Background Noise:**

- Background noise determines the minimum detectable apparent discharge, i.e., it determines the sensitivity of the measurement system.
- Severe noise can render partial discharge measurements impractical.

➢ **Key to anti-interference:** To eliminate interference, the first step is to find the source of interference

➢ **The sources of interference**

- Corona discharges from power lines
- Electromagnetic waves from radio broadcasting
- Switching operations
- Operations of welding machines and cranes
- Discharges from high-voltage lines in the test area
- Poor contact of conductors
- Inadequate grounding of the test circuit
- Poor shielding of the test transformer
- Internal discharges, etc.

2. Process of Applying High Voltage According to National Standards

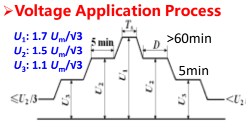
➢**PD test:** Conducted in accordance with IEC and national standards.

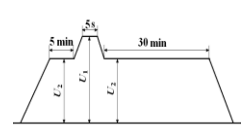
➢**Voltage Application Methods (Power Transformer, 66kV and above)**

- ✓Measurement without pre-applied voltage
- ✓Measurement with pre-applied voltage

➢**Role of pre-applied voltage:** excitation of local defects

➢**Voltage Application Process**

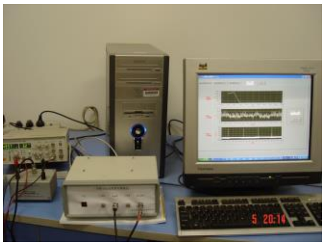




Current partial discharge standards | Old partial discharge standards

PD test process for power transformers (duration of pre-applied voltage: T_s=60×100/f

Digital partial discharge measurement system



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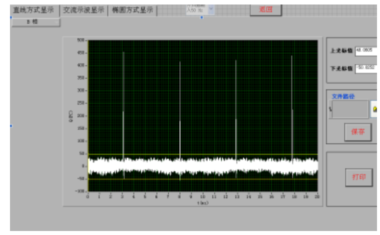
Spectrum under line mode with square wave calibrate signal



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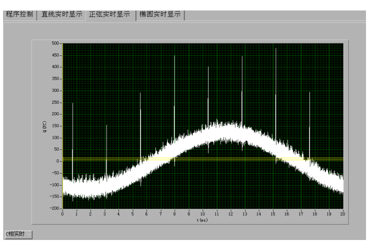
Spectrum under sine mode with square wave calibrate signal



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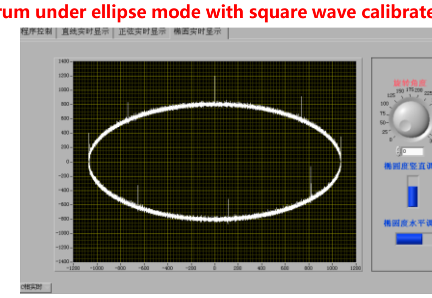
Spectrum under ellipse mode with square wave calibrate signal



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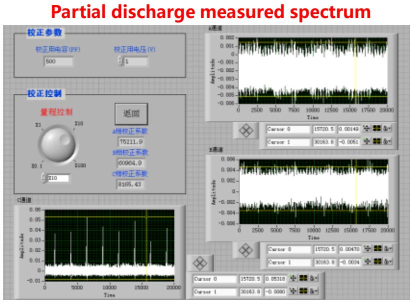
Partial discharge measured spectrum



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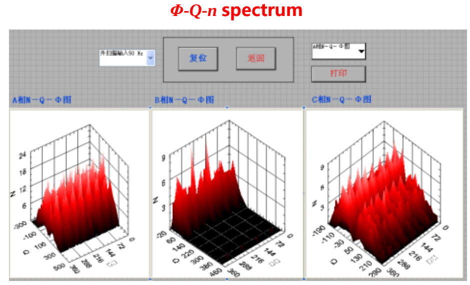
Φ-Q-n spectrum



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High Voltage Engineering

Insulation Test and Diagnosis (1)
Lecture 9

THE END! THAKS!