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Improvement Test –November 2017

Sub:	High Voltage Engineering							Code:	10EE73
Date:	17/11/2017	Duration:	90 mins	Max Marks:	50	Sem:	VII	Branch:	EEE

Note: Answer any FIVE full questions.

		Marks	OBE	
			CO	RBT
1.	Explain the application of high voltage with respect to a) Electrostatic painting and b) Electrostatic printing.	[5+5]	CO4	L1
2.	With the help of a neat schematic describe how the loss angle and dielectric loss of an insulator can be measured by using high voltage Schering bridge.	[10]	CO4	L3
3.	With a neat diagram, explain how a fault in a long cable can be detected and located using partial discharge technique.	[10]	CO5	L1
4.	Explain briefly what different tests are conducted on an insulator.	[5+5]	CO5	L2
5.	What are partial discharges? How are they measured by balanced detection method and straight detection method?	[2+4 +4]	CO5	L3
6.	Describe different methods of short circuit test on circuit breakers.	[10]	CO4	L1
7.	Write short notes on: a) impulse current generator, b) transformer ratio arm bridge.	[10]	CO5	L2

1.

Electrostatic Painting and Coating :-

→ EP is an innovative method used for painting metals and certain types of plastics.

→ It makes use of charged particles to efficiently paint a workpiece.

→ Paint in the form of either powdered particles or atomized liquid, is initially projected towards a conductive workpiece using normal spraying methods and is then accelerated towards the workpiece by a powerful electrostatic charge.

EP Process :-

→ EP works by creating an electric field. between the object and the paint.

→ The grounded object (the object being painted) is +vely charged in order to attract the negatively charged paint molecules to its surface.

→ By creating this electrostatic field, the grounded object acts like a magnet, pulling the paint molecules to its surface, forcing even disbursement.

→ Recent addition to electrostatic painting/coating is in the form of dipping electrically conductive part into a tank of paint.

that is then electrostatically charged.

→ the ionic bond of the paint to the metal creates the paint coating, in which its th is directly proportional to the length of the parts are left in the tank and the the charge remains active.

→ Once the parts are removed from the pain tank. They are rinsed off to remove any residual pain that is not ionically bonded, leaving a thin film of electrostatically bonded paint on the surface of the part.

Characteristics of EP :-

→ Uses a high voltage electrostatic charge wh is applied to both the work piece and th spraying mechanism.

→ It is incredibly efficient, uses 95% of sprayed paint due to reduced over-spra and better wrap- around.

→ Paint materials can be powdered or liqu

→ Process can be either automatic or man

→ Workpieces must be conductive.

→ Work pieces are usually baked after coated.

→ The baked on paint adheres extremely well and is difficult to remove without aggressive means of removal.

Advantages of EP :

→ Create strong bond between the paint and the workpiece to be painted.

→ It can cover 3D object ~~more~~, with good edge and wrap-around coverage.

→ It ~~seems~~ saves paint by using least amount of paint since it has a higher transfer efficiency.

→ Uniform and even coating especially on non-flat surfaces.

→ Dries quickly (within an hour).

→ Extremely durable.

Disadvantages of EP :-

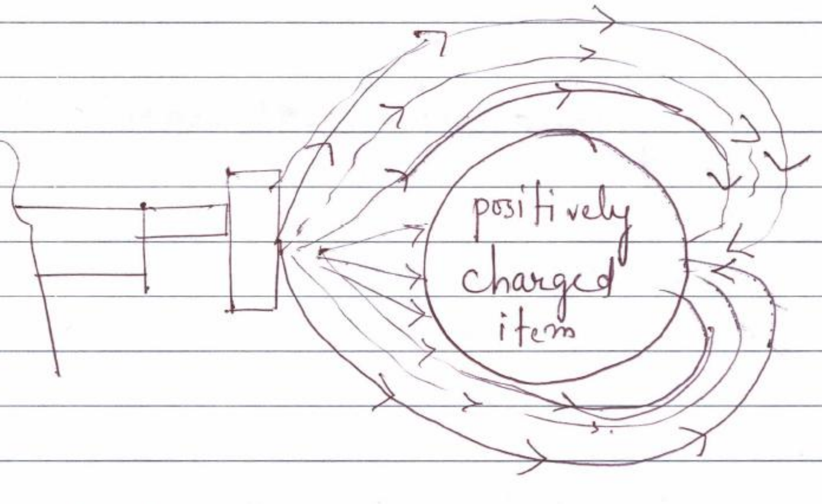
→ Material to be sprayed must be conductive or made conductive for bonding.

→ spray gun has to be handled very carefully as they are bulky and.

delicate.

→ It requires the use of grounding as improper usage can be a fire or safety hazard.

→ High cost.



Electrostatic painting.

Electrostatic Printing / Plotting.

→ Electrostatic printing (EPr) is a printing technique without any plate, ink or type form.

→ The paper is coated with a thin layer of zinc oxide making it an insulator in the dark and simultaneously a conductor of electricity when exposed to light.

EPr Process :-

→ EPr uses a positively charged toner/inks i.e attracted to paper which is negatively charged (liquid toners consist of pigment suspended in a hydro-carbon medium.

→ The paper is moved through a digital ink. bath, positively charged particles in ink stick to the negative charge on the paper.

→ The printer prints in black and white or color as the case may be.

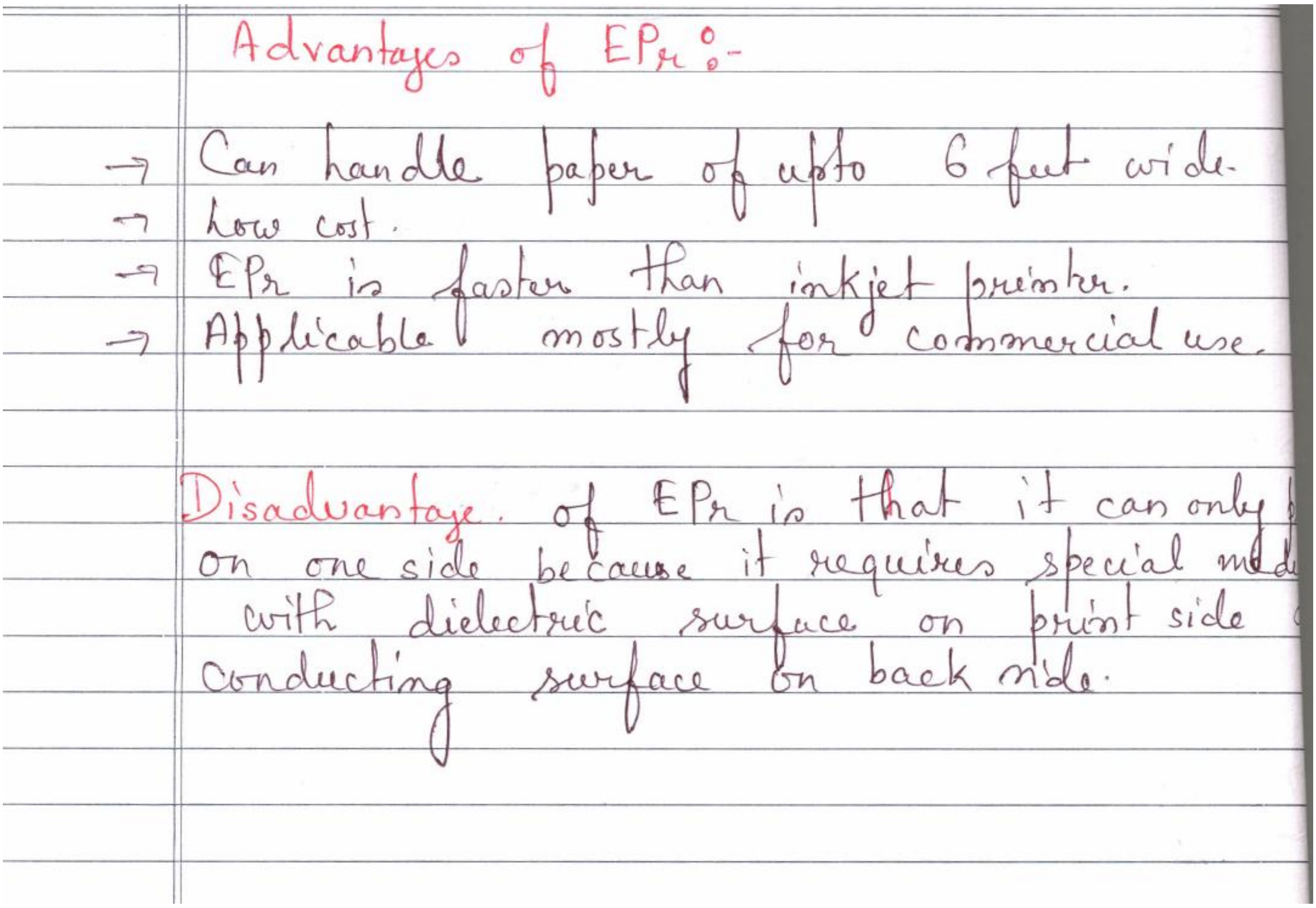
Applications of EPr :-

→ EPr are widely used in industries for short run printing.

→ Popular for photocopying jobs, both black and white and colored.

→ Used for printing geographic maps.

→ Used for printing small books.



Advantages of EPr :-

- → Can handle paper of upto 6 feet wide.
- → Low cost.
- → EPr is faster than inkjet printer.
- → Applicable mostly for commercial use.

Disadvantage. of EPr is that it can only
on one side because it requires special med
with dielectric surface on print side
conducting surface on back side.

2. The schematic diagram of the bridge is shown in Fig.. The lossy capacitor or capacitor with the dielectric between electrodes is represented as an imperfect capacitor of capacitance Cx together with a resistance rx. The standard capacitor is shown as Cs which will usually have a capacitance of 50 to 500 µF.

The variable arms are R4 and C3 /R3.

Balance is obtained when

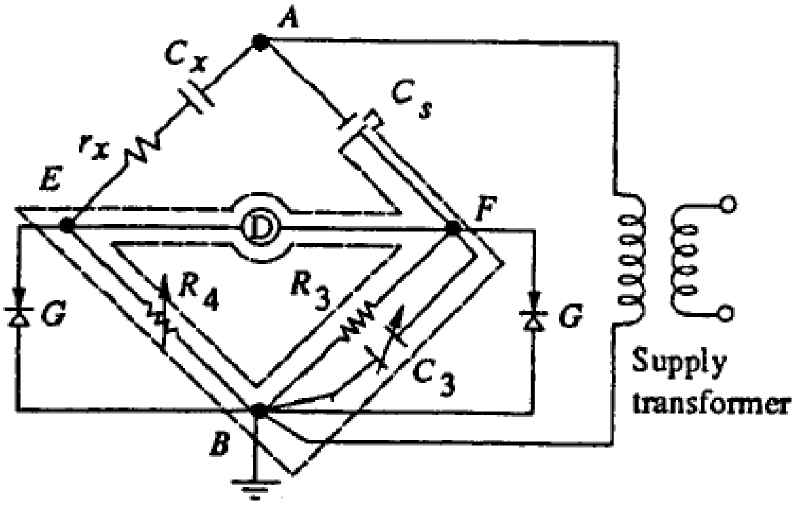
$$\frac{Z_1}{Z_2} = \frac{Z_4}{Z_3}$$

where,

$$Z_1 = r_x + \frac{1}{j\omega C_x}, \qquad Z_2 = \frac{1}{j\omega C_s}$$

$$Z_3 = \frac{R_3}{1 + j\omega C_3 R_3}, \text{ and } Z_4 = R_4$$

The balance equations are



- - - dotted line is the shielding arrangement. Shield is connected to *B*, the ground

Fig. 9.11 Schematic diagram of a Schering bridge

$C_x = \frac{R_3}{R_4} C_s$; and $r_x \frac{C_3}{C_2} R_1$ (diagram R1 and R4 are same , C2 and Cs are same.)

The loss angle, $\tan \delta_x = \omega C_x R_x$

$= \omega C_3 R_3$

Usually δ_x will be small at power frequencies for the common dielectrics so that

$$\cos \theta_x = \sin \delta_x = \delta_x = \tan \theta_x = \omega C_2 R_3 \qquad (9.17)$$

The lossy capacitor which is made as an equivalent C_x in series with r_x can be represented as a parallel combination of C_x and R_x where the parallel combination R_x is found to be

$$R_x = \frac{1}{\omega^2 C_x^2 r_x} \qquad (9.18)$$

with C_x having the same value.

- The normal method of balancing is **by fixing** the value of **R3** and **adjusting C3 and** *R4.*
- C3 giving a direct reading of tan δ.
- R4 will be a decade box with 5 to 6 decade dials.
- The maximum value of R4 is limited *to* 10^4*Ω and the* lowest value will not be less than 0.01 Ω

This range adequately takes care of the errors due to contact resistances as well as the stray capacitance effects across *R4* which are usually very small.

It is important to see that **the resistances are pure** and not **reactive and the standard capacitor has negligible tan δ** (air or gas Filled capacitor is used).

- The arrangement shown in Fig. is suitable when the test specimen is not grounded.
- The standard condenser Cs is usually a three terminal condenser.

- The low voltage arms of the bridge (R4 and R3 C3) and the detector are enclosed in grounded shielded boxes to avoid stray capacitances during the measurements.
- The detector is either a vibration galvanometer or in modern bridges a tuned electronic null detector of high sensitivity.
- The protective gaps G are so arranged that the low voltage arms

are protected from high voltages in case the test objects fail.

- The impedances of the low voltage arms are such that the voltage drop across EB or FB does not exceed 10 to 20 V.

The arms will be usually rated for a maximum instantaneous voltage of 100 V.

- **SOURCES OF ERROR:**
- For a very accurate measurement of the dissipation factor at **power frequency**, the **stray and grounded capacitances** should be eliminated and the **indirect capacitive** and **inductive coupling** of the arms are to be **minimized** to a level lower than the accuracy of the bridge arms.

In this bridge the **main source** of **error** is the **ground capacitance** of the low voltage terminals of high voltage arms, i.e. the stray capacitances from *E* and *F to ground. These are* **eliminated** *by* **shielding** *the low voltage arms using doubly* shielded cables for connections and using the "**Wagner earthing device**". Compensation for the stray capacitances is given by providing a parallel *R-L circuit* across *R4.*

Scherlng Bridge Arrangement for Grounded Capacitors

- For safety reasons and to define the shield potentials with respect to each other, one of the terminals of the bridge is earthed.
- This is usually the low voltage arm connection of the supply source (Terminal *B of Fig.), because a low impedance* arm with respect to the detector branch gives a high signal to noise ratio in measurements.
- While testing grounded test objects like underground cables or bushings with flanges grounded to the tank of a transformer, one of the detector terminals *(E or F)* has to be grounded.
- In such cases, either an inverted bridge (Fig.) or a grounded detector arrangement (Fig.) has to be adopted.

In the inverted bridge operation, the self-contained bridge is located inside a Faraday cage at the high voltage terminal and a standard capacitor is mounted on insulating supports.

The variable arms are operated by insulated isolating rods. Sometimes, the operator himself will be inside the Faraday cage.

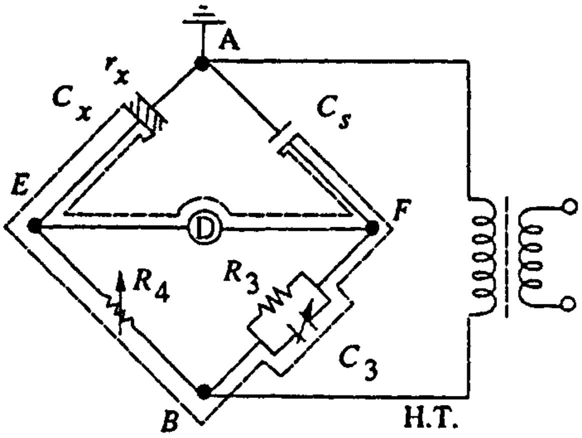


Fig. 9.12 Inverted Schering bridge for grounded capacitors

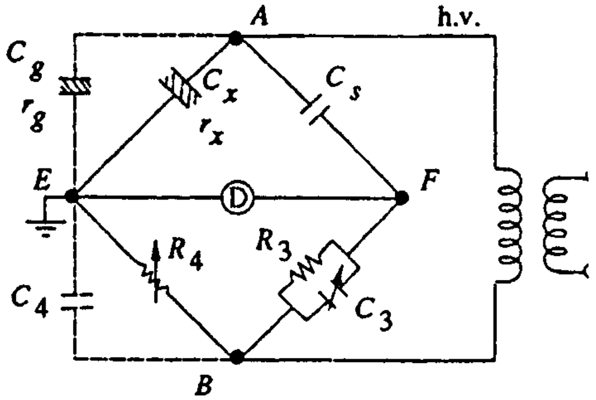


Fig. 9.13 Schering bridge for grounded objects (detector end grounded)

In the grounded detector arrangement, stray capacitances of the high voltage terminal *(Cg) and of the source, leads, etc. come in parallel with the test object.*

the balancing is to be done in two steps.

First, the test object is disconnected and the capacitance *Cg and tan (δ2) are measured.*

Then the test object is connected and a new balance is obtained.

The second balance gives,

$$C'_x = C_x + C_g$$

and
$$\tan\delta'_x = \frac{C_x \tan\delta_x + C_g \tan\delta_g}{C_x + C_g}$$

Hence, the actual capacitance and dissipation factor of the test object are

$$C_x = C'_x - C_g$$

and
$$\tan\delta_x = \frac{C'_x \tan\delta'_x - C_g \tan\delta_g}{C_x}$$

The accuracy of the measurement is poor, if the ground capacitance is large compared to the test object capacitance.

3.

TESTING OF CABLES

- Cables are very important electrical apparatus for transmission of electrical energy by underground means.
- They are also very important means for transmitting voltage signals at high voltages.
- For power engineers, large power transmission cables are of importance, and hence testing of power cables only is considered here.
- Of the different electrical and other tests prescribed, the following are important to ensure that cables withstand the most severe conditions that are likely to arise in service.
  - Different tests on cables may be classified into
    - mechanical tests like bending test, dripping and drainage test, and fire resistance and corrosion tests,
    - *thermal duty tests,*
    - *dielectric power factor tests,*
    - **power frequency withstand voltage tests,**
    - **impulse withstand voltage tests,**
    - **partial discharge tests, and**
    - **life expectancy tests.**

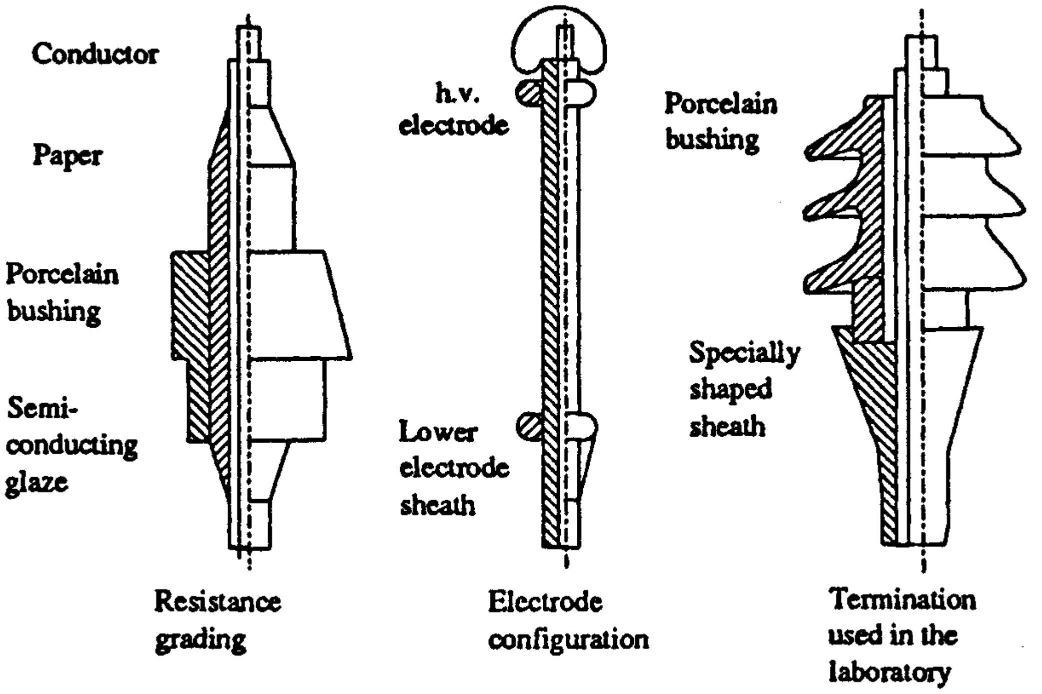


Fig. 10.5 Cable and terminals

Partial Discharges

a) Discharge Measurement

Partial discharge measurements and the discharge locations are important for cables, since the life of the insulation at a given voltage stress depends on the internal discharges.

Also, the weakness of the insulation or faults can be detected with the help of these tests; the portion of the cable if weak may be removed, if necessary.

The general arrangement for **partial discharge tests** is the same as described in Sec.9.4.

The equivalent circuit of the cable for discharges is shown in Fig. 10.6, and the cable connection to the discharge detector through the coupling condenser is shown in Figs. 10.7a and b.

- If the detector is connected through a coupling capacitor to one end of the cable as in Fig. 10.7a, it will receive the transient travelling wave directly from the cavity towards the nearer end, and after a short lime, a second travelling wave pulse reflected from the far end is observed.
- Thus, the detected response is the combination of the above two transient pulses.
- But, if the connections are made as in Fig. 107b, no severe reflection is involved except as a second order effect of negligible magnitude.
- Now two transients will arrive at both the ends of the cable, and the superposition of the two pulses is detected.
- This can be obtained by adding the responses of the two transients. The superpositions of the two responses may give rise to a serious error in the measurement of the discharge magnitude.
- The magnitude of the possible error may be determined mainly by the shape of the response of the discharge detector.

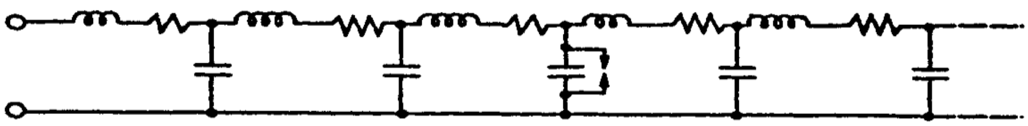


Fig. 10.6 Equivalent circuit of the cable for discharges

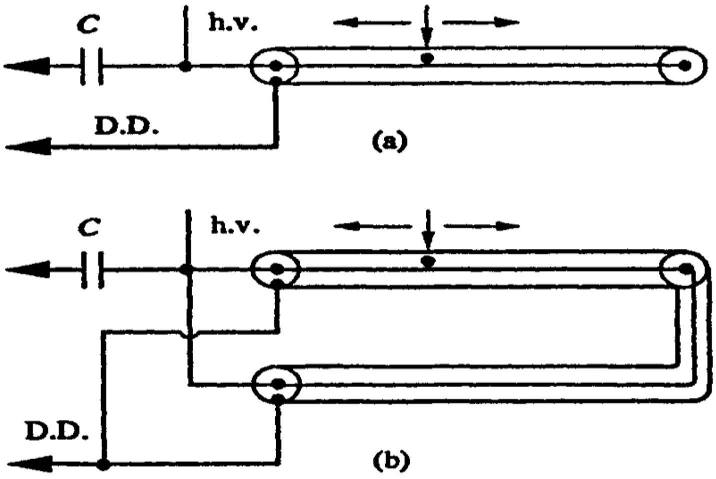


Fig. 10.7 Discharge detector connection to long length of cable
D.D.—Discharge detector

(b) Location of Discharges

4.**Tests on Insulators**

The tests are as (i) **type tests**, and (ii) **the routine tests.**

- **Type tests** to prove or check the design features and the quality.

The routine tests to check the quality of the individual test piece.

Type tests are done on samples when **new designs or design changes** are **introduced**,

the routine tests are done to ensure the **reliability of the individual test objects** and **quality** and **consistency** of the materials used in their manufacture.

High voltage tests include

(i) the power frequency tests,
(ii) impulse tests.

All the insulators are tested for both categories of test.

Power Frequency Tests

(a) **Dry and Wet Flashover Tests :** *In these tests the a.c. voltage of power* frequency is applied across the insulator and increased at a uniform rate of about 2 per cent per second of 75% of the estimated test voltage, to such a value that a breakdown occurs along the surface of the insulator.

- If the ,test is conducted under **normal conditions without any rain or precipitation,** it is called "**dry flashovcr test".**

If the test is done under **conditions of rain**, it is called "I**wet flashovcr test".**

(b) Wet and Dry Withstand Tests (One Minute):

- In these tests, the voltage specified in the relevant specification is applied under dry or wet conditions for a period of one minute with an insulator mounted as in service conditions.
- The test piece should withstand the specified voltage.

Impulse Tests

(a) **Impulse Withstand Voltage Test :**This test is done by applying standard impulse voltage of specified value **under dry conditions with both positive and negative polarities of the wave**.

If **five consecutive waves** do not cause a **flashover** or **puncture**, the insulator is deemed to have **passed** the **test**. I

If **two applications** cause **flashover**, the object is deemed to have failed.

If there is only **one failure,** additional **ten applications** of the voltage wave are made.

If the test object has **withstood** the subsequent applications, it is said to have passed the test.

(b) **Impulse Flashover Test** The test is done as **above with the specified voltage.**

Usually, the probability of failure is determined for 40% and 60% failure values or 20% and 80% failure values, since it is difficult to adjust the test voltage for the exact 50% flashover values.

The average value of the upper and the lower limits is taken.

The insulator surface should not be damaged by these tests, but slight marking on its surface or chipping off of the cement is allowed.

(c) **Pollution Testing** Because of the problem of pollution of outdoor electrical insulation and consequent problems of the maintenance of electrical power systems, pollution testing is gaining importance.

The **normal types of pollution** are

(i) dust, micro-organisms, bird secretions, flies, etc.,
(ii) industrial pollution like smoke, petroleum vapours, dust, and other deposits,
(iii) coastal pollution in which corrosive and hygroscopic salt layers are deposited on the insulator surfaces,
(iv) Desert pollution in which sand storms cause deposition of sand and dust layers,
(v) ice and fog deposits at high altitudes and in polar countries.

Effect of Pollution:

pollutions cause corrosion, non-uniform gradients along the insulator strings and surface of insulators and also cause deterioration of the material.

pollution causes partial discharges and radio interference.

pollution testing is important for **extra high voltage** systems.

there is no standard pollution test available.

The popular test that is normally done is the **salt fog test**.

the maximum normal withstand voltage is applied on the **insulator** and then **artificial salt fog** is created around the insulator by j**ets of salt water** and **compressed air**.

If the **flashover** occurs within **one hour**, the test is repeated **with fog of lower salinity**, **otherwise, with a fog of higher salinity.**

The maximum salinity at which the insulator withstands three out of four tests without flashover is taken as the representative figure.

Much work is yet to be done to standardize the test procedures .

5.

PARTIAL DISCHARGE MEASUREMENTS

Earlier the testing of insulators and other equipment was based on the insulation resistance measurements, dissipation factor measurements and breakdown tests.

It was observed that the dissipation factor (tan δ) was voltage dependent and hence became a criterion for the monitoring of the high voltage insulation

weak points in an insulation like voids, cracks, and other imperfections lead to internal or intermittent discharges in the insulation.

These imperfections being small were not revealed in capacitance measurements but were revealed as power loss components in contributing for an increase in the dissipation factor.

In modern terminology these are designated as "partial discharges" which in course of time reduce the strength of insulation leading to a total or partial failure or breakdown of the insulation

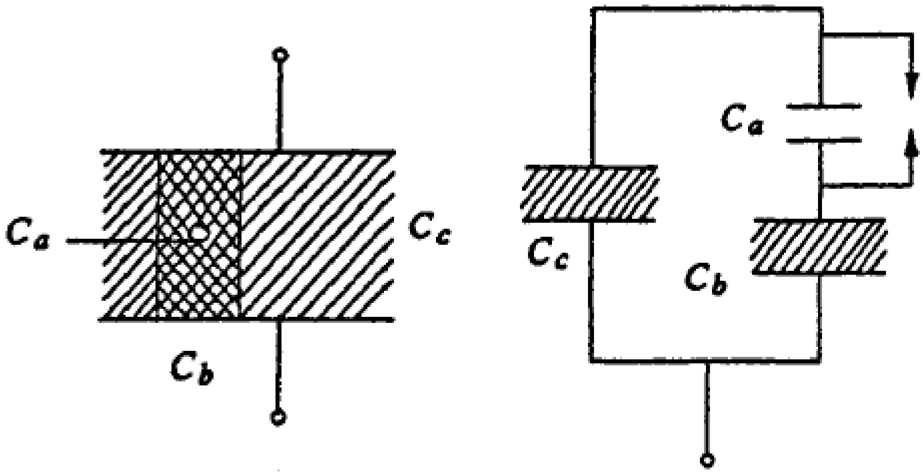
If the sites of partial discharges can be located inside an equipment, like in a power cable or a transformer, it gives valuable information to the insulation engineer about the regions of greater stress and imperfections in the fabrication.

Based on this information, the designs can be considerably improved

Electrical insulation with imperfections or voids leading to partial discharges can be represented by an electrical equivalent circuit shown in Fig. 9.20. Consider a capacitor with a void inside the insulation (Ca).

The capacitance of the void is represented by a capacitor in series with the rest of the insulation capacitance (Cb).

The remaining void-free material is represented by the capacitance Cc. When the voltage across the capacitor is raised, a critical value is reached across the capacitor Ca and a discharge occurs through the capacitor, i.e. it becomes short circuited.
This is represented by the closure of the switch



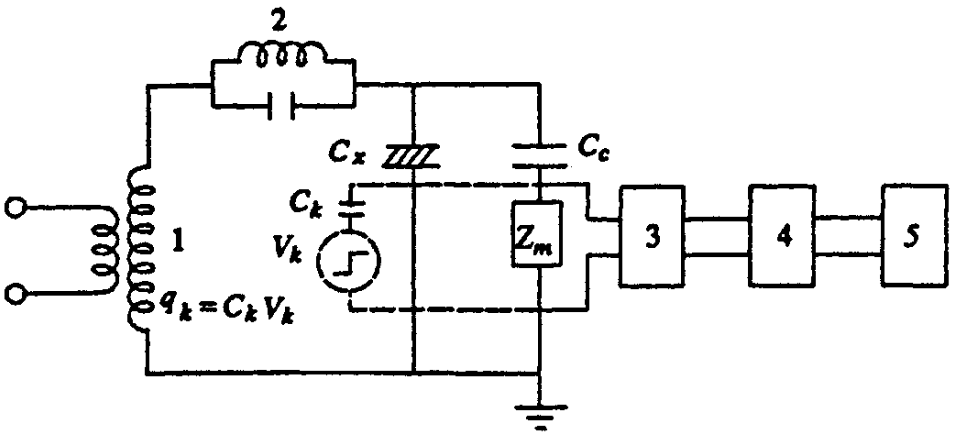
C_a — Capacitance of the void acting as a spark gap
C_b — Capacitance of the remaining series insulation with the void
C_c — Remaining part of the discharge free insulation of the test object

Insulating device with a void C_a and its simplified electrical equivalent circuit

Generally, Ca << Cb <<Cc.
A charge Δqa which was present in the capacitor Ca flows through Cb and Cc giving rise to a voltage pulse across the capacitor Cc.
A measure of the voltage pulse across the capacitor gives the amount of discharge quality.
But this measurement is difficult in practice, and an apparent charge measurement across a detecting impedance is usually made.

Discharge Detection Using Straight Detectors

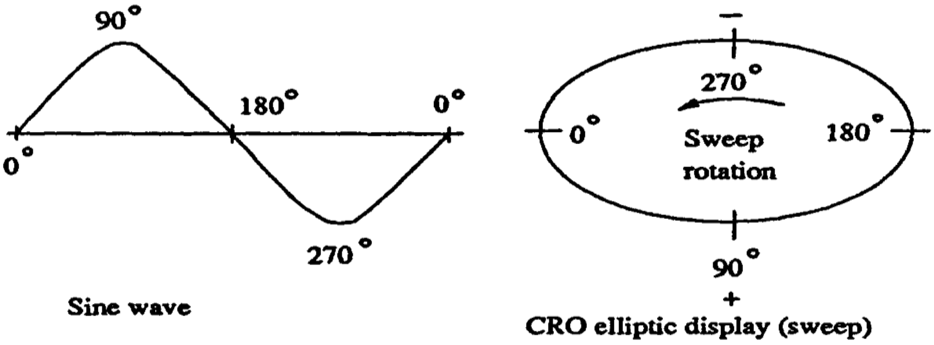
The circuit arrangement shown in Fig. 9.21 gives a simplified circuit for detecting "partial discharges".
The high voltage transformer shown is free from internal discharges.
A resonant filter is used to prevent any pulses starting from the capacitance of the windings and bushings of the transformer.
Cx is the test object, Cc is the coupling capacitor, and *Zm is a detection impedance.*
The signal developed across the impedance *Zm is passed through a band pass filter and amplifier and displayed on a* CRO or counted by a pulse counter multi-channel analyzer unit.



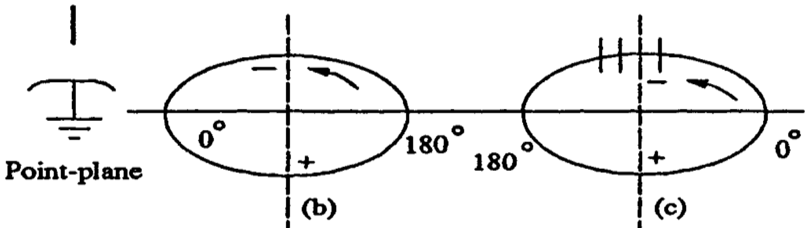
1 — H.V. testing transformer
2 — Filter
3 — Band pass filter
4 — Amplifier
5 — Display unit (CRO or pulse counter or multi-channel analyser unit)

C_x — Sample or test piece
C_c — Coupling condenser
Z_m — Detector impedance
V_k — Calibrating pulse
C_k — Calibrating capacitor
q_k — Calibrator charge

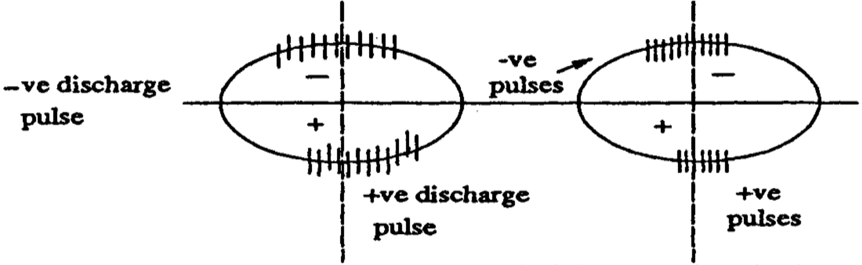
Straight discharge detection circuit



(a) Elliptic sweep display



(b), (c) Corona discharges in point-plane configuration



(d) Discharges in voids in the insulation

(e) Discharges in voids bound on one side with insulation, and on the other side by a conductor

- the discharge pattern displayed on the CRO screen of a partial discharge detector with an elliptical display is shown.
- The sinusoidal voltage and the corresponding ellipse pattern of the discharge are shown in Fig. 9.22a and a single corona pulse in a point-plane spark gap geometry is shown in Figs. 9.22b and c.
- When the voltage applied is greater than that of the critical inception voltage, multiple pulses appear (see Fig. 9.22c), and all the pulses are of equal magnitude.
- A typical discharge pattern in cavities inside the insulation is shown in Fig. 9.22d.
- This pattern of discharge appears on the quadrants of the ellipse which correspond to the test voltage rising from zero to the maximum, either positively or negatively.
- The discharges usually start near the peaks of the test voltage but spread towards the zero value as the test voltage is increased beyond the inception level.
- The number and magnitude of the discharges on both the positive and negative cycles are approximately the same.
- A typical discharge pattern from a void bounded on one side by the insulation and the other side by a conductor is shown in Fig. 9.22c.
- This pattern of discharge is common in insulated cables (like polyethylene and XLPE cables) when the discharge is made up of a large number of pulses of small magnitude on the positive cycle and a much smaller number of large magnitude pulses on the negative half-cycle
- In the narrow band detection scheme *Zm is a parallel L -C circuit tuned to 500*
- kHz.
- The bandpass filter has a bandwidth of about ± 10 kHz. The pulses after
- amplification are displayed in an elliptical time base of a CRO, and the resolution for the pulses is about 35 per quadrant
- **Balanced Detection Method**
- In the straight detection method, the external disturbances are not fully rejected.
- The filter used to block the noise sources may not be effective. The Schering bridge employed for the tan 5 measurement is sometimes used.
- In this method, the test object is not grounded.
- A modification to the Schering bridge detector is the differential discharge detector, given by Kreuger.
- Both the schemes are given in Fig. 9.23.
- The bridges are tuned and balanced at 50 Hz.
- A filter is used across the detector terminals to block the 50 Hz components present
- Signals in the range from 5 to 50 kHz are allowed to pass through the filter and amplified.
- The CRO gives the display of the pulse pattern.
- Any external interference from outside is balanced out, and only internally (test piece) generated pulses are detected.
- In the modified scheme, another test sample called dummy sample is used in the place of the standard condenser.
- The capacitance and tan δ of the dummy sample are made approximately equal, but need not be equal.
- **The disadvantage is that if two discharges occur in both the samples simultaneously, they cancel out, but this is very rare.**
- The main advantage of the second method is its capacity for better rejection of external noise and use of the wide frequency band with belter resolution of the individual pulses.
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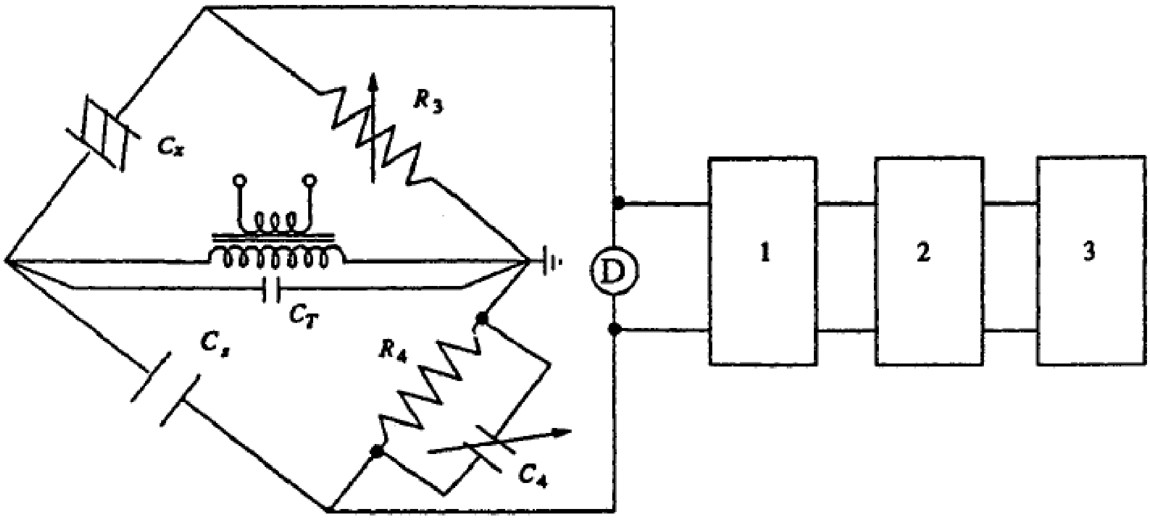
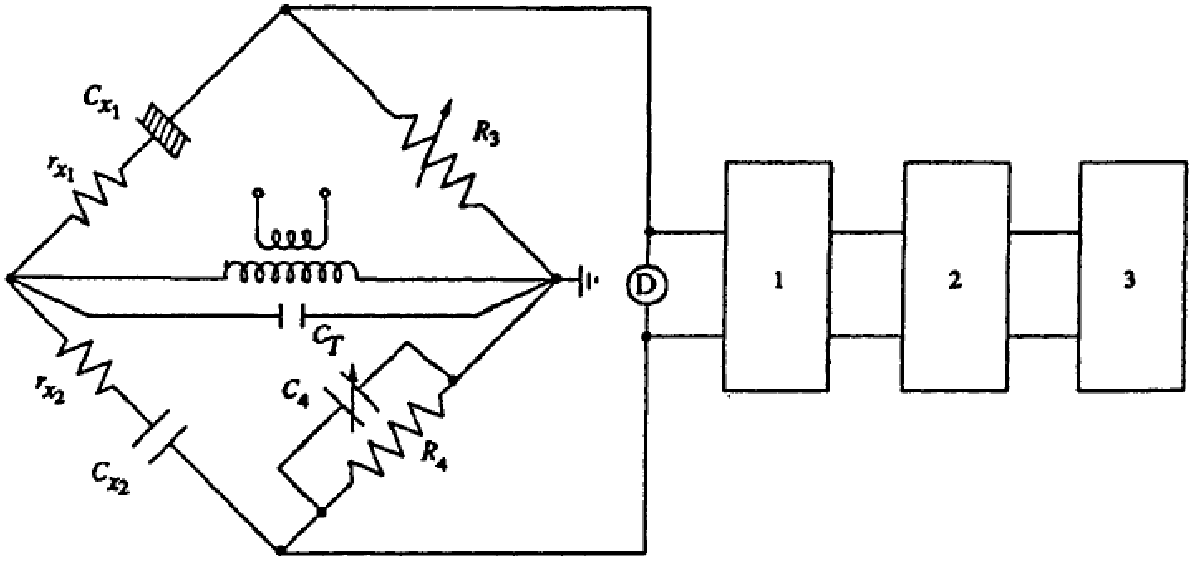


D — Power frequency detector
1 — Filter (band pass)
2 — Amplifier
3 — Display unit — CRO or counter

(a) Balanced detector using Schering bridge



(b) Differential detector

Fig. 9.23 Balanced discharge detector schemes

6.

- Testing of circuit breakers is intended to evaluate (a) the constructional and operational characteristics, and (b) the electrical charactristics of the circuit which the switch or the breaker has to interrupt or make.

The different characteristics of a circuit breaker or a switch may be summarized as per the following groups.

(i) (a) The electrical characteristics which determine the arcing voltage, the current chopping characteristics, the residual current, the rate of decrease of conductance of the arc space and the plasma, and the shunting effects in interruption.

(b) Other physical characteristics including the media in which the arc is extinguished, the pressure developed or impressed at the point of interruption, the speed of the contact travel, the number of breaks, the size of the arcing chamber, and the materials and configuration of the circuit interruption.

(ii) The charateristics of the circuit include the degree of electrical loading, the normally generated or applied voltage, the type of fault in the system which the breaker has to clear, the time of interruption, the time constant, the natural frequency and the power factor of the circuit, the rate of rise of recovery voltage, the restriking voltage, the decrease in the a.c. component of the short circuit current, and the degree of asymmetry and the d.c. component of the short circuit current,

To assess the above factors, the main tests conducted on the circuit breakers and isolator switches are

(I) the dielectric tests or overvoltage tests,
(iI) the temperature rise tests,
(III) the mechanical tests, and
(Iv) the short circuit tests

Dielectric tests consist of **overvoltage withstand tests of power frequency**, **lightning and switching impulse voltages**.

The impulse tests with the lightning impulse wave of standard shape are done in a similar manner as in the case of insulators.

In addition, the switching surge tests with switching overvoltages are done on circuit breakers and isolators to assess their performance under overvoltages due to switching operations.

Temperature rise and mechanical tests are tube tests on circuit breakers and are done according to the specifications

Short Circuit Tests

The most important tests carried out on circuit breakers **arc short circuit** tests, since these tests assess the primary performance of these devices, i.e. their ability to safely interrupt the fault currents.

These tests consists of determining the making and breaking capacities at various load currents and rated voltages.

In the case of isolators, the short circuit tests are conducted only with the limited purpose to determine their capacity to carry the rated short circuit current for a given duration; and no breaking or making current test is done.

The different methods of conducting short circuit tests ar**e**

(I) Direct Tests

(a) using a short circuit generator as the source
(b) using the power utility system or network as the source.

(II) Synthetic Tests

(a) Direct Testing in the Networks or in the Fields Circuit breakers are sometimes tested for their ability to make or break the circuit under normal load conditions or under short circuit conditions in the network itself.

This is done during period of limited energy consumption or when the electrical energy is diverted to other sections of the network which are not connected to the circuit under test.

The advantages of field tests are:

1 The circuit breaker is tested under actual conditions like those that occur in a given network.
2 Special occasions like breaking of charging currents of long lines, very short line faults, interruption of small inductive currents, etc. can be tested by direct testing only.

3 to assess the thermal and dynamics effects of short circuit currents, to study applications of safety devices, and to revise the performance test procedures, etc.

The disadvantages are:

1 The circuit breaker can be tested at only a given rated voltage and network capacity.
2 The necessity to interrupt the normal services and to test only at light load conditions.
3 Extra inconvenience and expenses in installation of controlling and measuring equipment in the field.

(b) Direct Testing in Short Circuit Test Laboratories

In order to test the circuit breakers at different voltages and at different short circuit currents, short circuit laboratories are provided.

The schematic layout of a short circuit testing laboratory is given in Fig. 10.3.

It consists of a short circuit generator in association with a master circuit breaker, resistors, reactors and measuring devices.

A make switch initiates the short circuit and the master circuit breaker isolates the test device from the source at the end of a predetermined time set on a test sequence controller.

Also, the master circuit breaker can be tripped if the test device fails to operate properly.

Short circuit generators with induction motors as prime movers are also available

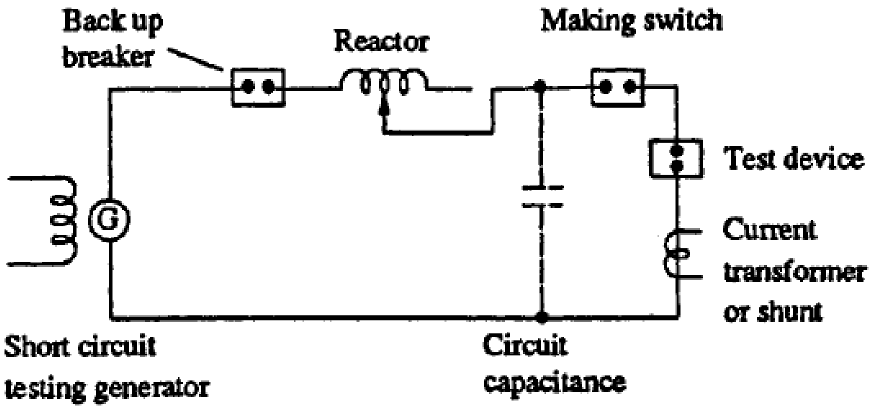
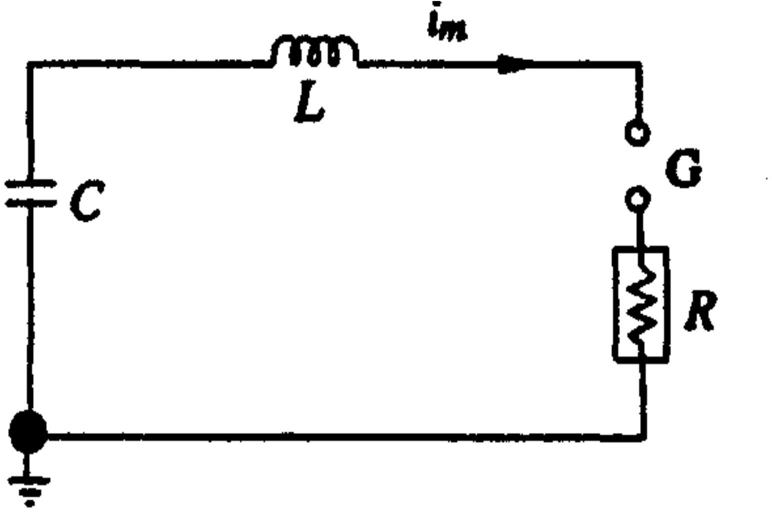
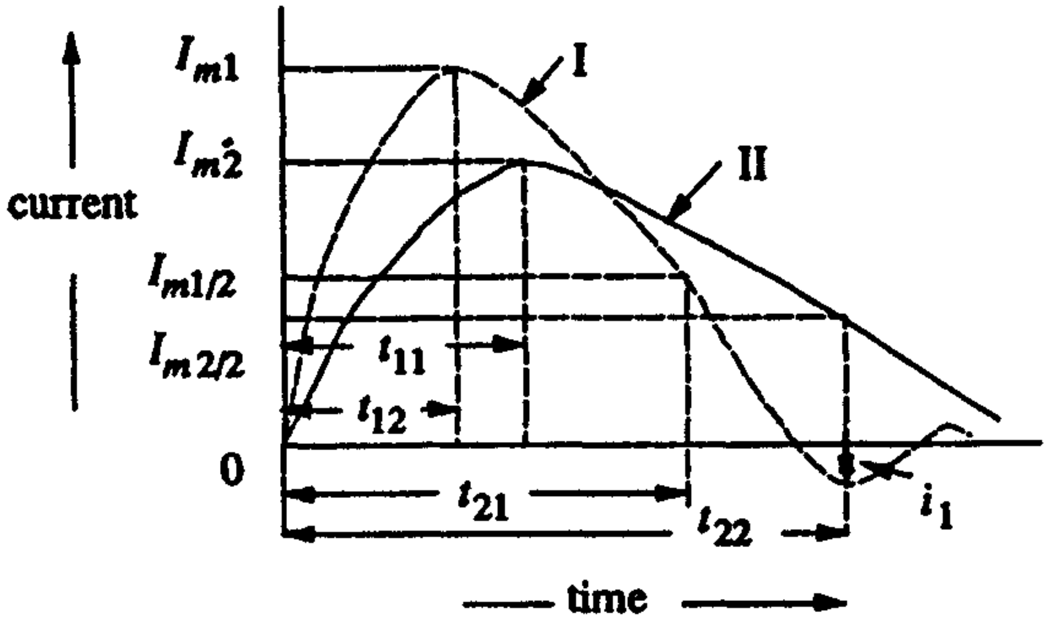


Fig. 10.3 Schematic diagram showing basic elements of a short circuit testing laboratory

7a Impulse curent generator



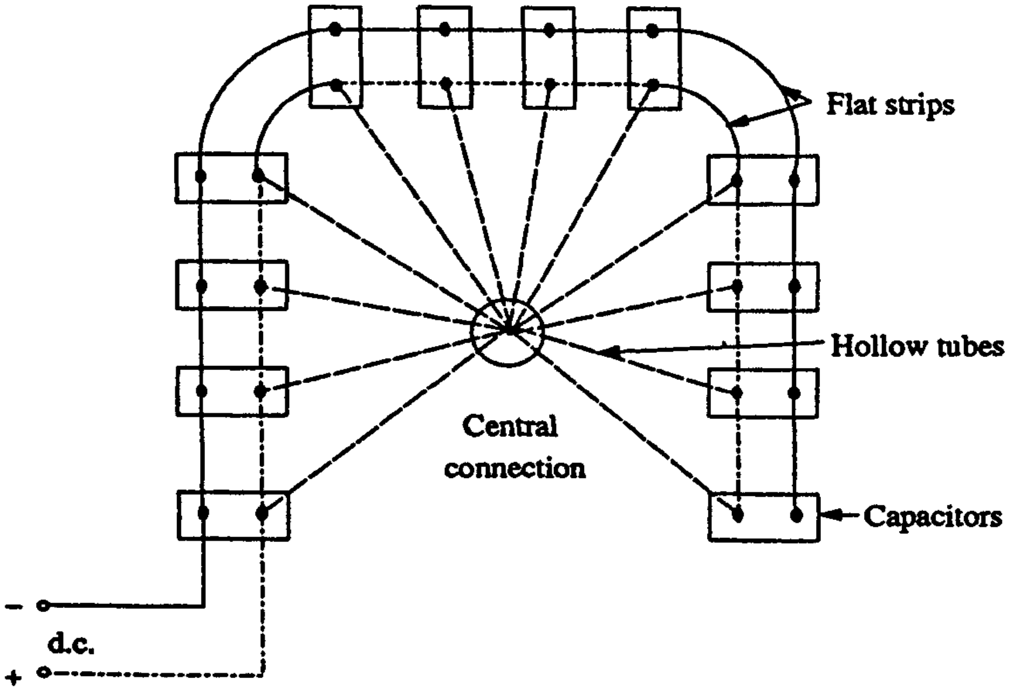
(a) Basic circuit of an impulse current generator



t_1 and t_{12} = time-to-front of waves I and II
t_{21} and t_{22} = time-to-tail of waves I and II

I — damped oscillatory wave
II — overdamped wave
i_1 — overshoot

(b) Types of impulse current waveforms



(c) Arrangement of capacitors for high impulse current generation

Fig. 6.20 Impulse current generator circuit and its waveform

- **For producing impulse currents of large value, a bank of capacitors connected in parallel are charged to a specified value and are discharged through a series *R-L circuit* as shown in Fig. 6.20.**
- ***C represents a bank of capacitors connected in parallel which* are charged from a d.c. source to a voltage up to 200 kV.**
- ***R represents the dynamic* resistance of the test object and the resistance of the circuit and the shunt.**
- ***L is an air* cored high current inductor, usually a spiral tube of a few turns**
- If the capacitor is charged to a voltage *V and discharged when the spark gap is* triggered, the current *im will be given by the equation*

$$V = R\,i_m + L\frac{di_m}{dt} + \frac{1}{C}\int_0^t i_m\,dt$$

The circuit is usually underdamped, so that

$$\frac{R}{2} < \sqrt{L/C}$$

Hence, im is given by

$$i_m = \frac{V}{\omega L}\left[\exp(-\alpha t)\right]\sin(\omega t) \qquad (6.25)$$

where

$$\alpha = \frac{R}{2L} \text{ and } \omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} \qquad (6.25a)$$

The time taken for the current i_m to rise from zero to the first peak value is

$$t_1 = t_f = \frac{1}{\omega}\sin^{-1}\frac{\omega}{\sqrt{LC}} = \frac{1}{\omega}\tan^{-1}\frac{\omega}{\alpha} \qquad (6.26)$$

The duration for one half cycle of the damped oscillatory wave t_2 is,

$$t_2 = \frac{\pi}{\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}} \qquad (6.27)$$

- **It can be shown that the maximum value of im is normally independent of the value of V and C for a given energy,**

and the effective inductance L.

- **Eq. (6.25) shows that a low inductance is needed in order to get high current magnitudes for a given charging voltage V.**
- **The present practice as per IEC 60.2 is to express the characteristic time t2 as the time for half value of the peak current, similar to the definition given for standard impulse voltage waves.**
- **With this definition, the values of α and ω for 8/20 µs impulse wave will be α= 0.0535 x 106 and ω = 0.113 x 106,**
- **R, L, C are expressed in ohms, henries and farads respectively.**
- **The product LC will be equal to 65 and the peak value of im is given by (VC/14).**
- **Here, the charging voltage is in kV and im is in kA**
- **Generation of High Impulse Currents**

- For producing large values of impulse currents, a number of capacitors are **charged in parallel and discharged in parallel** into the circuit.
- The arrangement of capacitors is shown in Fig 6.20c
- In order to minimize the effective inductance, the capacitors are subdivided into smaller units.
- If there are **n1** groups of capacitors, each consisting of **n2** units
- **L0** is the inductance of the common discharge path,
- **L1**is that of each group and **L2**is that of each unit, then the effective inductance L is given by

$$L = L_0 + \frac{L_1}{n} + \frac{L_2}{n_1 n_2}$$

7b

Transformer Ratio Arm Bridges

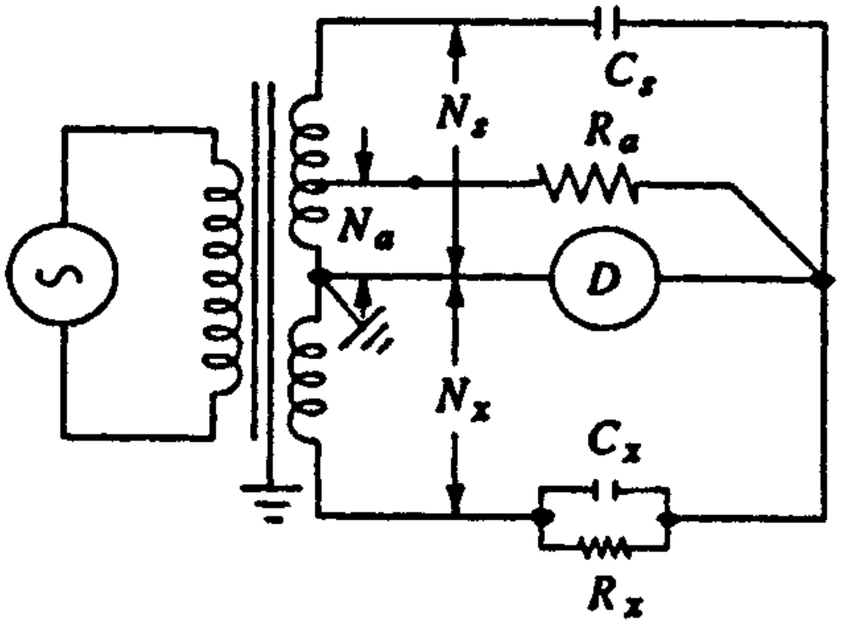
- It is a common practice to use the four arm Wheatstone bridge network for a.c. measurements.
- In high frequency measurements, the arms with high values of resistances lead to difficulties due to their residual inductances, capacitances, and skin effect.
- shielding and grounding becomes difficult in large arms.
- at high frequencies the transformer ratio arm bridges which eliminate at least two arms are preferred.
- These bridges are also **useful for the measurement of low value of capacitances** accurately.
- The ratio arm bridges can be either **voltage ratio type** or **current ratio type**;
- the former being used for high frequency low voltage applications.
- The schematic diagram of a ratio arm bridge (voltage ratio) is given in Fig. 9.18.
- Assuming ideal transformer conditions, for a null indication of the detector

$$\frac{V_s}{V_x} = \frac{N_s}{N_x} = \frac{C_x}{C_s}; \quad \text{and} \quad \frac{R_x}{R_a} = \frac{N_x}{N_a}$$

where *Cx and Cf are unknown and standard capacitances respectively,*

Rx and Ra are unknown and standard resistances,

Nx, Na and Ns are the corresponding turns of the transformer ratio windings



- In practical transformers, the voltage ratio slightly differs from the turns ratio due to the no load magnetizing current and is also affected by the load current
- the balance conditions shown above involve errors.
- The errors are classified as the ratio and loading errors and are determined separately and compensated for in the construction.

- useful range from a fraction of one pF to about 100 µF and covers a wide range of frequency from 100 Hz to 100 kHz, the accuracy being better than 0.5%.
- For high voltage applications where sensitive measurements at **fixed frequency** (at 50 Hz) are required, the **current comparator** or the **current ratio method** (Fig. 9.19a) is used.
- This bridge has the **advantage** that **full voltage is applied across** the test capacitor but also has the drawback that a **standard conductance has to be built for high voltages.**

It is difficult to construct a precision conductance suitable for high voltage operation.

This **disadvantage is overcome by generating a low voltage signal Ef proportional to and in phase with the supply vo**ltage as shown in the modified Fig. 9.19b

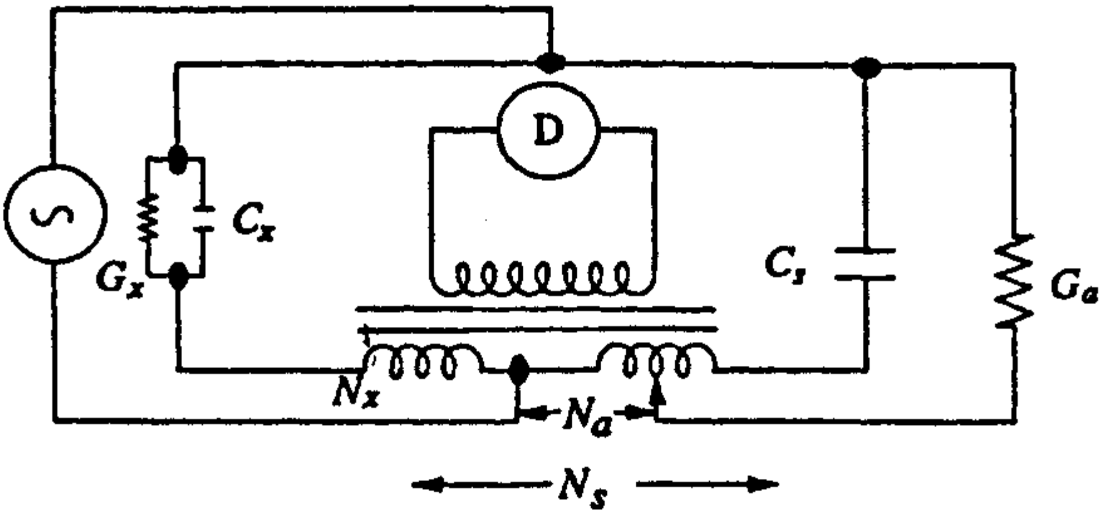


Fig. 9.19a Current comparator bridge