AKGEC/IAP/FM/02

AJAY KUMAR GARG ENGINEERING COLLEGE, GHAZIABAD

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGG.

SESSIONAL TEST – 2 (solution)

Course	: B. Tech.	Semester	: III
Session	: 2017-18	Section	: EN- 1 & 2
Subject	: EMMI	Sub. Code	: REE-302
Max. Marks	: 50	Time	: 2 hours

Section 'A'

1. For measurement purpose, resistances are classified as
   (a) Low resistance : $R < 1\,\Omega$
   (b) Medium Resistance : $1\,\Omega < R < 100\,K\Omega$
   (c) High Resistance : $R > 100\,K\Omega$

2. Expression for unknown Inductance for Hay's Bridge is given by
$$L_x = \frac{R_2 R_3 C_4}{1+(1/Q)^2} \quad ; \quad Q = \frac{1}{\omega C_4 R_4}$$

- Hay's Bridge is suited for the measurement of high Q inductor, especially those inductors having $Q > 10$. For inductors having $Q < 10$, the term $(1/Q)^2$ in the expression for inductor L_x becomes rather important and thus cannot be neglected. Hence this Bridge is not suited for for measurement of coils having Q less than 10.

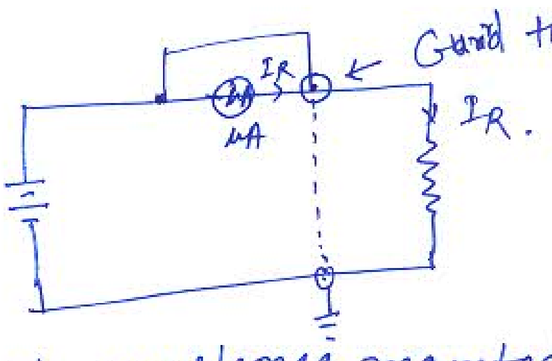
Q3. No of turns in secondary of C.T. is very high compare to primary, therefore, induced voltage on secondary is very high when it is kept open. This high voltage may distroy insulation or may be unsafe for working personnel. Therefore, sec. should never be kept open while primary is energized.

4. Total load accross the secondary winding expressed as the output in V-A at the rated secondary winding voltage, is known as burden on the Instrument transformer.

Burden is the volt-amper loading which is permissible without errors exceeding the limits for the particular class of accuracy.

$\therefore$ Total sec. winding burden $= \dfrac{(E_2)^2}{(\text{sec. winding load})}$

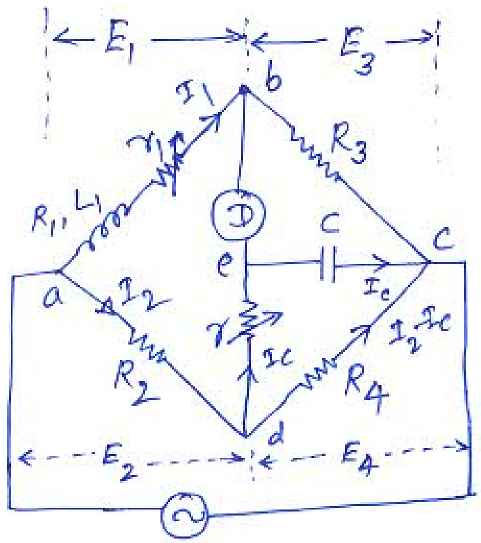
5. Guard circuit is used to eliminate the errors caused by leakage currents over insulation.



when a high resistance mounted on a piece of insulating material is measured by ammeter-voltmeter method, the micro-ammeter reads sum of the current through resistor (R) and the current through leakage path around the Resistor.

Guard wire is provided to bypass this leakage current.

6. Anderson's Bridge:-



L_1 = unknown Induction

R_1 = Resistance of unknown Induction

r_1 = resistance connected in series with un Inductance

r_1, R_2, R_3, R_4 = Known Non-Inductive resistance.

C = Fixed capacitance.

At balance, $V_b = V_e$

$$\Rightarrow \quad \bar{I}_1 (R_1 + r_1 + j\omega L_1) = \bar{I}_2 R_2 + \bar{I}_c r \quad \text{--- (1)}$$

$$\bar{I}_c \left(r + \frac{1}{j\omega c}\right) = (\bar{I}_2 - \bar{I}_c) R_4 \quad \text{--- (2)}$$

$$\bar{I}_1 R_3 = \bar{I}_c \frac{1}{j\omega C} \quad \text{--- (3)}$$

Solving above equations to remove I_1, I_2 & I_c we get

$$R_1 = \frac{R_2 R_3}{R_4} - r_1$$

$$L_1 = \frac{R_3 C}{R_4} \left[r(R_4 + R_2) + R_2 R_4 \right]$$

— Balance equations shows that to obtain easy convergence of balance, alternate adjustment of r_1 and r should be done.

Advantages: (i) In case adjustments are carried out by manipulating control over r_1 and r_1 the become independent of each other. This is a marked superiority over sliding balance condotions met with low Q. coils.

(ii) A study of convergence conditions would reveal that it is much easier to obtain balance in case of this bridge over Maxwell's bridge for low Q-coils.

(iii) A fixed capacitor can be used instead of a variable capacitor in case of Maxwell's bridge

Disadvantages:

— More complex than its prototype Maxwell's bridge.

— An additional junction point increases the difficulty of shielding the bridge.

7. Given,

100/5 A, 50Hz C.T. with bar primary.

Sec. Rated burden = 12.5 VA

Sec. winding current = I_s = 5 A

$\therefore$ Sec. circuit Impedance = $\frac{12.5}{(5)^2} = 0.5\,\Omega$

Sec. " reactance = $2\pi \times 50 \times 0.96 \times 10^{-3}$

$= 0.3\,\Omega$

$\therefore$ sec. phase angle $(\delta) = \sin^{-1}(0.3/0.5) = \sin^{-1}(0.6)$

$\therefore \cos\delta = 0.8, \sin\delta = 0.6$

$N_p = 1$ & $N_s = 196$

$\therefore n = N_s/N_p = 196$

$$K_n = 1000/5 = 200$$

$$I_m = \frac{\text{Magnetizing mmf}}{\text{primary winding turns}} = \frac{16}{1} = 16\,A$$

$$\text{Loss component } (I_e) = \frac{\text{excitation for loss}}{\text{primary winding turns}}$$

$$= \frac{12}{1} = 12\,A.$$

$$\therefore \quad R = n + \frac{I_e \cos\delta + I_m \sin\delta}{I_s}$$

$$= 196 + \frac{12 \times 0.8 + 16 \times 0.6}{5} = 199.84$$

$$\text{Ratio error} = \frac{K_n - R}{R} \times 100 = \frac{200 - 199.84}{199.84}$$

$$= +0.08\%.$$

$$\text{Phase angle error } \theta = \frac{180}{\pi}\left[\frac{I_m \cos\delta - I_e \sin\delta}{n I_s}\right]$$

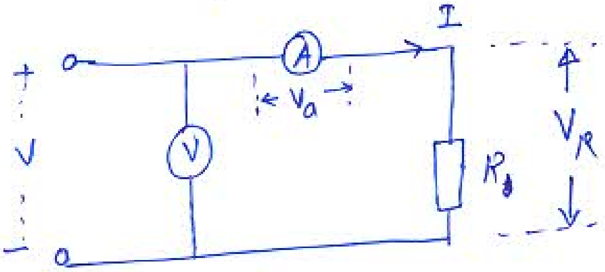
$$= \frac{180}{\pi}\left[\frac{16 \times 0.8 - 12 \times 0.6}{196 \times 5}\right]$$

$$= 19.6' = 0.327^{\circ}$$

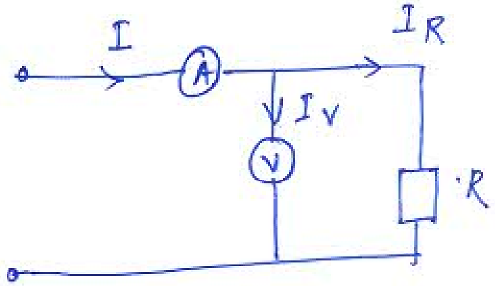
8. Voltmeter-Ammeter Method for measurement of Medium resistance:-

$$\because \quad R = \frac{V}{I}$$

following circuits topologies can be used for measurement of medium resistance.



(a)



(b)

- The measured value of R in both circuit $R_m = \frac{V}{I}$ would be equal to the true value R, if the ammeter resistance is zero and the voltmeter resistance is infinite.

But drop due to ammeter resistance in part 'a' and current through voltmeter in part 'b' give error in measurement.

For the circuit in fig 'a':

$$R_{m1} = \frac{V}{I} = \frac{V_R + V_a}{I} = \frac{IR + IR_a}{I} = R + R_a$$

where R_a = Resistance of ammeter.

$$\therefore \text{True value of } R = R_{m1} - R_a = R_{m1}\left(1 - \frac{R_a}{R_{m1}}\right)$$

if $R_a << R_{m1}$ (resistance to be measured), error in measuremen by circuit in fig 'a' gives negligible error

$$\therefore \text{Relative error}(\epsilon_r) = \frac{R_{m1} - R}{R} = \frac{R_a}{R} \quad \text{—} \ (1)$$

For circuit in fig 'b':

$$R_{m2} = \frac{V}{I} = \frac{V}{I_R + I_V} = \frac{V}{(V/R + V/R_V)}$$

$$\therefore R_{m2} = \frac{R}{1 + R/R_V}$$

$$\therefore R = \frac{R_{m2} R_V}{R_V - R_{m2}} = R_{m2}\left[\frac{1}{1 - R_{m2}/R_V}\right]$$

If $R_V >> R_{m2}$ (Resistance to be measured), error in measurement due to cirut in fig 'b' is negligible.

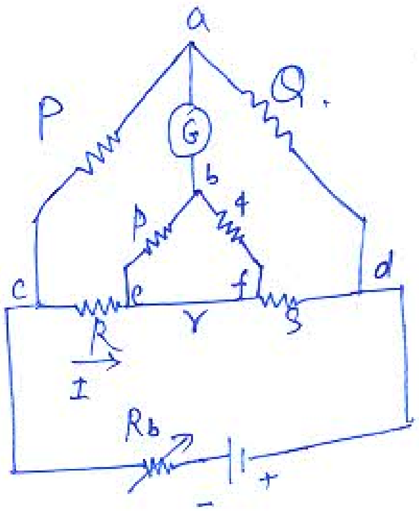
$\therefore$ Relative error $e_r = \frac{R_{m2} - R}{R} = \frac{R_{m2}^2}{R_V R}$.

For optimal value of unknown Resistance

Let relative errors in measurement by using the both methods are equal.

$$\frac{R_a}{R} = \frac{R}{R_V} \Rightarrow \boxed{R = \sqrt{R_a R_V}}$$

9. Measurement of low resistance using kelvin's double bridge:-



- The kelvin double bridge incorporates the idea of a second set of ratio arms. and the use of four terminal resistors for the low resistance arms.

- The second set of ratio arms p and q is used to connect the galvanometer to a point d at the appropriate potential between points 'm' and 'n' to eliminate the effect of connecting lead of resistance r between the known resistance R and the standard resistance 's'

At balance, $V_a = V_b$ $\therefore$ ~~E_{ca}~~ ~~E_a~~

$\therefore$ $E_{ca} = E_{ceb}$

$E_{ca} = \frac{P}{P+Q} E_{cd}$; $E_{cd} = I\left[R+S+\frac{(p+q)r}{p+q+r}\right]$

$E_{amd} = I\left[R + \frac{p}{q+p}\left\{\frac{(p+q)r}{p+q+r}\right\}\right] = I\left[R+\frac{pr}{p+q+r}\right]$

$\therefore$ At balance.

$$\frac{P}{P+Q} \cdot I \cdot \left[R+S+\frac{(p+q)r}{p+q+r}\right] = I \cdot \left[R+\frac{pr}{p+q+r}\right]$$

$$\Rightarrow \boxed{R = \frac{P}{Q}\cdot S + \frac{qr}{p+q+r}\left[\frac{P}{Q}-\frac{p}{q}\right]}$$

If $\frac{P}{Q} = \frac{p}{q}$ [Inner arm ratio is same as outer arm ratio]

$$\boxed{R = \frac{P}{Q}\cdot S}$$

— Therefore, the resistance of connecting lead r has no effect on the measurement, provided that the two sets of ratio arms have equal ratios.

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10. Given, for a single phase potential transformer:—

turns ratio(n) = 3810/63

$E_2 = 63\ V$

$r_{e2} = 2\,\Omega = R_s$

$x_{e2} = 4\,\Omega = X_s$

Sec. burden $= (100 + j200)\Omega$.

~~cosΔ~~ $\tan\Delta = \frac{(200+1)}{100+2} = \frac{201}{102} = 1.97$

$\Delta = 63.1^\circ$

$\cos\Delta = 0.452$, $\sin\Delta = 0.892$

Assuming neglegible exciting currents, ~~and magnetizing currents~~.

$$R \cong \frac{V_p}{V_s} = n + \frac{n I_s (R_s \cos A + X_s \sin A)}{V}$$

$$\theta = \frac{I_s}{V_s}(X_s \cos A - R_s \sin A)$$

$$n = 3810/63 = 60.5$$

$$I_s = \frac{V_s}{|Z|} = \frac{63}{\sqrt{(102)^2 + (200)^2}}$$

$$= 0.279\,A$$

$$\therefore R = 60.5 + \frac{60.5 \times 0.279 (2 \times 0.452 + 1 \times 0.892)}{63}$$

$$= 60.981 \simeq 61$$

$$\text{Ratio error} = \frac{K_n - R}{R} = \frac{60.5 - 61}{61}$$

$$= 0.80\%$$

phase angle error

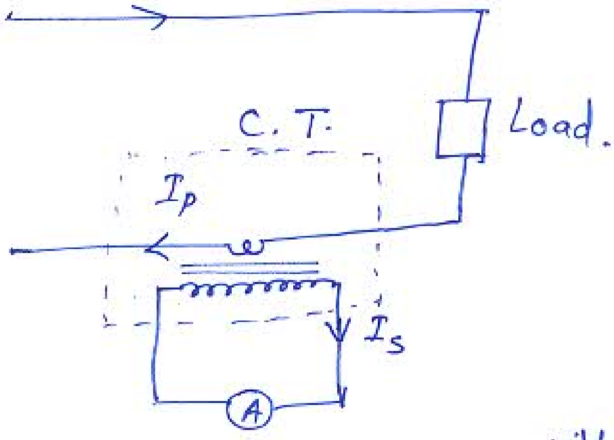
$$\tan\theta = \frac{I_s}{V_s}(X_s \cos A - R_s \sin A)$$

$$= \frac{0.279}{63}\left[1 \times 0.452 - 2 \times 0.892\right]$$

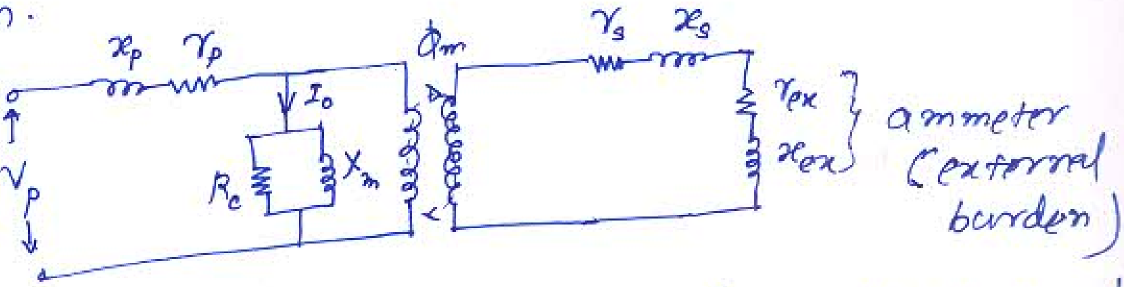
$$= -0.00589$$

$$\Rightarrow \boxed{\theta = -0.337^{\circ}}$$

11. Ratio and phase angle error in Current transformer:-



Equivalent circuit of C.T. with ammeter as external burden.



Various quantities and parameters from above circuit are as follows.

n = turns ratio = $\dfrac{\text{Number of sec winding turns}}{\text{Number of primary winding turns}}$,

r_s = resistance of sec. winding

x_s = reactance of " "

r_{ex} = resistane of ext Burden.

x_{ex} = reactance of " "

E_p = primary winding induced voltage

E_s = Sec. winding induced voltage

N_p = primary Number of turns.

N_s = sec. " "

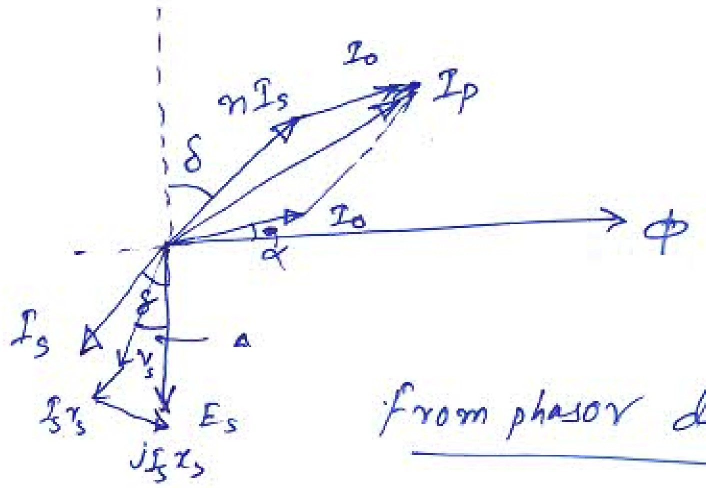
Δ = phase angle of sec. winding load circuit (ext. burden)

$= \tan^{-1} \frac{x_{en}}{r_{en}}$.

δ = phase angle of sec. winding impedance.

$= \tan^{-1} \left(\frac{x_s + x_{en}}{r_s + r_{en}} \right)$

Phasor diagram.



from phasor diagram, I_p can be written by using parallelogram law of vector addition.

$$I_p^2 = (nI_s)^2 + 2(nI) \cdot I_0 \cos(90^\circ - \alpha - \delta) + I_0^2$$

$\therefore$ Transformation ratio

$$R = \frac{I_p}{I_s} = \frac{\sqrt{(nI_s)^2 + 2nI_sI_0 \sin(\alpha+\delta) + I_0^2}}{I_s}$$

usually I_0 is less than 1% of I_p and I_p is very nearly equal to nI_s

$\therefore \; I_0 << nI_s$

$$\therefore R \cong \frac{\left[n^2 I_s^2 + 2n I_s I_0 \sin(\alpha+\delta) + I_0^2 \sin^2(\alpha+\delta)\right]^{1/2}}{I_s}$$

$$= \frac{nI_s + I_0 \sin(\alpha+\delta)}{I_s}$$

$$= n + \frac{I_0}{I_s}\sin(\alpha+\delta) = n + \frac{I_m \sin\delta + I_e \cos\delta}{I_s}.$$

$$\left[\because \begin{array}{l} I_m = I_0 \cos\alpha \\ I_e = I_0 \sin\alpha \end{array}\right]$$

$$\therefore \text{Ratio Error} = \frac{K_n - R}{R} \times 100\,\%.$$

Phase angle Error (θ)

From phasor, $\tan\theta = \dfrac{I_0 \cos(\delta+\alpha)}{nI_s + I_0 \sin(\delta+\alpha)}$

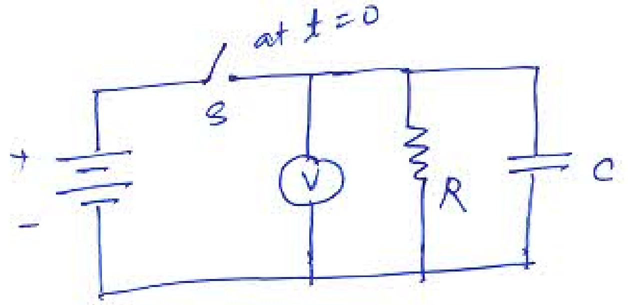
$\because \theta$ is very small,

$$\theta \simeq \frac{I_0 \cos(\alpha+\delta)}{nI_s + I_0 \sin(\alpha+\delta)} \cong \frac{I_0 \cos(\alpha+\delta)}{nI_s} \text{ rad}$$

$$\boxed{\therefore\ \theta = \frac{180}{\pi}\left(\frac{I_m \cos\delta - I_e \sin\delta}{nI_s}\right)}$$

12. Measurement of high resistance

(a) <u>Loss of charge method</u> : -



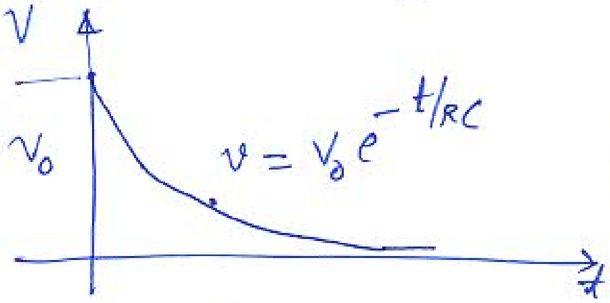
- In this method, the insulation resistance R to be measured is connected in parallel with a capacitor C and an electrostatic voltmeter.
- The capacitor is charged to some suitable voltage v and is then allowed to discharge through the unknown resistance.

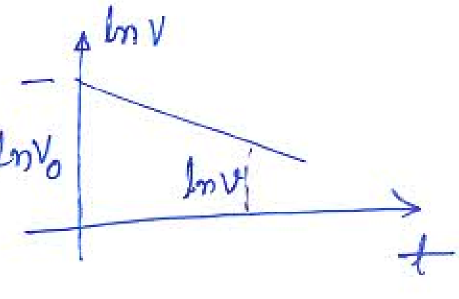
Let C is charged upto a voltage V_0. and now at $t=0$ switch 'S' is opened.

Let after time 't', Voltage at capacitor is V, then

$$V = V_0 e^{-t/RC}$$

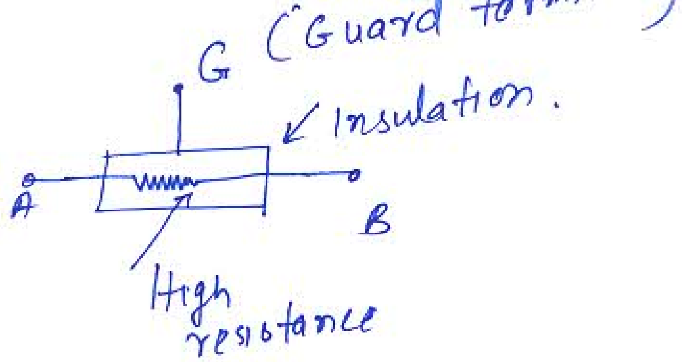
$$\therefore \; R = \frac{t}{C \log_e V_0/V} = \frac{0.4343\, t}{C \log_{10}(V_0/V)}$$





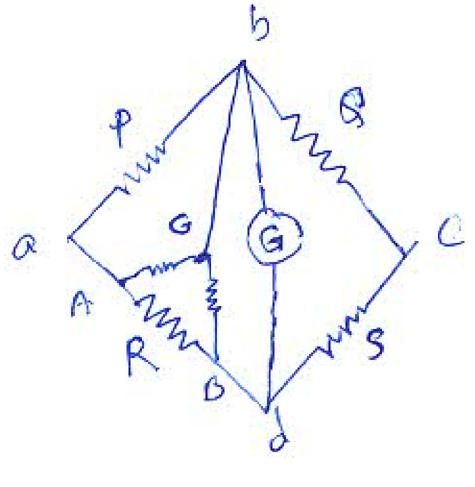
Therefore, by measuring change in voltage across capacitor for a given time interval, R can be calculated as above.

(b) Megohm Bridge :-



- The resistance R is between main terminals A and B and the leakage resistances R_{AG} and R_{BG} between the main terminals A and B to form a "Three terminal resistance".
- If such a high resistance is measured by using an ordinary Wheatstone's bridge, a large error (approx 33%) is introduced due to leakage resistances.

Therefore, a modified bridge with the guard connection G connected as shown in fig. below, is used to reduce the error in measurement.



- The resistance R_{BG} is put in parallel with the Gal. and thus it has no effect on the balance and only effects the sensitivity of the galvanometer slightly.

- The resistance $R_{AG} = 100 M\Omega$ is put in parallel with a resistance p, therfore, the measured value has an error of 0.01%. and this error is entirely negligible for measurement of this type.

Therefore, for the measurement of high resistance, megohm can be implemented as below.