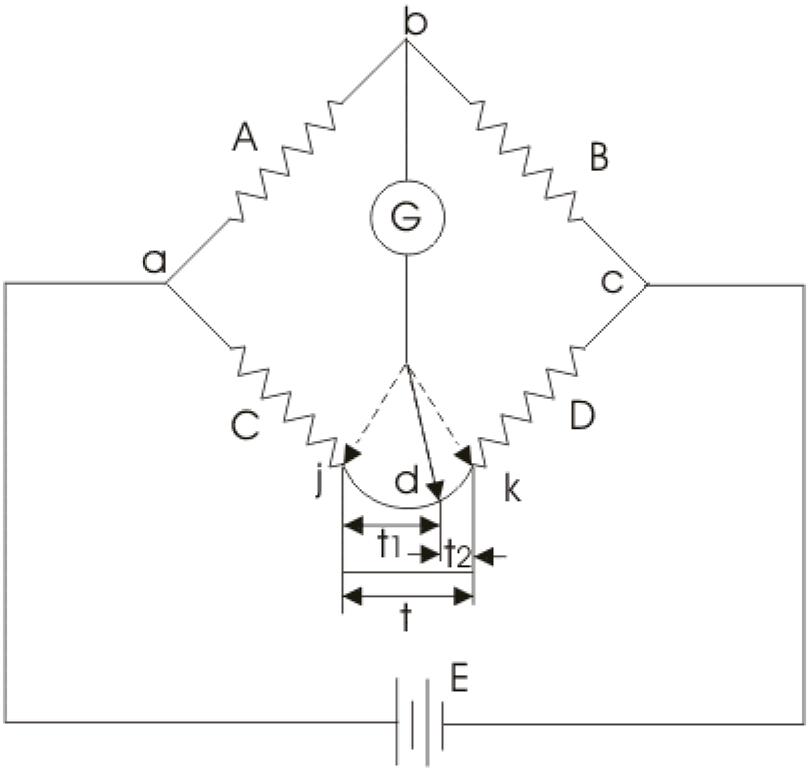
1 **With neat sketch explain Kelvin's double bridge and obtain an expression for balancing condition. Write advantage and disadvantage.**

SOL:



$$C + t_1 = \frac{A}{B}(D + t_2)$$

$$Also\ we\ have\ \frac{t_1}{t_2} = \frac{A}{B} \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

$$So,\ \frac{t_1}{t_1 + t_2} = \frac{A}{A + B} \Rightarrow t_1 = \frac{A}{A + B} \times t$$

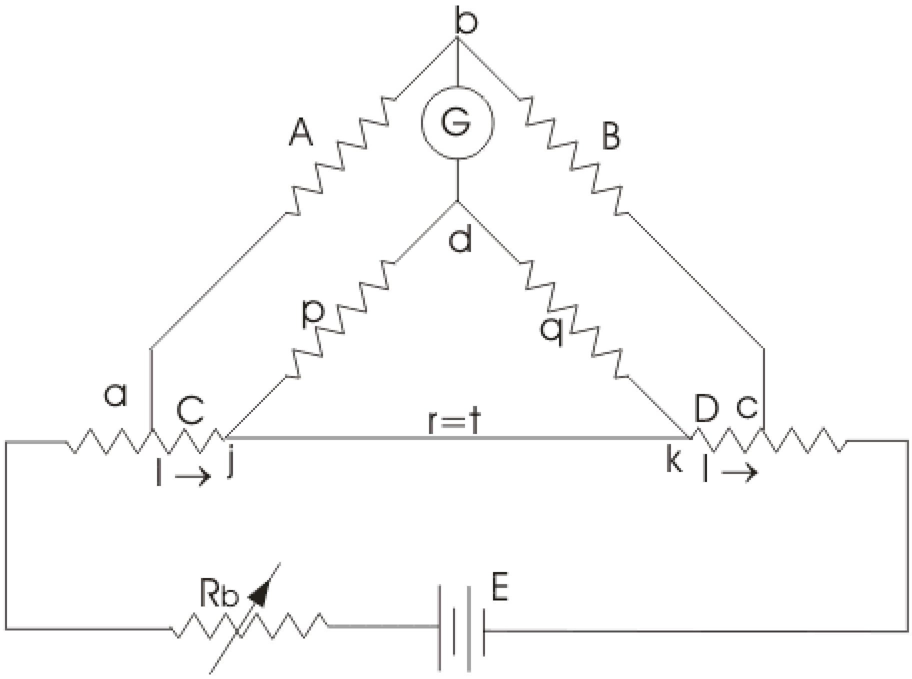
$$As\ t_1 + t_2 = t\ and\ t_2 = \frac{B}{A + B} \times t$$

We can write equation (1) as

$$C + \frac{A}{A + B} \times t = \frac{A}{B} \times \left(D + \frac{B}{A + B} \times t\right)$$

$$It\ implies\ that\ C = \frac{A}{B} \times D$$

As we have discussed that Kelvin Bridge is a modified Wheatstone bridge and provides high accuracy especially in the measurement of low resistance. Now the question that must be arise in our mind that where do we need the modification. The answer to this question is very simple – it is the portion of leads and contacts where we must do modification because of these there is an increment in net resistance.



$$Hence,\ E = \frac{A}{A + B} \times F$$

$$\Rightarrow F = I \times \left(C + D + \frac{p + q}{p + q + t} \times t\right)$$

$$Hence,\ G\ i.e.\ (voltage\ drop\ between\ a\ and\ d) = I \times \left(C + \frac{p \times t}{p + q + t}\right)$$

$$or\ \frac{A}{A + B} \times I\left(C + D + \frac{p + q}{p + q + t} \times t\right) = I \times \left(C + \frac{p}{p + q + t} \times t\right)$$

$$\Rightarrow C = \frac{A}{B} \times D + \frac{q}{p + q + t}\left(\frac{P}{Q} - \frac{p}{q}\right) \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

$$If\ \frac{A}{B} = \frac{p}{q}\ then\ C = \frac{A}{B} \times D$$

In this the ratio arms p and q are used to connect the galvanometer at the correct point between j and k to remove the effect of connecting lead of electrical resistance t. Under balance condition voltage drop between a and b (i.e. E) is equal to F (voltage drop between a and c)

For zero galvanometer deflection, E = F

2. Explain the construction of electrodynamometer type wattmeter and derive the torque expression.

SOL: Construction and Working Principle of Electrodynamometer Type Wattmeter

Now let us look at constructional details of electrodynamometer. It consists of following parts.

There are two types of coils present in the electrodynamometer. They are :

Moving Coil

Moving coil moves the pointer with the help of spring control instrument. Limited of current flows through the moving coil so as to avoid heating. So in order to limit the current we have connected the high value resistor in series with the moving coil. The moving is air cored and is mounted on a pivoted spindle and can move freely. In electrodynamometer type wattmeter, moving coil works as pressure coil. Hence moving coil is connected across the voltage and thus the current flowing through this coil is always proportional to the voltage.

Fixed Coil

The fixed coil is divided into two equal parts and these are connected in series with the load, therefore the load current will flow through these coils. Now the reason is very obvious of using two fixed coils instead of one, so that it can be constructed to carry considerable amount of electric current. These coils are called the current coils of electrodynamometer type wattmeter. Earlier these fixed coils are designed to carry the current of about 100 amperes but now the modern wattmeter are designed to carry current of about 20 amperes in order to save power.

Control System

Out of two controlling systems i.e.

Gravity control

Spring control, only spring controlled systems are used in these types of wattmeter. Gravity controlled system cannot be employed because there will be appreciable amount of errors.

Damping System

Air friction damping is used, as eddy current damping will distort the weak operating magnetic field and thus it may leads to error.

Scale

There is uniform scale which is used in these types of instrument as moving coil moves linearly over a range of 40 degrees to 50 degrees on either side.

Now let us derive the expressions for the controlling torque and deflecting torques. In order to derive these expressions let us consider the circuit diagram given below:

Electrodynamometer Type Wattmeter

We know that instantaneous torque in electrodynamic type instruments is directly proportional to the product of instantaneous values of currents flowing through both the coils and the rate of change of flux linked with the circuit.

Let I1 and I2 be the instantaneous values of currents in pressure and current coils respectively. So the expression for the torque can be written as:

Where, x is the angle.

Now let the applied value of voltage across the pressure coil be

Assuming the electrical resistance to the pressure coil be very high hence we can neglect reactance with respect to its resistance. In this the impedance is equal to its electrical resistance therefore it is purely resistive.

The expression for instantaneous current can be written as I2 = v / Rp where Rp is the resistance of pressure coil.

If there is phase difference between voltage and electric current, then expression for instantaneous current through current coil can be written as

As current through the pressure coil is very very small compared to the current through current coil hence current through the current coil can be considered as equal to total load current.

Hence the instantaneous value of torque can be written as

Average value of deflecting torque can be obtained by integrating the instantaneous torque from limit 0 to T, where T is the time period of the cycle.

Controlling torque is given by Tc = Kx where K is spring constant and x is final steady state value of deflection.

3. What do you mean by sensitivity?Derive an expression for galavanometer current under unbalanced condition.

SOL:

$$V_{TH} = \frac{E R_3 \Delta R}{(R_3 + R_4)^2} \quad \text{... (12)}$$

and now

$$R_{eq} = (R_1 || R_2) + (R_3 || R_4 + \Delta R)$$

$$= \frac{R_3 (R_4 + \Delta R)}{R_3 + R_4 + \Delta R} + \frac{R_1 R_2}{R_1 + R_2}$$

Neglecting ΔR compared to R_3 and R_4,

$$R_{eq} = \frac{R_3 R_4}{R_3 + R_4} + \frac{R_1 R_2}{R_1 + R_2} \quad \text{... (13)}$$

$$\therefore \quad I_g = \frac{V_{TH}}{R_{eq} + R_g} \quad \text{... (14)}$$

For bridge with equal arms $R_1 = R_2 = R_3 = R_4 = R$ then

$$V_{TH} = \frac{E R \Delta R}{4 R^2} = \frac{E \Delta R}{4 R}$$

and

$$R_{eq} = \frac{R^2}{2 R} + \frac{R^2}{2R} = R$$

$$\therefore \quad \boxed{I_g = \frac{\frac{E \Delta R}{4R}}{R + R_g} = \frac{E(\Delta R / 4R)}{R + R_g}} \quad \text{... (15)}$$

4. With proper phasor diagram, derive the balancing equation for Anderson bridge.

SOL:

16.5.4 Anderson's Bridge

This bridge, in fact, is a modification of the Maxwell's inductance capacitance bridge. In this method, the self-inductance is measured in terms of a standard capacitor. This method is applicable for precise measurement of self-inductance over a very wide range of values.

Figure 16.6 shows the connections and the phasor diagram of the bridge for balanced conditions.

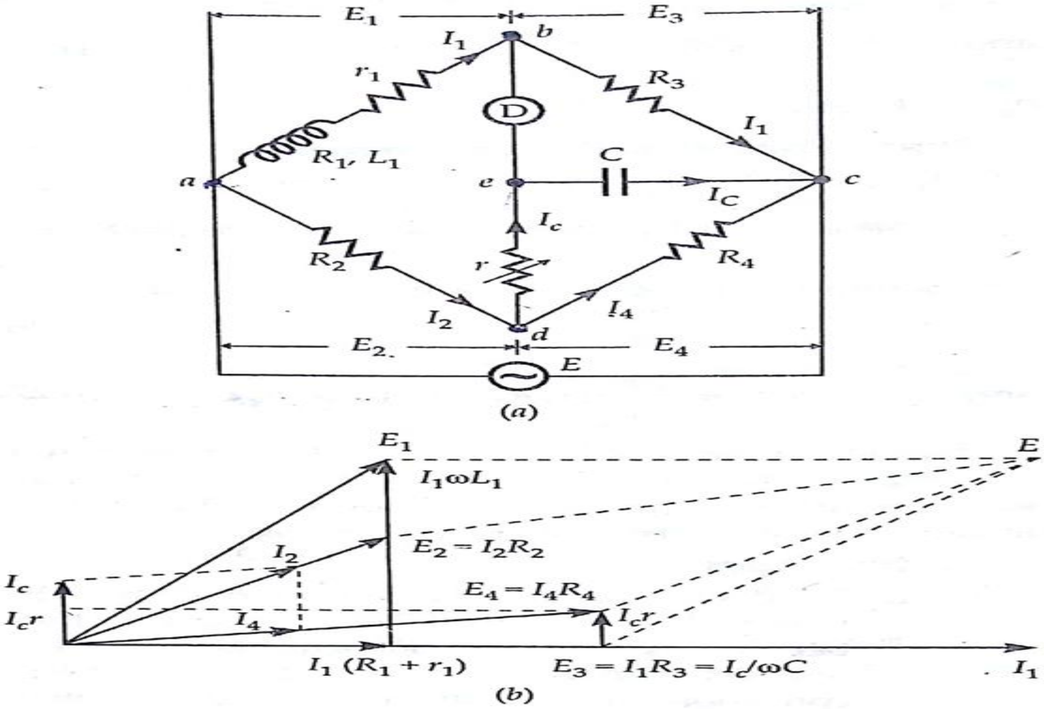


Fig. 16.6 Anderson's Bridge.

Let

L_1 = self-inductance to be measured,

R_1 = resistance of self-inductor,

r_1 = resistance connected in series with self-inductor,

r, R_2, R_3, R_4 = known non-inductive resistances,

and C = fixed standard capacitor.

At balance,

$$I_1 = I_3 \text{ and } I_2 = I_c + I_4$$

Now, $I_1 R_3 = I_c \times \dfrac{1}{j\omega C}$

$\therefore$ $I_c = I_1 j\omega C R_3$.

Writing the other balance equations

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_c r$$

and $$I_c\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_c) R_4.$$

Substituting the value of I_c in the above equations, we have

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_1 j\omega C R_3 r$$

or $$\boldsymbol{I}_1(r + R_1 + j\omega L_1 - j\omega C R_3 r) = \boldsymbol{I}_2 R_2 \quad \text{...}(i)$$

and $$j\omega C R_3 \boldsymbol{I}_1\left(r + \frac{1}{j\omega C}\right) = (\boldsymbol{I}_2 - \boldsymbol{I}_1 j\omega C R_3) R_4$$

or $$\mathbf{I}_1(j\omega C R_3 r + j\omega C R_3 R_4 + R_3) = \boldsymbol{I}_2 R_4 \quad \text{...}(ii)$$

From Eqns. (*i*) and (*ii*), we obtain

$$\boldsymbol{I}_1(r_1 + R_1 + j\omega L_1 - j\omega C R_3 r) = \boldsymbol{I}_1\left(\frac{R_2 R_3}{R_4} + \frac{j\omega C R_2 R_3 r}{R_4} + j\omega C R_3 R_2\right)$$

Equating the real and the imaginary parts,

$$R_1 = \frac{R_2 R_3}{R_4} - r_1 \quad \text{...(16.26)}$$

and $$L_1 = C\frac{R_3}{R_4}[r(R_4 + R_2) + R_2 R_4] \quad \text{...(16.27)}$$

An examination of balance equations reveals that to obtain easy convergence of balance, alternate adjustments of r_1 and r should be done as they appear in only one of the two balance equations.

Advantages :

1. In case adjustments are carried out by manipulating control over r_1 and r, they become independent of each other. This is a marked superiority over sliding balance conditions met with low Q coils when measuring with Maxwell's bridge. A study of convergence conditions would reveal that it is much easier to obtain balance in the case of Anderson's bridge than in Maxwell's bridge for low Q-coils.
2. A fixed capacitor can be used instead of a variable capacitor as in the case of Maxwell's bridge.
3. This bridge may be used for accurate determination of capacitance in terms of inductance.

Disadvantages :

1. The Anderson's bridge is more complex than its prototype Maxwell's bridge. The Anderson's bridge has more parts and is more complicated to set up and manipulate. The balance equations are not simple and in fact are much more tedious.
2. An additional junction point increases the difficulty of shielding the bridge.

Considering the above complication of the Anderson's bridge, in all the cases where a variable capacitor is permissible the more simple M

5. **Explain the construction and working of 1-phase induction type energy-meter. Discuss the various adjustments in brief required in energy-meter for accurate reading.**

SOL: The induction type single phase energy meters are universally used for energy measurements in domestic and industrial establishments since they possess some of the very useful features such as :

Accurate characteristics

Lower friction

Higher torque weight ratio

Cheaper manufacturing methods and

Ease of maintenance.

Constructional Details

The single phase induction energy meter is schematically shown in figure.Basically, it has four systems of operation: driving system, moving system, braking system and registering system.

Driving system consists of a series magnet and a shunt magnet. The coil of the series magnet is excited by load current while that of the shunt magnet is excited by a current proportional to the supply voltage. These two coils are respectively referred as current coil and potential coil (or pressure coil) of the energy meter.

Moving system consists of a freely suspended, light aluminum disc mounted on an alloy shaft and placed admidst the air-gap of the two electromagnets.

Braking system consists of a position-adjustable permanent magnet placed near one edge of the disc. When the disc rotates in the gap between the two poles of the brake magnet, eddy currents are set up in the disc. These currents react with the brake magnet field and provide the required braking torque damping out the disc motion if any, beyond the required speed.. The braking torque can be adjusted as required by varying the position of the braking magnet.

Recording system is a mechanism used to record continuously a number which is proportional to the revolutions made by the disc. Thus it is the counter part of the pointer and scale of indicating instruments. The shaft that supports the disc is connected by a gear arrangement to a clock mechanism on the front of the meter. It is provided with a decimally calibrated read out of the total energy consumption in KWh.

6.

$$V_{TH} = \frac{E R_3 \Delta R}{(R_3 + R_4)^2} \quad \text{... (12)}$$

and now $R_{eq} = (R_1 || R_2) + (R_3 || R_4 + \Delta R)$

$$= \frac{R_3 (R_4 + \Delta R)}{R_3 + R_4 + \Delta R} + \frac{R_1 R_2}{R_1 + R_2}$$

Neglecting ΔR compared to R_3 and R_4,

$$R_{eq} = \frac{R_3 R_4}{R_3 + R_4} + \frac{R_1 R_2}{R_1 + R_2} \quad \text{... (13)}$$

$$\therefore \quad I_g = \frac{V_{TH}}{R_{eq} + R_g} \quad \text{... (14)}$$

For bridge with equal arms $R_1 = R_2 = R_3 = R_4 = R$ **then**

$$V_{TH} = \frac{E R \Delta R}{4 R^2} = \frac{E \Delta R}{4 R}$$

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$$\therefore \quad \boxed{I_g = \frac{\frac{E \Delta R}{4R}}{R + R_g} = \frac{E(\Delta R / 4R)}{R + R_g}} \quad \text{... (15)}$$

7.

7(a) Actual energy consumed at half load during 138 sec.

$= VI\cos\phi \, t \times 10^{-3} = 230 \times 5 \times 1 \times (138/3600) \times 10^{-3}$

$= 44.08 \times 10^{-3}$ KWh

Energy recorded $= \frac{\text{number of revolutions made}}{\text{revolutions / KWhr}}$

$= \frac{80}{1800} = 44.4 \times 10^{-3}$ KWhr

% Error $= \frac{44.4 - 44.08}{44.08} \times 100 = 0.817\%$

7(b) (a) Power consumed by load $= 220 \times 20 \times 0.6$
$= 2640W$

(i) The wattmeter measures the loss in the current coil for this connection.

Loss in current coil $= I^2 R_c = (20)^2 \times 0.03 = 12W$

Error $= (12/2640) \times 100 = 0.45\%$

(ii) The wattmeter measures the loss in the press coil circuit for this connection.

Loss in pressure coil circuit $= V^2/R_p = (220)^2/6000$
$= 8.06W$

Error $= (8.06/2640) \times 100 = 0.31\%$

(b) For equal errors for the two connections

$I^2 R_c = V^2/R_p$ or $I^2 = \frac{V^2}{R_p R_c} = \frac{(220)^2}{0.03 \times 6000} \Rightarrow I = 16.4A.$