2017

MADE EASY WORKBOOK

Detailed Explanations of Try Yourself Questions

Electrical Engineering

Measurements

MADE EASY Publications

1 Error Analysis & Basics

Detailed Explanation of Try Yourself Questions

T1 : Solution

(d)

Probable error, $$\delta I = \sqrt{\left(\frac{\partial I}{\partial I_1}\right)^2 \delta I_1^2 + \left(\frac{\partial I}{\partial I_2}\right)^2 \delta I_2^2}$$

Here, $$I = I_1 + I_2$$

So, $$\frac{\partial I}{\partial I_1} = \frac{\partial I}{\partial I_2} = 1$$

$$\delta I = \sqrt{(1)^2(1)^2 + (1)^2(2)^2} = 2.24 \text{ A}$$

therefore, $$I = 300 \pm 2.24 \text{ A}$$

T3 : Solution

Bridge is under balanced condition.

So, $$R_1R_4 = R_2R_3$$

$$R_4 = \frac{(500 \pm 5\%)(200 \pm 5\%)}{(250 \pm 5\%)} = 400 \pm 15\%$$

T4 : Solution

$$R_{eq.} = R_1 + R_2 + R_3$$
$$= (37 \pm 2\%) + (50 \pm 2\%) + (75 \pm 2\%)$$
$$= 162 \pm 2\%$$

2 Indicating Instruments

Detailed Explanation of Try Yourself Questions

T1 : Solution

$$S_{dc} = \frac{1}{I_{fs}} = \frac{1}{1\times 10^{-3}} = 1000\ \Omega/\text{v}$$

$$R_m = S_{dc}v = 1000 \times 1 = 1000\ \Omega$$

$\because$ $$R_s = 0.45 \times 1000 \times 10 - 1000$$

$$R_s = 3.5\ \text{k}\Omega$$

T2 : Solution

(d)

Average value of rectangular current wave $= \sqrt{\frac{1}{2T}\left[(12^2 \times T) + (5^2 \times T)\right]} \simeq 9.2$

$$\text{Average volts} = 9.2 \times 10 = 92\ \text{V}$$

The MI meter will read 92 V.

T3 : Solution

For the range extension of electrostatic voltmeter the capacitor is connected in series with meter and its value is given by

$$C_s = \frac{C_v}{m-1}$$

Where $$m = \frac{V}{v} = \frac{20\ \text{kV}}{2\ \text{kV}} = 10$$

So, $$C_s = \frac{0.5}{10-1} = 0.05\ \text{pF}$$

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3 Measurement of Power & Energy

Detailed Explanation *of* Try Yourself Questions

T1 & T2 : Sol.

Total power in the circuit, $P = W_1 + W_2 = 500 \text{ W} + (-100) \text{ W} = 400 \text{ W}$

Power factor of the circuit, $\cos\phi = \cos\left[\tan^{-1}\left\{\left[\frac{W_1 - W_2}{W_1 + W_2}\right].\sqrt{3}\right\}\right]$

$$= \cos\left[\tan^{-1}\left\{\left[\frac{0.5-(-0.1)}{0.5+(-0.1)}\right].\sqrt{3}\right\}\right]$$

$$= \cos\left[\tan^{-1}(1.5 \times \sqrt{3})\right] = 0.359$$

Load current per phase, $I_P = \frac{P}{\sqrt{3}\,V_L \cos\phi} = \frac{400}{\sqrt{3} \times 440 \times 0.359} = 1.462 \text{ A}$

Load impedance per phase, $Z_p = \frac{V_p}{I_p} = \frac{440/\sqrt{3}}{1.462} = 173.76\ \Omega$

Load resistance per phase, $R_p = Z_p \cos\phi = 62.38\ \Omega$

Load reactance per phase, $X_p = Z_p \sin\phi = 162.18\ \Omega$

Reading of wattmeter B will be zero when p.f. $= \cos\phi' = 0.5$

or $\phi' = 60°$

Since there is no change in resistance,

Reactance in the circuit per phase,

$$X_p' = R_p \tan\phi'$$

$$X_p' = 62.38 \times \sqrt{3} = 108.045\ \Omega$$

value of capacitive reactance to be introduced in each phase $= X_p - X_p'$

$$= 162.18\ \Omega - 108.045\ \Omega$$

$$= 54.135\ \Omega$$

T3 : Solution

Case-1:

$$\text{p.f.} = 1 \Rightarrow \phi = 0°$$
$$P_m = V_L I_L \sin(\Delta - \phi)$$
$$P_m = V_L I_L \sin(88° - 0°)$$
$$P_T = V_L I_L \sin(90° - 0°)$$
$$\%\ \text{error} = \frac{P_m - P_T}{P_T} \times 100$$
$$= \frac{\sin(88°) - \sin(90°)}{\sin(90°)} \times 100 = -0.061\%$$

Case-2:

$$\text{p.f.} = 0.5 \Rightarrow \phi = 60°$$
$$P_m = V_L I_L \sin(88° - 60°)$$
$$P_m = V_L I_L \sin(28°)$$
$$P_T = V_L I_L \sin(90° - 60°)$$
$$P_T = V_L I_L \sin 30°$$
$$\%\ \text{error} = \frac{\sin(28°) - \sin(30°)}{\sin(30°)} \times 100 = -6.1\%$$

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4 Power Factor Meter, Potentiometer, Flux Meter, Instrumentation Transformers

Detailed Explanation of Try Yourself Questions

T1 : Solution

(c)

$$\text{Phase angle error for CT is } = \frac{180}{\pi}\left(\frac{I_m \cos\delta - I_e \sin\delta}{K_t\, I_s}\right)\text{degree}$$

Here,
$$K_t = \frac{1000}{5} = 200,\ I_s = 5 \text{ A}$$
$$I_m = 11 \text{ A}$$
$$I_e = 6.5 \text{ A}$$
$$\delta = 30^\circ$$

$$\text{So, phase angle error } = \frac{180}{\pi}\left(\frac{11\cos 30^\circ - 6.5\sin 30^\circ}{200\times 5}\right) = 0.359^\circ$$

T2 : Solution

(b)

Secondary circuit phase angle, $\delta = \tan^{-1}\left(\frac{1}{1.5}\right) = 33.69^\circ$

$$\cos\delta = \cos 33.39^\circ = 0.835$$

or,
$$\sin\delta = \sin 33.69^\circ = 0.555$$

Turn ratio,
$$K_t = \frac{N_s}{N_p} = \frac{300}{1} = 300$$

Magnetizing current,
$$I_m = \frac{\text{Magnetising mmf}}{N_p} = \frac{100}{1} = 90 \text{ A}$$

Secondary circuit burden impedance = $\sqrt{(1.5)^2 + (1.0)^2} = 1.8\ \Omega$

Secondary induced voltage, $E_s = 5 \times 1.8 = 9$ V

Primary induced voltage, $E_p = \dfrac{E_s}{300} = \dfrac{9\text{ V}}{300}$

Loss component, $I_w = \dfrac{\text{iron loss}}{E_p} = \dfrac{1.2}{(9/300)} = 40$ A

Phase angle, $\theta = \dfrac{180}{\pi}\left(\dfrac{I_m \cos\delta - I_w \sin\delta}{K_t I_s}\right)$

$$= \frac{180}{\pi}\left(\frac{100 \times 0.835 - 40 \times 0.555}{300 \times 5}\right) = 2.34^\circ$$

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5 Measurement of R, L, C Bridges

Detailed Explanation of Try Yourself Questions

T1 : Solution

Schering bridge D-factor = $\omega C_x R_x$ after substituting C_x and R_x.

$$\text{D-factor} = \omega R_1 C_1$$
$$= 2\pi \times 10^3 \times 10^3 \times 0.5 \times 10^{-6}$$
$$= 3.14$$

T2 : Solution

(b)

At balance,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\frac{10\times10^3 \times X_C}{10\times10^3 + X_C}\times Z = 500\times10^3$$

as,

$$X_C = \frac{1}{j\omega c} = \frac{1}{j\times100\pi\times100\times10^{-9}} = -j\frac{10^5}{\pi}$$

∴

$$\frac{-j10^4\times10^5}{\pi\left(10^4-\frac{j\times10^5}{\pi}\right)}\times 2 = 5\times10^5$$

⇒

$$\frac{-j10^3}{1000\pi - j10^4}(R+jX) = 5$$

⇒

$$-jR + X = 5\pi - j5\times10$$

⇒

$$R = 50\ \Omega$$

and

$$L = \frac{5}{2\times50} = 50\text{ mH}$$

T3 : Solution

Since r is negligible and P, Q, p and q have large values, the effect of ratios arms can be neglected for the purpose of calculation of current,

$$\therefore \qquad I = \frac{E}{R_b + R + S} \qquad \text{...(1)}$$

and $$R = \frac{P}{Q}\cdot S = \frac{1000}{1000}\times 0.001 = 0.001\ \Omega$$

From equation (1), $$I = \frac{100}{5 + 0.001 + 0.001} \cong 20\text{ A}$$

T4 : Solution

$$R_3 = 5\ \Omega,$$
$$C = 1\text{ mF},$$
$$R_1 = 160\ \Omega,$$
$$R_2 = 20\ \Omega$$

By using balance equation, $$R = \frac{R_2 R_1}{R_3}$$

$$L = R_2\, R_1 C$$

and $$\text{quality factor } = Q = \frac{\omega L}{R}$$

So, $$R = \frac{20\times 160}{5} = 640\ \Omega$$

$$L = 20 \times 160 \times 1 \times 10^{-3} = 3.2\text{ H}$$

$$Q = \frac{2\pi\times 50\times 3.2}{640} = 1.57$$

T5 : Solution

Measured value of resistance $= 90\ \Omega$

Resistance of voltmeter, $R_v = 2000\ \Omega$

Voltage across voltmeter, $V = 180$

$$\text{Current through voltmeter} = \frac{V}{R_V} = \frac{180}{2000} = 0.09\text{ A}$$

Current through resistance, $(R) = I_R = 2 - I_V = 2 - 0.09$

$\Rightarrow$ $I_R = 1.91$ A

True value of resistance, $$\frac{V}{I_R} = \frac{180}{1.91} = 94.24\,\Omega$$

$$\%\text{ error} = \frac{\text{Measured value} - \text{True value}}{\text{True value}}\times 100$$

$$= \frac{90 - 94.24}{94.24}\times 100 = -4.5\%$$

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6 CRO, Q-meter

Detailed Explanation *of* Try Yourself Questions

T1 : Solution

Using the equation,

$$V_{p-p} = \left(\frac{\text{volts}}{\text{div}}\right) \times \left(\frac{\text{no. of div}}{1}\right)$$

$$V_{p-p} = 0.5\text{ V} \times 3 = 1.5\text{ V}$$

T2 : Solution

The period of the signal is calculate using the equation

$$T = \left(\frac{\text{time}}{\text{div}}\right) \times \left(\frac{\text{no. of div}}{\text{cycle}}\right)$$

$$T = 2\text{ μs} \times 4 = 8\text{ μs}$$

Hence, frequency is

$$f = \frac{1}{T} = \frac{1}{8\text{ μs}} = 125\text{ kHz}$$

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