Signals & Networks Laboratory Experiment Manual

Department of Electrical Engineering, I.I.T. Kharagpur

Experiment No. : 1

Maximum power transfer and Reciprocity theory

Objective: Verification of Maximum Power Transfer theorem and Reciprocity theorem.

Theory: Maximum power is transfer from a source of given voltage and an initial impedance to the load impedance Z_C in a circuit (Fig: 1) under three different condition.

a) When only Xi is adjustable:

Under this condition the power consumed by the load (I^2R_L) is maximum, when I is maximum, since R_L is constant.

$$I = \frac{V_S}{R_i + jX_i + R_L + JX_L} \quad \text{.................................(1)}$$

$$\Rightarrow \ |I|_{max} = \frac{V_S}{R_i + R_L} \quad \text{..(2)}$$

Where, $X_i = - X_L$

This means that if the Load reactance X_L is made equal in magnitude and opposite in sign to the internal reactance X_i, the power is transferred maximum.

b) When only R_L are adjustable:

From equation (1) in section (a), one may write,

$$P = |I^2| R_L$$

$$= \frac{V_S{}^2}{(R_i + R_L)^2 + (X_i + X_L)^2} * R_L \quad \text{...................... (3)}$$

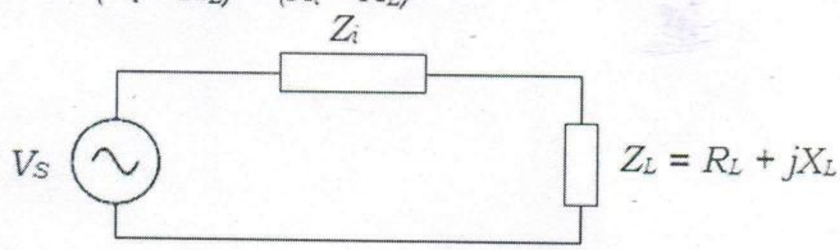

Fig. 1

Differentiating equation (3) w.r.t. R_L and equating to zero, one obtains,

$$R_L = \sqrt{R_i{}^2 + (X_i + X_L)^2} \quad \text{..................................(4)}$$

c) When both R_L and X_L are adjustable:

Under this condition both equation (2) and (4) are valid simultaneously and one obtains,

$$R_L = R_i\ ,\ \ X_L = -X_i$$

Procedure: (A)

i) Take a suitable set of values of V_S, R_i and X_i as shown in fig. (2). You can choose X_i to be inductive (assume the resistive loss of the coil to be negligible).

ii) Next choose a suitable load resistance R_L and a variable capacitance C such that the critical value of C, ($C_0 = \frac{1}{4\pi^2 f^2 L}$) falls within the range of the values of C, available (decade box) in steps. This is to ensure that for a particular frequency, we can obtain the condition;

$$|\ X_C\ | = |\ X_L\ | \quad \text{or,} \quad \frac{1}{\omega C} = \omega L, \text{ for some value of C}$$

within the range provided.

Now for different value of C note down V_3 and V_1,

$$P_L = I^2R_L = I.IR_L = \frac{V_1}{100} \ .\ V_3 = K.V_1V_3 \qquad \text{where } K = \frac{1}{100} = \frac{1}{R_i}$$

Enter the values of the voltage for different values of C and obtain the set corresponding to the maximum value of (V_1V_3). Verify that for this set $V_2 = V_4$.

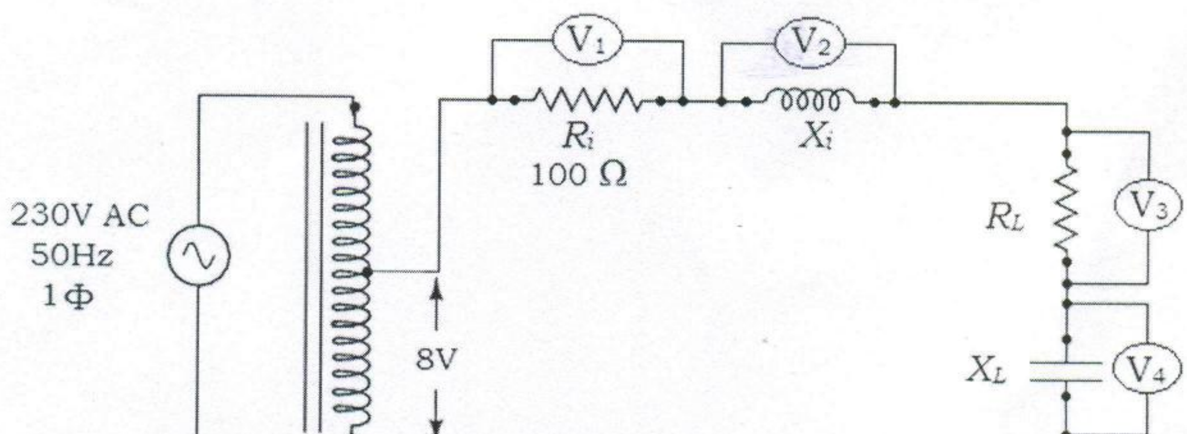

Fig. 2

Enter the data in the following table:

SL. No.	C	V_1	V_3	$(V_1.V_3)$	Max. value $(V_1.V_3)$
1					
2					
3					
4					
5					

(B) Repeat the procedure of part (A), with C fixed and R_L varied. At the point of maximum power, check

$$R_L = \sqrt{R_i^2 + (X_i + X_L)^2} \quad \text{.................................(4)}$$

(C) Repeat the procedure of part (B), varying C and obtain the maximum power condition. Check under this condition;

$V_{RL} = V_{Ri}$ i.e. $V_1 = V_3$

and $V_{XL} = V_{Xi}$ i.e. $V_2 = V_4$

Theory: Consider 2-Port (4-terminal) linear bilateral passive networks as shown in Fig.3. Apply a voltage V_S across terminals 1-1' and I_3 flows through the ammeter connecting terminals 2-2'. Next interchange the positions of the ammeter and the source voltage. The magnitude of the source voltage in this new position is set to V's. Measure the corresponding current I'_1. The reciprocity theorem states that for passive bilateral network;

$$\frac{V_S}{I_3} = \frac{V_{S'}}{I_{1'}}.$$

Procedure: Connect the given resistive network. Apply 220V, single phase phase 50 Hz AC voltage at 1-1' and measure the ammeter current I_3 through 2-2'. Check the ratio V_S/I_3. Now apply the AC voltage across 2-2' with V'_s=110 V and measure the current I'_1 through 1-1' by ammeter. Find the ratio $V_{S'}/I_{1'}$. These two ratio should be identical and calculate branch currents and node voltages for two circuit configurations.

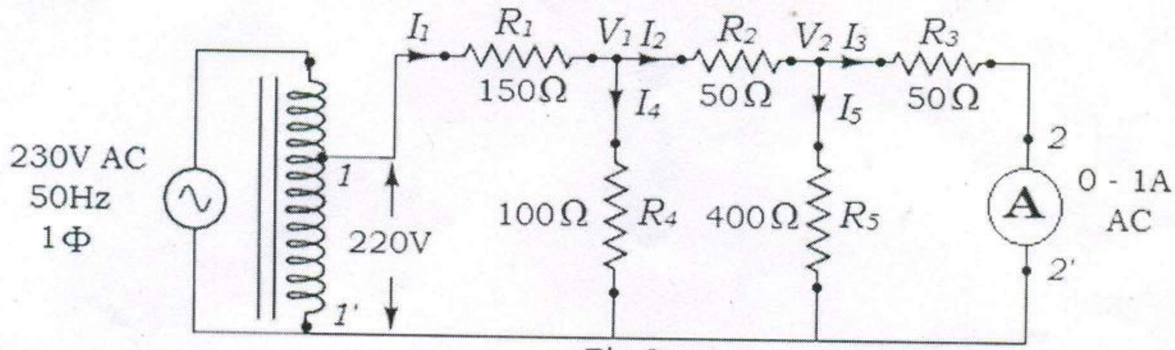

Fig.3

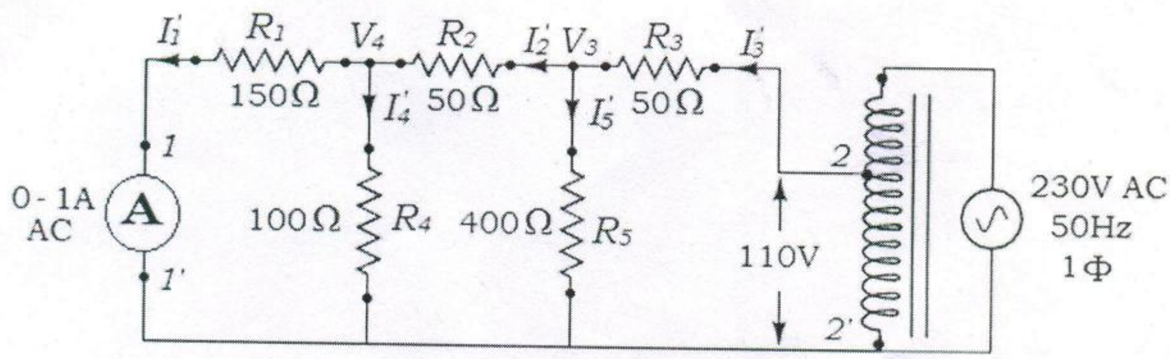

Fig. 4

Enter the data in the following table:

V_S	I_3	V_S/I_3	$V_{S'}$	$I_{1'}$	$V_{S'}/I_{1'}$