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EE1101: Circuits and Network Analysis

Lecture 33: Network Theorems

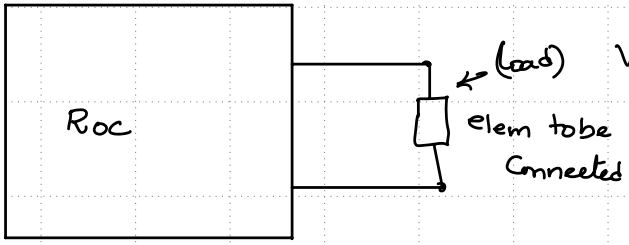
October 24, 2025

Topics :

1. Maximum Power Transfer Theorem
2. Examples

Maximum Power Transfer Theorem - Scenario 1

Problem Statement : to connect a network element such that maximum active power can be extracted from the network



Value of the Component

Set up an optimization Problem

Scenarios 1 & 2 : $\max_{R_L} P_L$.

Scenario 3 : $\max_{R_L, X_L} P_L$

Scenario 1 : Roc → dependent + Independent Sources + Resistive elements

elem to connect } → R_{eq} (for what value of R_L max. Power is extracted from the Roc)

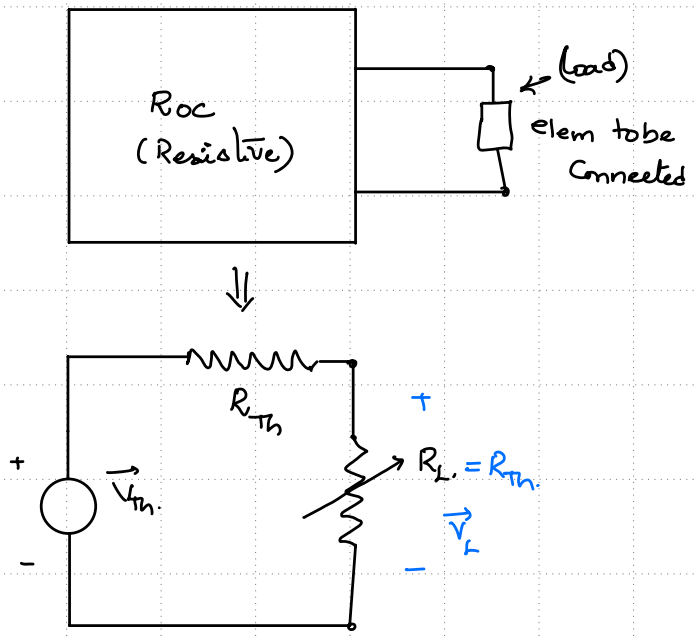
Scenario 2 : Roc → dependent + Independent Sources + (R, L, C)

elem to connect } → R_{eq} (for what value of R_L max. Power is extracted from the Roc)

Scenario 3 : Roc → dependent + Independent Sources + (R, L, C)

elem to connect } → $R+jX$ (for what value of R and X, max. Power is extracted from the Roc)

Maximum Power Transfer Theorem - Scenario 1



$\max_{R_L} P_L$.

P_L (for a time Varying source): $\vec{S}_{load} = \vec{V}_L \vec{I}_L^*$

↓

Sinusoidal signal

for a resistor: $\vec{I}_L = \frac{\vec{V}_L}{R}$ (or) $\vec{V}_L = \vec{I}_L R$

$$\vec{S}_{load} = \frac{|\vec{V}_L|^2}{R} = \frac{V_L^2}{R} \text{ or } I_L^2 R$$

↑ RMS value.

mathematical Problem: $\max_{R_L} |\vec{I}_L|^2 R_L = \left(\frac{|\vec{V}_{Th}|}{R_{Th}+R_L}\right)^2 R_L$.

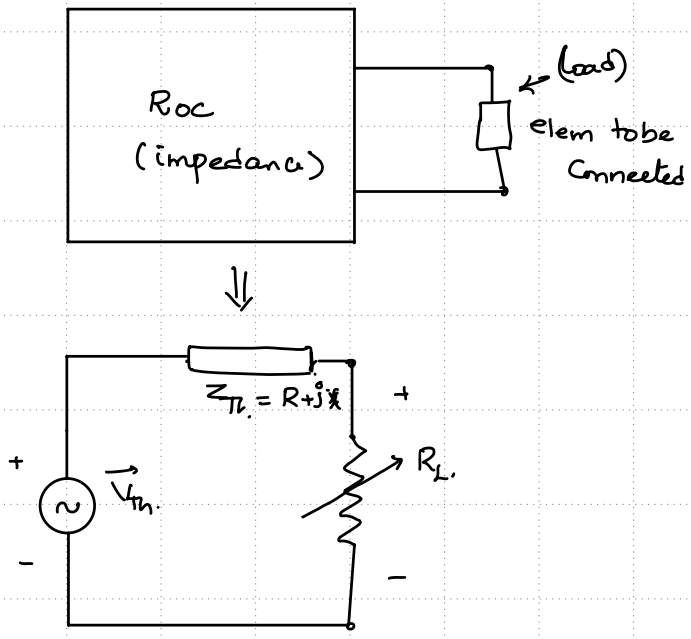
optimum value. (max) → check for 2nd order cond

$$R_L : \left.\frac{dP_L}{dR_L}\right| = 0 \Rightarrow R_L = R_{Th}$$

(go back & verify)

Voltage across the load under max. power Transfer $= \frac{\vec{V}_{Th}}{2}$

Maximum Power Transfer Theorem - Scenario 2



$$\max_{R_L} P_L.$$

$$\max_{R_L} |\vec{I}_L|^2 R_L.$$

for this Scenario $\vec{I}_L = \dfrac{\vec{V}_{Th}}{\underbrace{R_{Th} + jX_{Th}}_{Z_{Th}} + R_L}$

$$|\vec{I}_L|^2 = \frac{|\vec{V}_{Th}|^2}{(R_{Th}+R_L)^2 + X_{Th}^2}$$

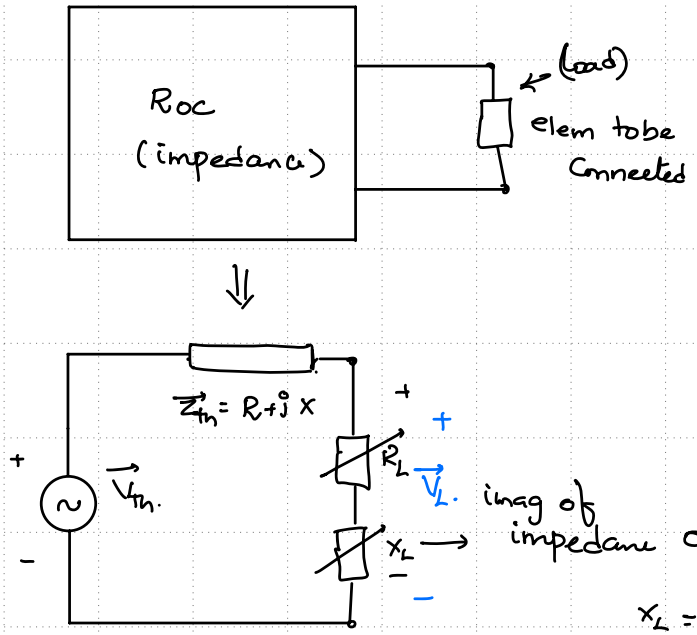
mathematically $\max_{R_L} \dfrac{|\vec{V}_{Th}|^2}{(R_{Th}+R_L)^2 + (X_{Th})^2} \cdot R_L.$

optimum value of R_L : $\left.\dfrac{dP_L}{dR_L}\right| = 0.$

Value of $R_L = \sqrt{R_{Th}^2 + X_{Th}^2} = |\vec{Z}_{Th}|$ ← Verify

Voltage under max. power T/F $\Big\}$ = ??
Cond

Maximum Power Transfer Theorem - Scenario 3



imag of impedance of an inductor

$X_L = (2\pi f)L$

of an cap.

$X_C = \frac{1}{2\pi f C}$

max P_L.
(R_L, X_L)

max $|\vec{I}_L|^2 R_L$.
(R_L, X_L)

for this Scenario $\vec{I}_L = \dfrac{\vec{V}_{Th}}{R_{Th} + jX_{Th} + (R_L + jX_L)}$

Z_{Th}

$$|\vec{I}_L|^2 = \frac{|\vec{V}_{Th}|^2}{(R_{Th} + R_L)^2 + (X_{Th} + X_L)^2}$$

Mathematically $\max_{R_L, X_L} |\vec{I}_L|^2 R_L$

$$\max_{R_L, X_L} \frac{|\vec{V}_{Th}|^2}{(R_{Th} + R_L)^2 + (X_{Th} + X_L)^2} R_L$$

optimum value of R_L : $\frac{dP_L}{dR_L} = 0$ and X_L : $\frac{dP_L}{dX_L} = 0$.

Value of R_L : R_{Th} and $X_L = -X_{Th}$.

Voltage Under maximum Power TF: ??

Maximum Power Transfer Theorem - Scenario 3

Example