$\vec{F} = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$ $\quad d\mathcal{L} = -q\vec{E}\cdot d\vec{l}$ $\quad \vec{J} = \rho_v \vec{v}$

$\vec{E} = \frac{\vec{F}}{q}$ $\quad I = \int_S \vec{J}\cdot d\vec{S}$

$a_{kj} = \begin{cases} +1 & \text{lato } j \text{ incide nel nodo } k \text{ ed è uscente} \\ -1 & \text{'' '' '' '' '' '' '' '' entrante} \\ 0 & \text{il lato } j \text{ non incide in } k \end{cases}$

$\begin{cases} A\underline{i} = 0 \\ \underline{v} - A^T\underline{u} = 0 \end{cases}$

$\underline{v}^T\underline{i} = \underline{v}\,\underline{i}^T = 0 \;|\; \sum P_k = 0$

$P_a = \sum v_k i_k$ $\quad$ Max Trasf. su R: $R = R_{TH}$

1) Tensioni di lato in funzione dei pot. di nodo
2) Tramite le eq. cost. si scrivono le correnti di lato
3) Si risolvono i vari tagli nodali.

K-0: rimuovi KCL su K e aggiungi eq cost.
K-h: supernodo che ingloba b.b e aggiungi le eq. cost.

$V_j = V\frac{R_j}{\sum R_k}$ $\quad i_j = I\frac{G_j}{\sum G_k}$

$\left\{ N=2: \; i_1 = I\frac{R_2}{R_1+R_2}\;;\; i_2 = I\frac{R_1}{R_1+R_2} \right\}$

	SIMMETRICO	
	RECIPROCO	
$\mathcal{R}$	$R_{12} = R_{21}$	$R_{11} = R_{22}$
$\mathcal{G}$	$G_{12} = G_{21}$	$G_{11} = G_{22}$
$\mathcal{T}$	$\lvert\mathcal{T}\rvert = 1$	$T_{11} = T_{22}$
$\mathcal{H}$	$H_{12} = -H_{21}$	$\lvert\mathcal{H}\rvert = 1$
$\mathcal{H}'$	$H'_{12} = -H'_{21}$	$\lvert\mathcal{H}'\rvert = 1$

1) Passivo ind.
2) Ricavo rappresentazione annullando una delle due incognite
3) Calcolo contributo degli ind. studiando le porte con modelli appositi

$\underline{R}^{-1} = \underline{G}$

$P' = \underline{v}''^T\underline{i}'$ $\quad P'' = \underline{v}'^T\underline{i}''$

reciproco: $P' = P''$ $\quad \forall \underline{v}', \underline{v}'', \underline{i}', \underline{i}''$

Serie: $R_{eq} = R_1 + R_2$

Parallelo: $G_{eq} = G_1 + G_2$

Cascata: $T_{eq} = T_1 T_2$

$\begin{cases} V_1 = \frac{n_1}{n_2} V_2 \\ i_1 = -\frac{n_2}{n_1} i_2 \end{cases}$ $\quad$ INV: $V = -\frac{R_2}{R_1}E$ $\quad$ N INV: $V = \left(1 + \frac{R_2}{R_1}\right)E$

$\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$ $\quad \vec{B} = \frac{\mu_0}{4\pi} q \frac{\vec{v}\times\hat{u}_r}{r^2}$ $\quad$ filo: $\vec{B} = \frac{\mu_0}{2\pi r} I\cdot\hat{u}_\theta$ $\quad$ Spira lungo l'asse: $B = \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}}$

Staz: $d\vec{B} = \frac{\mu_0}{4\pi} I \frac{dl}{r^2}\hat{u}_t \times \hat{u}_r$

Var: $f_{em} = -\frac{d\Phi}{dt}$ $\quad V = \frac{d\Phi}{dt}$

STAZ.	VAR.
$\oint_S \vec{E}\cdot d\vec{S} = \frac{Q}{\varepsilon}$	$\oint_S \vec{E}\cdot d\vec{S} = \frac{Q}{\varepsilon}$
$\oint_S \vec{B}\cdot d\vec{S} = 0$	$\oint_S \vec{B}\cdot d\vec{S} = 0$
$\oint_L \vec{E}\cdot d\vec{l} = 0$	$-\oint_L \vec{E}\cdot d\vec{l} = \int_S \frac{\partial}{\partial t}\vec{B}\cdot d\vec{S}$
$\oint_L \vec{B}\cdot d\vec{l} = \mu_0 I$	$\oint_L \vec{B}\cdot d\vec{l} = \mu_0 I + \mu_0\varepsilon_0 \int_S \frac{\partial}{\partial t}\vec{E}\cdot d\vec{S}$

$i = C\frac{dv}{dt}$ $\quad V = L\frac{di}{dt}$ $\quad$ Regime stazionario: $\begin{cases} \equiv C.A \\ \equiv C.C. \end{cases}$

$C = \varepsilon\frac{S}{d}$ $\quad L = \frac{\mu N^2 S}{\ell}$

$\alpha e^{\beta(t-\bar{t})} \rightarrow \gamma e^{\beta(t-\bar{t})}$

$\sum_{k=0}^{N}\alpha_k(t-\bar{t})^k \rightarrow \sum_{k=0}^{N}\gamma_k(t-\bar{t})^k$

$\alpha\cos(\omega t + \varphi) \rightarrow \beta\cos(\omega t) + \gamma\sin(\omega t)$

$\frac{d}{dt}x = \lambda x + u \rightarrow x = Ke^{\lambda(t-t_0)} + x_{ip}$

$\lambda < 0 \rightarrow$ stabile

$x = \underbrace{Ke^{\lambda(t-t_0)}}_{\text{TRANSITORIO}} + \underbrace{x_{ip}}_{\text{REGIME}}$

$\cos^2(\alpha) + \sin^2(\alpha) = 1$

$\cos(\alpha - \beta) = \cos(\alpha)\cos(\beta) + \sin(\alpha)\sin(\beta)$

$\cos(\alpha + \beta) = \cos(\alpha)\cos(\beta) - \sin(\alpha)\sin(\beta)$

$\sin(\alpha - \beta) = \sin(\alpha)\cos(\beta) - \cos(\alpha)\sin(\beta)$

$\sin(\alpha + \beta) = \sin(\alpha)\cos(\beta) + \cos(\alpha)\sin(\beta)$

$\cos(\alpha + \pi/2) = -\sin(\alpha)$

$\cos(\alpha - \pi/2) = \sin(\alpha)$

$\frac{1}{2}[\cos(\alpha - \beta) + \cos(\alpha + \beta)] = \cos(\alpha)\cos(\beta)$

$X_m\cos(\omega t + \varphi) \longleftrightarrow X_m e^{j\varphi}$

$x(t) = \mathrm{Re}\{e^{j\omega}\bar{X}\}$

$\frac{d}{dt}\bar{X} = j\omega\bar{X}$

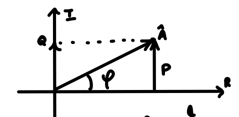
$\bar{I} = j\omega C\bar{V} \Rightarrow \bar{I}$ anticipo $\frac{\pi}{2}$

$\bar{V} = j\omega L\bar{I} \Rightarrow \bar{V}$ anticipo $\frac{\pi}{2}$

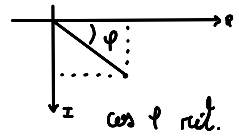
$\bar{Z} = \frac{\bar{V}}{\bar{I}}$ $\quad Y = Z^{-1}$

$H(j\omega) = \frac{V_{OUT}}{V_{IN}}$

$\omega_T: \; |H(j\omega)| = \frac{\sqrt{2}}{2}$



cos φ ant.



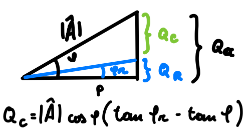
cos φ rit.

$P_a(t) = \frac{VI}{2}\cos(\varphi_v - \varphi_i) + \frac{VI}{2}\cos(\varphi_v - \varphi_i)\cos(2\omega t + 2\varphi_v) + \frac{VI}{2}\sin(\varphi_v - \varphi_i)\sin(2\omega t + 2\varphi_v)$

$\hat{A} = \frac{\bar{V}\bar{I}^*}{2} = \bar{V}^{RMS}\cdot\bar{I}^{RMS*} = P + jQ$

$\cos\varphi = \frac{P}{|\hat{A}|} \rightarrow P = |\hat{A}|\cos\varphi$ $\quad Q = P\tan\varphi = |\hat{A}|\sin\varphi$ $\quad$ Max trasf su Z se $Z = Z^*_{TH}$

$\frac{\underline{V}^T\underline{I}^*}{2} = 0 \longleftrightarrow \sum P_k + jQ_k = 0$ $\quad$ Rifasare: $\mathrm{Im}\{C \| Z\} = 0\;;\; \mathrm{Im}\{Q^E_c\} = 0$



$Q_c = |\hat{A}|\cos\varphi(\tan\varphi_R - \tan\varphi)$

Serie positiva: $\varphi_a = 0\;;\; \varphi_b = -\frac{2}{3}\pi\;;\; \varphi_c = -\frac{4}{3}\pi$

Serie negativa: $\varphi_a = 0\;;\; \varphi_c = -\frac{2}{3}\pi\;;\; \varphi_b = -\frac{4}{3}\pi$

$\bar{Z}_Y = |\bar{z}_Y|e^{j\theta} \rightarrow P_a^{Z_Y} = 3V_p I_p\cos\theta = \sqrt{3}V_L I_L\cos\theta$

EFF $\quad$ EFF.

$X_{EFF} = \frac{X_m}{\sqrt{2}}$ $\quad Z_\Delta = 3Z_Y$ $\quad \Delta\rightarrow Y: \; V_p^Y = \frac{V_p^\Delta}{\sqrt{3}}e^{-j\frac{\pi}{6}}$

Y-Y: $\bar{V}_L = \sqrt{3}\bar{V}_p e^{j\frac{\pi}{6}}\;;\; \bar{I}_L = \bar{I}_p$ $\quad$ Δ-Δ: $\bar{V}_L = \bar{V}_p\;;\; \bar{I}_L = \sqrt{3}\bar{I}_p e^{-j\frac{\pi}{6}}$

Y-Δ: $\bar{V}_L = \sqrt{3}\bar{V}_p e^{j\frac{\pi}{6}}\;;\; \bar{I}_L = \sqrt{3}\bar{I}_p e^{-j\frac{\pi}{6}}$ $\quad$ Δ-Y: $\bar{V}_L = \bar{V}_p\;;\; \bar{I}_p = \bar{I}_L$

$\begin{bmatrix} L_1 & M \\ M & L_2 \end{bmatrix}^{L} \rightarrow$ acc. perfetto per $|L| = 0$

Circuito elettrico		Circuito magnetico	
R	resistenza	$\mathcal{R}$	riluttanza
i	corrente	Ψ	flusso
e	forza elettromotrice	Ni	forza **magnetomotrice**
v	tensione elettrica	$v_H = \mathcal{R}\Psi$	"tensione magnetica"

$\begin{cases} V_1 = L_1\frac{di_1}{dt} + M\frac{di_2}{dt} \\ V_2 = M\frac{di_1}{dt} + L_2\frac{di_2}{dt} \end{cases}$ $\quad K = \frac{M}{\sqrt{L_1 L_2}}$ $\quad P_a = \frac{d}{dt}W_a$ $\quad W_a = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 + M i_1 i_2$

Serie equiv.: $Z_{eq} = j(X_1 + X_2 + 2X_m)$ $\quad$ Parallelo equiv.: $Z_{eq} = j\frac{X_1X_2 - X_m^2}{X_1 + X_2 - 2X_m}$

'' contrar.: $Z_{eq} = j(X_1 + X_2 - 2X_m)$ $\quad$ '' contrar.: $Z_{eq} = j\frac{X_1X_2 - X_m^2}{X_1 + X_2 + 2X_m}$

$KCL_m: \; \sum \Psi_k = 0$ $\quad KVL_m: \; \sum v_{Hk} = \sum N_k i_k$

$\vec{B} = \mu_0(1 + \chi_m)\vec{H} = \mu_0\mu_r\vec{H}$ $\quad \mathcal{R} = \frac{l}{\mu_0\mu_r S}$ $\quad \Phi = N\Psi = \sum L_k i_k$

Nel Traferro: $\mathcal{R} = \mathcal{R}_F + \mathcal{R}_T$, se $\mu \gg \mu_0$ $\mathcal{R} \cong \mathcal{R}_T$