

**Elektrik Tesisleri Tasarım
Formülleri**

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1. Bir ve üç fazlı temel elektrik formülleri

Bir fazlı AC sistemler

Sanal Birim j $j^2 = -1$	Karmaşık sayılar: $z = x + jy$, x ve y gerçel sayılardır.		
$x = \text{Re } z$ $y = \text{Im } z$ $z^* = x - jy$ $ z = \sqrt{x^2 + y^2}$	Euler-Formülü	Faz açısı	Faz kayması
	$e^{j\varphi} = \cos \varphi + j \sin \varphi$ $\cos \varphi = \frac{1}{2}(e^{j\varphi} + e^{-j\varphi})$ $\sin \varphi = \frac{1}{2j}(e^{j\varphi} - e^{-j\varphi})$	$\varphi(t) = \omega t + \varphi_u$ $\varphi(t) = \omega t + \varphi_i$	$\varphi_{ui} = \varphi_u - \varphi_i$ $\varphi_u = \arctan\left(\frac{\text{Im}\{\underline{u}\}}{\text{Re}\{\underline{u}\}}\right)$
Açısal frekans: $\omega = 2\pi f = \frac{2\pi}{T}$			

Karmaşık sayılarla akım ve gerilim fazörü

$u(t) = \hat{u} \cos(\omega t + \varphi_u) = U\sqrt{2} \cos(\omega t + \varphi_u)$ $\underline{u} = \hat{u} (\cos(\omega t + \varphi_u) + j \sin(\omega t + \varphi_u)) =$ $\underline{u} = \hat{u} e^{j(\omega t + \varphi_u)} = \sqrt{2}U e^{j(\omega t + \varphi_u)} = \underline{\hat{u}} e^{j\omega t}$ $\underline{\hat{u}} = \hat{u} e^{j\varphi_u} \quad ; \quad \underline{U} = U e^{j\varphi_u}$	$i(t) = \hat{i} \cos(\omega t + \varphi_i) = I\sqrt{2} \cos(\omega t + \varphi_i)$ $\underline{i} = \hat{i} (\cos(\omega t + \varphi_i) + j \sin(\omega t + \varphi_i)) =$ $\underline{i} = \hat{i} e^{j(\omega t + \varphi_i)} = \sqrt{2}I e^{j(\omega t + \varphi_i)} = \underline{\hat{i}} e^{j\omega t}$ $\underline{\hat{i}} = \hat{i} e^{j\varphi_i} \quad ; \quad \underline{I} = I e^{j\varphi_i}$
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\hat{u}/\hat{i} : Tepe noktası/Amplitude U/I : RMS değeri $\underline{\hat{u}}/\underline{\hat{i}}$: Karmaşık tepe değeri/Amplitude $\underline{U}/\underline{I}$: Karmaşık RMS değeri	RMS ve tepe değeri verileri Genel olarak: $U = \frac{\hat{u}}{\sqrt{2}}; I = \frac{\hat{i}}{\sqrt{2}} \quad U_{eff} = U = \sqrt{\frac{1}{T} \int_{t_0}^{t_0+T} U^2(\tau) d\tau} = \frac{\hat{u}}{\sqrt{2}}$
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AC Devre Hesapları

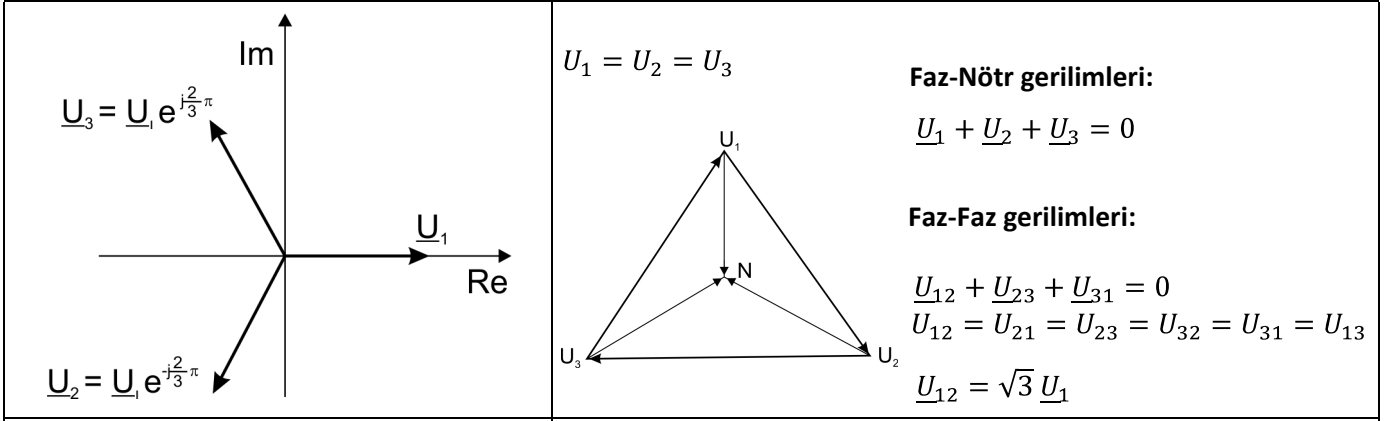
Kapasitif Empedans: $\underline{Z} = \frac{1}{j\omega C}$ Endüktif Empedans: $\underline{Z} = j\omega L$	$\underline{\hat{u}} = \underline{Z} \underline{\hat{i}}$	Kapasitif Admitans: $\underline{Y} = \frac{1}{\underline{Z}} = j\omega C$ Endüktif Admitans: $\underline{Y} = \frac{1}{\underline{Z}} = \frac{1}{j\omega L}$	$\underline{\hat{i}} = \underline{Y} \underline{\hat{u}}$
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AC empedans	AC admitans
$\underline{Z} = \underline{Z} \varphi_z = R + jX$ Z - Empedans (Görünür direnç) φ_z - Empedans açısı R - Rezistans (etkin direnç) X - Reaktans (reaktif direnç) $ \underline{Z} = \sqrt{R^2 + X^2}$ $\varphi_z = \arctan \frac{X}{R}$	$\underline{Y} = \underline{Y} \varphi_y = G + jB$ Y - Admitans φ_y - Admitans açısı G - Konduktans B - Suseptans $ \underline{Y} = \sqrt{G^2 + B^2}$ $\varphi_y = \arctan \frac{B}{G}$

Elektrik Güçleri

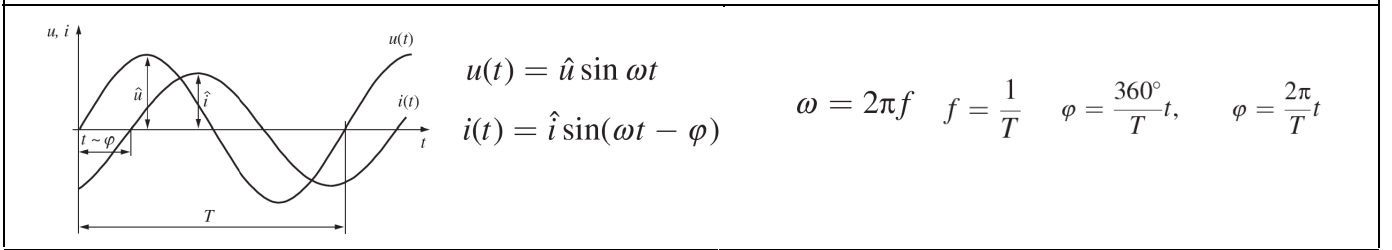
Güç: $p(t) = u(t) \cdot i(t) = \hat{u} \cos(\omega t + \varphi_u) \cdot \hat{i} \cos(\omega t + \varphi_i)$	
Karmaşık güç: $\underline{S} = \underline{U} \cdot \underline{I}^* = \frac{1}{2} \underline{\hat{u}} \cdot \underline{\hat{i}}^*$ $\underline{\tilde{S}} = \underline{U} \cdot \underline{I} = \frac{1}{2} \underline{\hat{u}} \cdot \underline{\hat{i}}$ $S = P + jQ$ $P_W = \text{Re}\{\underline{S}\} [W]$ $P_B = Q = \text{Im}\{\underline{S}\} [Var]$ $P_S = S = \underline{S} = U \cdot I [VA]$	Güç katsayısı $\lambda = \frac{ P }{S} = \cos \varphi $ 50 Hz'de Etkin katsayı: $\frac{P_W}{S} = \cos \varphi$ Reaktif katsayı: $\frac{Q}{S} = \sin \varphi$ $I_W = I_R \dots > P$ $I_B = I_Q \dots > Q$ $Q = \sqrt{S^2 - P^2}; I = \sqrt{I_W^2 + I_B^2}$

2. Üç fazlı AC sistemler (dengeli sistem)

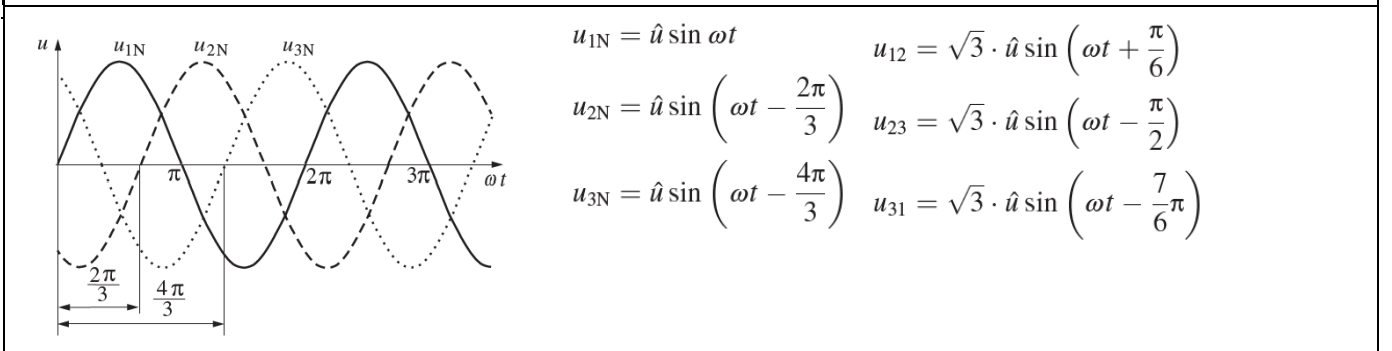
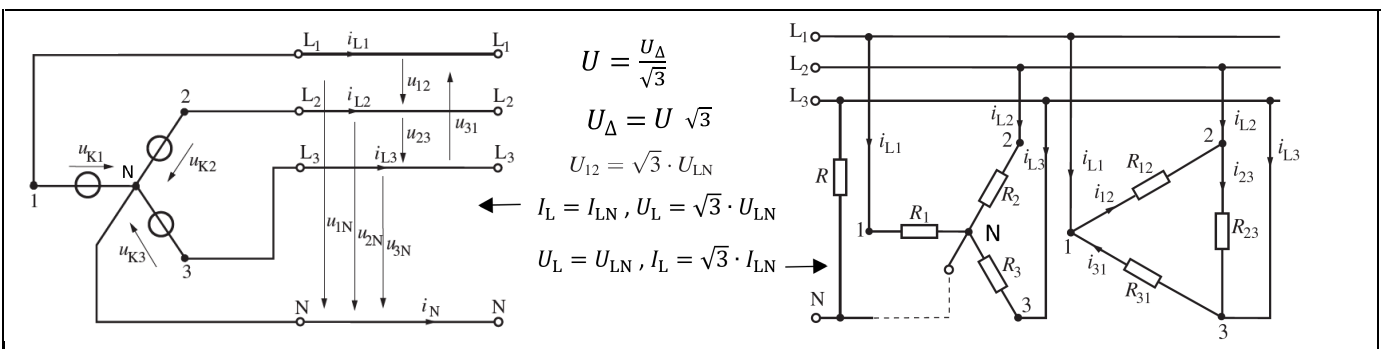


Operatörler	Görünür güç
$\underline{a}^0 = \underline{a}^3 = 1$ Birim fazör $\underline{a}^0 + \underline{a}^1 + \underline{a}^2 = 0$ $\underline{a}^1 = e^{j\frac{2\pi}{3}} = e^{j120^\circ}$ $\underline{a}^2 \underline{U}_1 = \underline{U}_2$ $\underline{a}^2 = \underline{a}^* = e^{j\frac{4\pi}{3}} = e^{j240^\circ}$ $\underline{a}^1 \underline{U}_1 = \underline{U}_3$	$\underline{S} = \underline{U}_1 \cdot \underline{I}_1^* + \underline{U}_2 \cdot \underline{I}_2^* + \underline{U}_3 \cdot \underline{I}_3^*$ $\underline{S} = 3 \underline{U}_1 \cdot \underline{I}_1^*$ $\underline{\tilde{S}} = \underline{U}_1 \cdot \underline{I}_1 + \underline{U}_2 \cdot \underline{I}_2 + \underline{U}_3 \cdot \underline{I}_3$ $\underline{\tilde{S}} = 0$

Bir fazlı sistemlerde gerilim ve akım



Üç fazlı sistemlerde gerilim ve akım, tüketici bağlantıları



3. Temel elektroteknik formülleri

$$U = R \cdot I \quad P = U \cdot I \quad W = P \cdot t$$

$$\eta = \frac{P_{\text{in}}}{P_{\text{out}}} \quad P = U \cdot I \cdot \cos \varphi \quad P = \sqrt{3} \cdot U \cdot I \cdot \cos \varphi \quad P_{\text{T}} = g \cdot P_{\text{k}}$$

$$U_{3\phi} = \sqrt{3} \cdot U_{1\phi} \quad I_{3\phi} = \sqrt{3} \cdot I_{1\phi}$$

$$S = U \cdot I \quad S = \sqrt{3} \cdot U \cdot I \quad P = S \cdot \cos \varphi \quad Q = S \cdot \sin \varphi \quad S = \sqrt{P^2 + Q^2}$$

$$\tan \varphi = \frac{Q}{P} \quad \lambda = \frac{|P|}{S} = |\cos \varphi| \quad \cos \varphi^{-1} \rightarrow \varphi \rightarrow \tan \varphi$$

$$\underline{S} = P + jQ = U(I_w + jI_b)$$

$$I_w = I \cdot \cos \varphi \quad I_b = I \cdot \sin \varphi$$

$$i(t) = \hat{i} \cdot \sin(\omega t + \varphi_i)$$

$$u(t) = \hat{u} \cdot \sin(\omega t + \varphi_u)$$

$$X = \omega L \quad \underline{U} = \underline{Z} \cdot \underline{I}$$

$$\underline{Y} = \frac{1}{\underline{Z}}$$

$$\tan \Psi_L = \frac{X'_L}{R'_L} \quad \cos \Psi_L = \frac{1}{\sqrt{1 + \tan^2 \Psi_L}} \quad \sin \Psi_L = \sqrt{1 - \cos^2 \Psi_L}$$

$$\underline{Z} = \underline{Z}_1 + \underline{Z}_2 \quad \underline{I} = \underline{I}_1 = \underline{I}_2 \quad \underline{Z} = \frac{\underline{Z}_1 \cdot \underline{Z}_2}{\underline{Z}_1 + \underline{Z}_2} \quad \underline{I} = \underline{I}_1 + \underline{I}_2 \quad \underline{Z} = R + jX$$

4 Kısa devre akım hesapları (IEC (EN) 60909-0)

4.1 Üç kutuplu kısa devre I''_{k3}

$$I''_{k3} = \frac{c \cdot U_n}{\sqrt{3} \cdot |Z_{(1)}|} = \frac{c \cdot U_n}{\sqrt{3} \cdot \sqrt{R_{(1)}^2 + X_{(1)}^2}}, \quad I_{sc} > I''_{k3}$$

4.2 İki kutuplu kısa devre I''_{k2}

$$I''_{k2} = \frac{c \cdot U_n}{|Z_{(1)} + Z_{(2)}|} = \frac{c \cdot U_n}{2 \cdot |Z_{(1)}|} = \frac{\sqrt{3}}{2} \cdot I''_{k3}$$

4.3 Bir kutuplu kısa devre I''_{k1}

$$I''_{k1} = \frac{c \cdot \sqrt{3} \cdot U_n}{\sqrt{(2 \cdot R_Q + 2 \cdot R_T + 2 \cdot R_{L1} + 2 \cdot R_{L2} + R_{0T} + R_{0L1} + R_{0L2})^2 + (2 \cdot X_Q + 2 \cdot X_T + 2 \cdot X_{L1} + 2 \cdot X_{L2} + X_{0T} + X_{0L1} + X_{0L2})^2}}$$

$$I''_{k1} = \frac{\sqrt{3} \cdot c \cdot U_n}{Z_1 + Z_2 + Z_0} \quad Z_2 = Z_1 \quad I''_{k1} = \frac{\sqrt{3} \cdot c \cdot U_n}{|2 \cdot Z_1 + Z_0|} \quad Z_0 = Z_L + 3 \cdot Z_N$$

4.4 Termik kısa devre akım dayanımı

$$I_{th} = I''_{k3} \cdot \sqrt{m + n} \quad q = \frac{I_{th}}{S_{th}} \text{ veya } q \geq \frac{I_{th}}{J_{thr}} \cdot \sqrt{\frac{t_k}{t_{kr}}} \quad (q = A = S)$$

4.5 Dinamik kısa devre akım dayanımı

$$i_p = \kappa \cdot \sqrt{2} \cdot I''_{k3}$$

5. IEC 60364-4-43'e göre aşırı yük hesabı

$$I_B \leq I_n \leq I_Z \quad I_2 \leq 1,45 \cdot I_n \quad I_2 \leq 1,45 \cdot I_Z \quad I'_z = I_r \cdot f_1 \cdot f_2 \cdot f_n$$

6. IEC 60364-4-43'e göre kısa devre hesabı

$$I_k^2 \cdot t_k \leq k^2 \cdot S^2$$

7. Müsaade edilen kısa devre zamanı

$$t_k \leq \left(\frac{k \cdot S}{I_k} \right)^2$$

8. Çevrim empedansı

a) TN-Sistem

$$Z_S \leq \frac{U_0}{I_a} \quad I_{k1}'' = \frac{c_{\min} \cdot U_n}{\sqrt{3} \cdot Z_S} \quad c_{\min} = 0,9, U_n = 400 \text{ V} \quad I_{k1}'' > I_a$$

b) TT-Sistem

$$Z_S \leq \frac{U_0}{I_a} \quad I_F = \frac{U_0}{R_A + R_B} \quad R_A \leq \frac{U_T}{I_{\Delta n}}$$

B: $I_a = 5 \cdot I_n$ C: $I_a = 10 \cdot I_n$ K: $I_a = 15 \cdot I_n$ D: $I_a = 20 \cdot I_n$

9. Gerilim düşümü hesabı

$$\Delta U = \sqrt{3} \cdot l \cdot I_B \cdot (R_L' \cdot \cos \varphi \pm X_L' \sin \varphi) \quad \Delta U = \frac{P_w \cdot (R_L' \cdot \cos \varphi \pm X_L' \sin \varphi) \cdot l \cdot 10^{-3}}{U_n \cdot \cos \varphi}$$

$$Z = R_L' \cdot \cos \varphi \pm X_L' \sin \varphi$$

$$\Delta U = 2 \cdot l \cdot I_B \cdot (R_L' \cdot \cos \varphi \pm X_L' \cdot \sin \varphi)$$

$$\cos \varphi = \cos \left(\arctan \frac{X_L'}{R_L'} \right)$$

$$\Delta u = \frac{\Delta U}{U_n} \cdot 100 \% \quad \Delta u = \frac{\Delta U}{U_0} \cdot 100 \%$$

$$\Delta U = \frac{2 \cdot l \cdot I \cdot \cos \varphi}{\kappa \cdot S} \quad \Delta U = \frac{\sqrt{3} \cdot l \cdot I \cdot \cos \varphi}{\kappa \cdot S}$$

$$S = \frac{\sqrt{3} \cdot l \cdot I \cdot \cos \varphi \cdot 1,12 \cdot 100}{\kappa \cdot \Delta u \cdot U_n} \quad (50^\circ\text{C})$$

$$\Delta U = \frac{\sqrt{3} \cdot l \cdot I}{\kappa \cdot S} \quad \Delta U = \frac{2 \cdot l \cdot I}{\kappa \cdot S}$$

$$l_{\max} = \frac{U_0 \cdot \Delta u}{2 \cdot I_n \cdot (R_L' \cdot \cos \varphi \pm X_L' \cdot \sin \varphi) \cdot 10^{-3} \cdot 100 \%}$$

$$l_{\max} = \frac{U_n \cdot \Delta u}{\sqrt{3} \cdot I_n \cdot (R_L' \cdot \cos \varphi \pm X_L' \cdot \sin \varphi) \cdot 10^{-3} \cdot 100 \%}$$

$$l_{\text{müs}} = \frac{\frac{c_{\min} \cdot U_n}{\sqrt{3}} - Z_v}{2 \cdot z_L'}$$