第十二章　三相正弦稳态电路

1　三 相 电 源

2　负载星形联接的三相电路分析

3　负载三角形联接的三相电路分析

4　三相电路的功率

1　三相电源

三相制电力系统：由三个频率相同、振幅相同、相位互差120°的正弦交流电源供电的系统。又称三相电路。

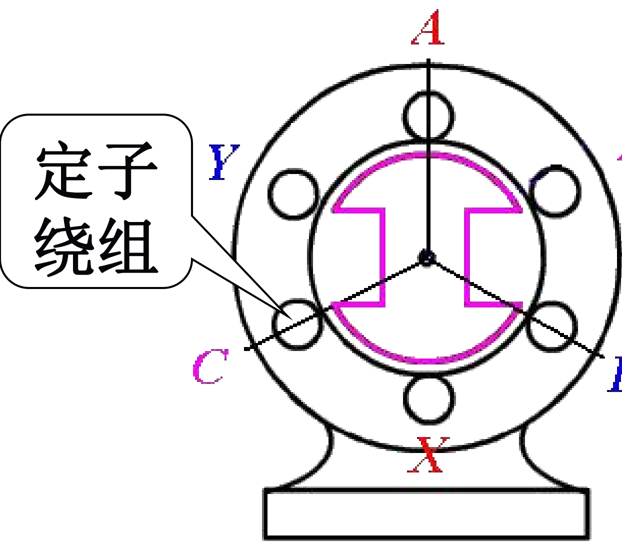
三相电力系统组成：由三相电源、三相负载和三相输电线路三部分构成。

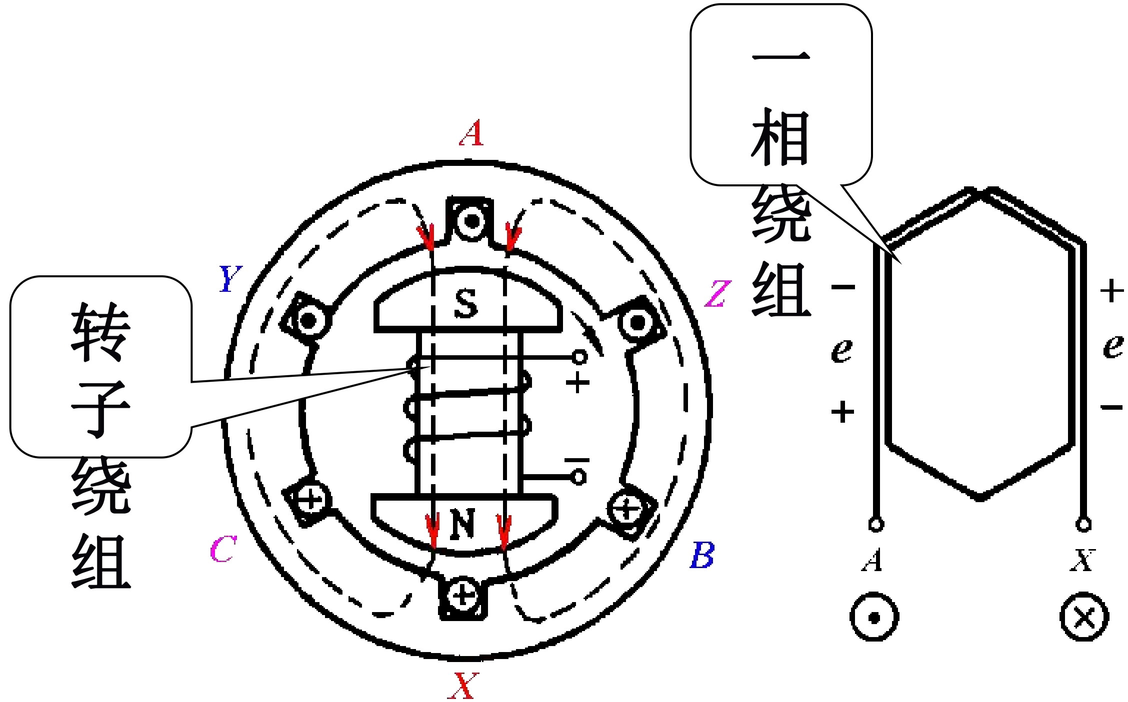
研究三相电路要注意其特殊性：

（1）特殊的电源；（2）特殊的负载；

（3）特殊的连接；（4）特殊的求解方式。

一、对称三相电源





1. 瞬时值表达式

$$u_A = U_m \sin(\omega t + 0°)$$

$$u_B = U_m \sin(\omega t - 120°)$$

$$u_C = U_m \sin(\omega t + 120°)$$

2. 相量表示式

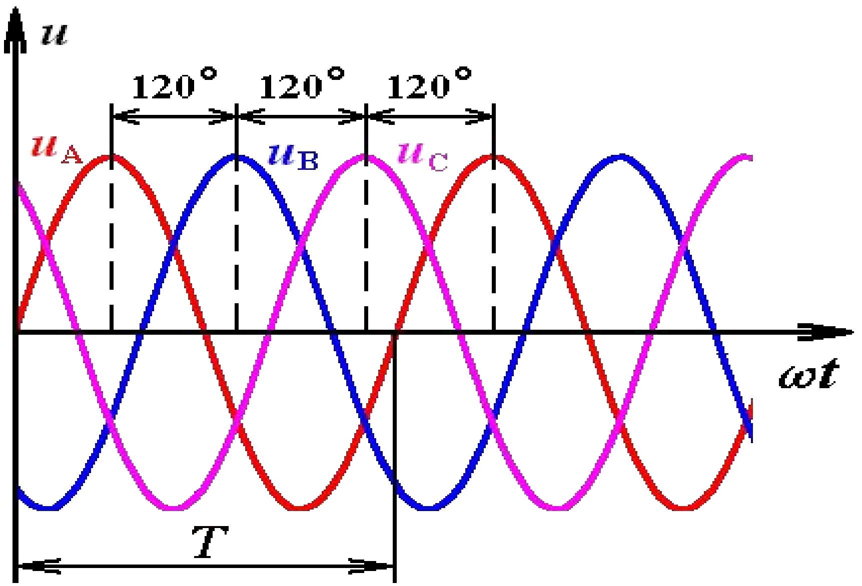
$$\dot{U}_A = U\angle 0^{\circ} \quad \text{V}$$

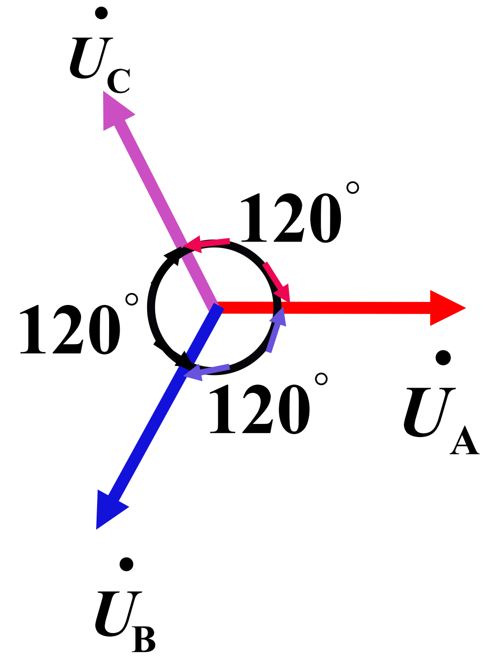
$$\dot{U}_B = U\angle -120^{\circ} = U\angle 240^{\circ} \quad \text{V}$$

$$\dot{U}_C = U\angle -240^{\circ} = U\angle 120^{\circ} \quad \text{V}$$

一、对称三相电源

3. 波形图及相量图





4. 三相对称交流电源的特征

(1) 有效值相等，即：$U_A = U_B = U_C = U$

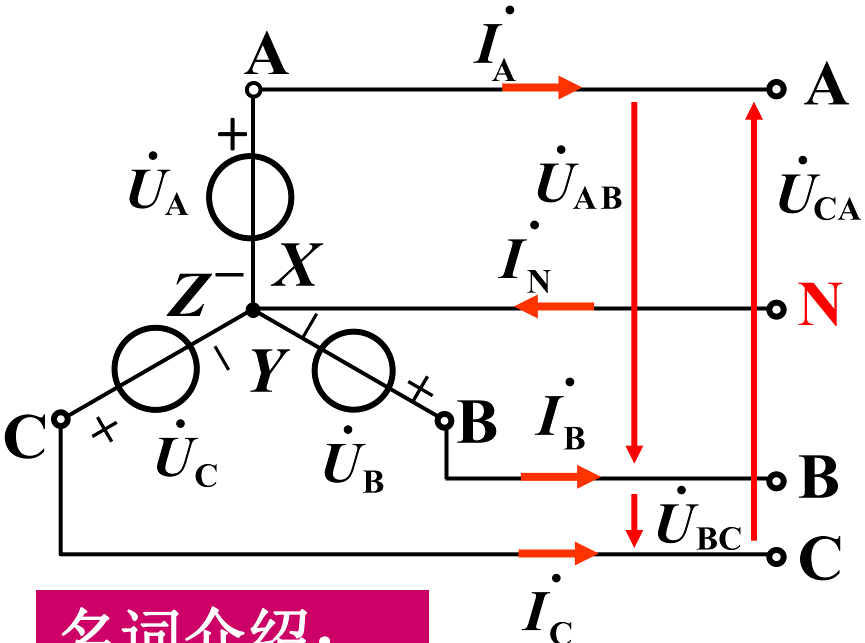
(2) 频率相等，即：$f_A = f_B = f_C = f = 50\text{Hz}$

(3) 相位按相序依次互差120°，即：$\varphi = 120°$

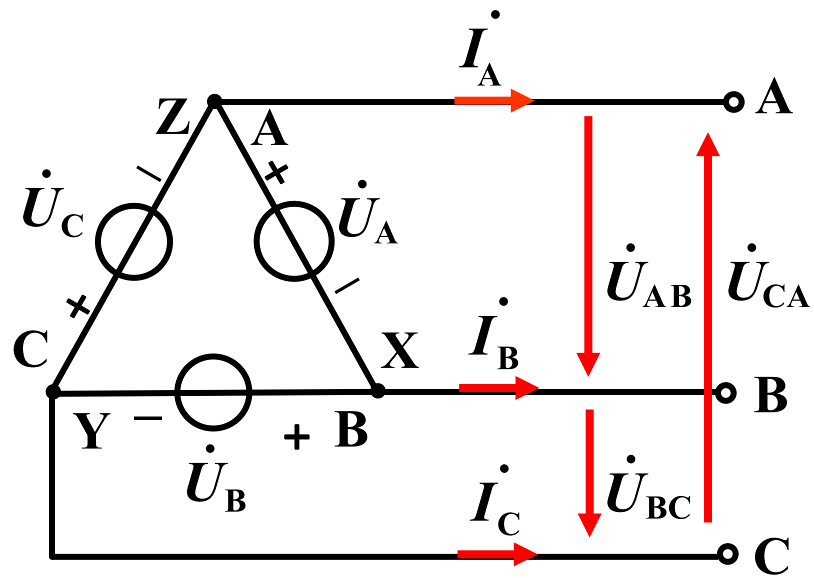
(4) $u_A + u_B + u_C = 0$ $\quad\quad$ $\dot{U}_A + \dot{U}_B + \dot{U}_C = 0$

二、三相电源的联接

1. 星形(Y)联接：



2. 三角形(△)联接



名词介绍：

① 端线(火线) ② 中线(零线) ③ 三相三线制、三相四线制

④ 线电压：端线与端线之间的电压。 $\dot{U}_{AB}$、$\dot{U}_{BC}$、$\dot{U}_{CA}$

⑤ 相电压：每相电源(负载)的电压。

Y接：u_{AN}、u_{BN}、u_{CN} Δ接：u_{AB}、u_{BC}、u_{CA}

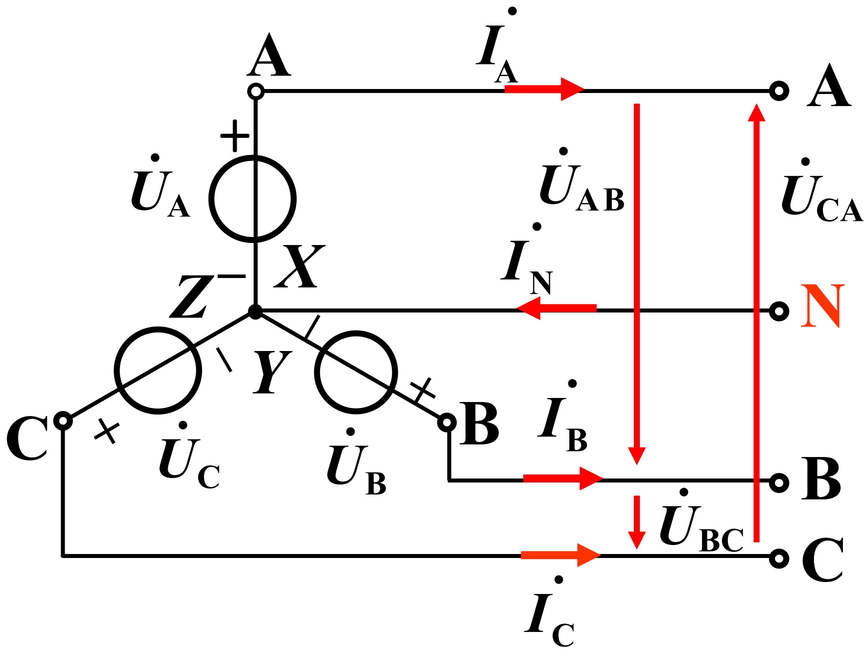
三、三相对称电源线电压与相电压的关系

1. 星形(Y)联接：

$$\because\ \dot{U}_{AN} = U\angle 0^{o}\,\text{V}$$

$$\dot{U}_{BN} = U\angle -120^{o}\ \text{V}$$

$$\dot{U}_{CN} = U\angle 120^{o}\,\text{V}$$



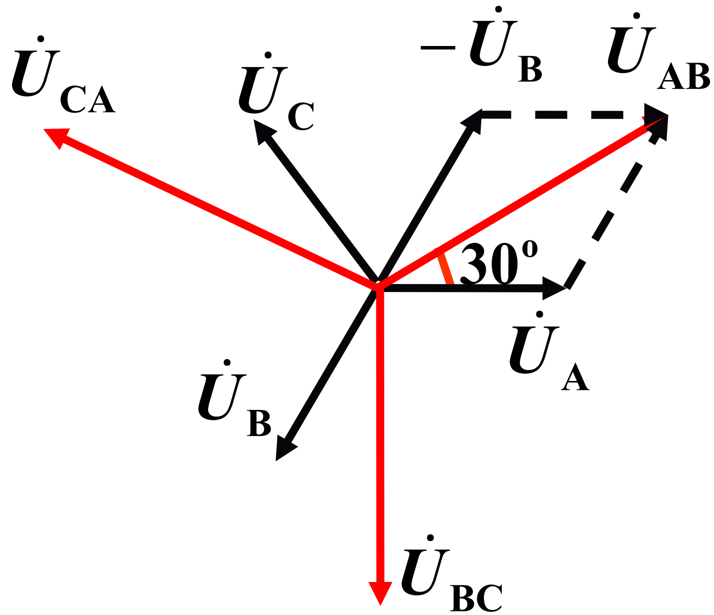
$$\therefore\ \dot{U}_{AB} = \dot{U}_{AN} - \dot{U}_{BN} = U\angle 0^{o} - U\angle -120^{o} \ = \sqrt{3}U\angle 30^{o}\,\text{V}$$

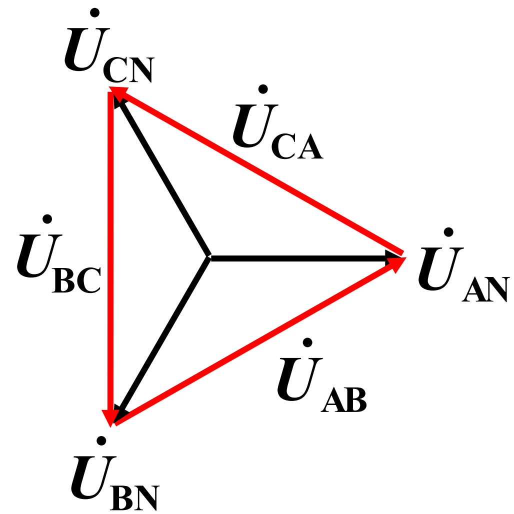
$$\dot{U}_{BC} = \dot{U}_{BN} - \dot{U}_{CN} = U\angle -120^{o} - U\angle 120^{o} = \sqrt{3}U\angle -90^{o}\,\text{V}$$

$$\dot{U}_{CA} = \dot{U}_{CN} - \dot{U}_{AN} = U\angle 120^{o} - U\angle 0^{o} = \sqrt{3}U\angle 150^{o}\,\text{V}$$

三、三相对称电源线电压与相电压的关系

利用相量图得到相电压和线电压之间的关系：





一般表示为：

$$\dot{U}_{AB}=\dot{U}_{AN}-\dot{U}_{BN}=\sqrt{3}\dot{U}_{AN}\angle 30^{o}\,\mathrm{V}$$

$$\dot{U}_{BC}=\dot{U}_{BN}-\dot{U}_{CN}=\sqrt{3}\dot{U}_{BN}\angle 30^{o}\,\mathrm{V}$$

$$\dot{U}_{CA}=\dot{U}_{CN}-\dot{U}_{AN}=\sqrt{3}\dot{U}_{CN}\angle 30^{o}\,\mathrm{V}$$

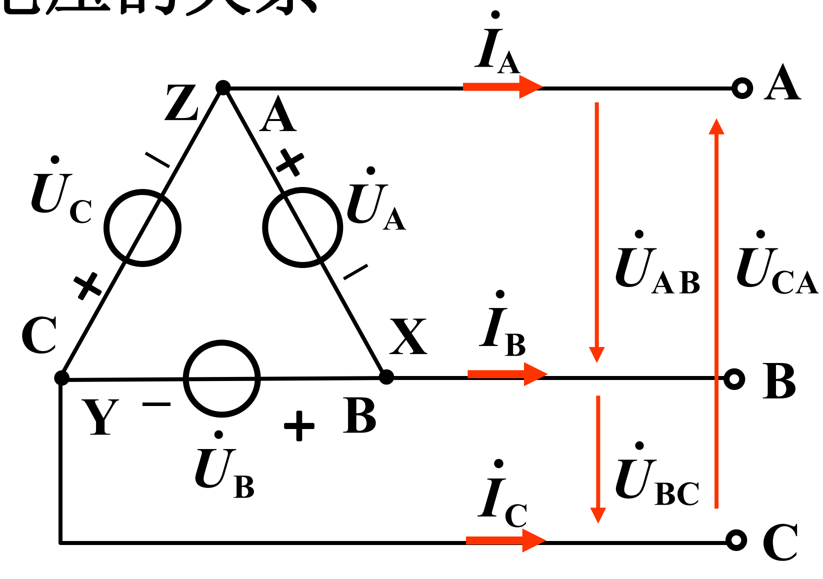
结论

$$U_{L}=\sqrt{3}U_{P}$$

线电压超前对应相电压30°

三、三相对称电源线电压与相电压的关系

2. 三角形(△)联接



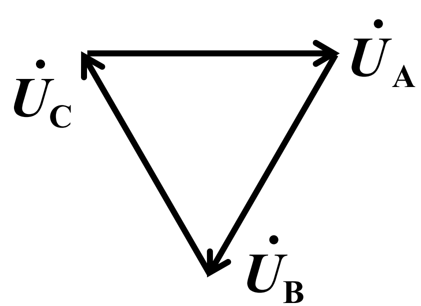
由接线方式可知：

线电压等于对应的相电压

设：$\dot{U}_A = U\angle 0^\circ$ V

$\dot{U}_B = U\angle -120^\circ$ V

$\dot{U}_C = U\angle 120^\circ$ V



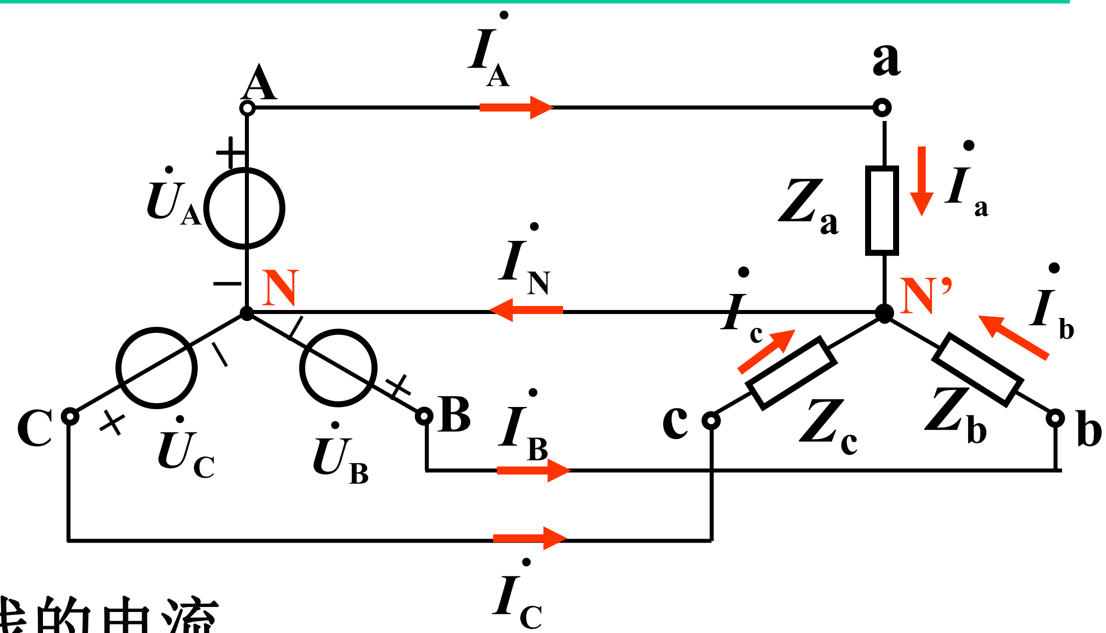
得：$\dot{U}_{AB} = \dot{U}_A = U\angle 0^\circ$ V

$\dot{U}_{BC} = \dot{U}_B = U\angle -120^\circ$ V

$\dot{U}_{CA} = \dot{U}_C = U\angle +120^\circ$ V

2 负载星形联接的三相电路分析

一、三相四线制系统



名词介绍：

线电流：流经端线的电流。

i_A、i_B、i_C 或 $\dot{I}_A$、$\dot{I}_B$、$\dot{I}_C$

相电流：流过每相负载的电流。

i_a、i_b、i_c 或 $\dot{I}_a$、$\dot{I}_b$、$\dot{I}_c$

中线电流：流过中线的电流 i_N

特点：

1) $I_P = I_L$

2) $\dot{I}_N = \dot{I}_a + \dot{I}_b + \dot{I}_c$

一、三相四线制系统

分析：三相电路的解题关键，找准相电压

$$\dot{I}_{a}=\frac{\dot{U}_{A}}{Z_{a}}\qquad \dot{I}_{b}=\frac{\dot{U}_{B}}{Z_{b}}\qquad \dot{I}_{c}=\frac{\dot{U}_{C}}{Z_{c}}$$

1. 三相负载不对称，即：

$$Z_{a}=|Z_{a}|\angle\varphi_{a}\qquad Z_{b}=|Z_{b}|\angle\varphi_{b}\qquad Z_{c}=|Z_{c}|\angle\varphi_{c}$$

$$\left.\begin{aligned}\therefore \dot{I}_{a}&=\frac{\dot{U}_{A}}{Z_{a}}=\frac{U_{A}}{|Z_{a}|}\angle-\varphi_{a}\\ \dot{I}_{b}&=\frac{\dot{U}_{B}}{Z_{b}}=\frac{U_{B}}{|Z_{b}|}\angle(-\varphi_{b}-120^{\circ})\\ \dot{I}_{c}&=\frac{\dot{U}_{C}}{Z_{c}}=\frac{U_{C}}{|Z_{c}|}\angle(-\varphi_{c}+120^{\circ})\end{aligned}\right\}$$

结论：

1) $I_{a}=U_{A}/|Z_{a}|=I_{A}$

$I_{b}=U_{B}/|Z_{b}|=I_{B}$

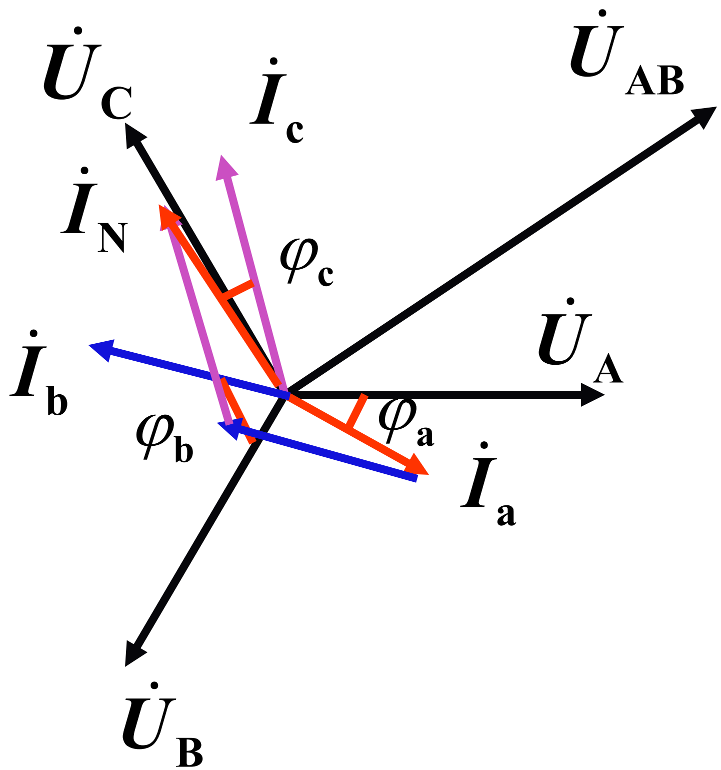
$I_{c}=U_{C}/|Z_{c}|=I_{C}$

2) $\dot{I}_{N}=\dot{I}_{a}+\dot{I}_{b}+\dot{I}_{c}\neq 0$

一、三相四线制系统

三相负载不对称

电压和电流的相量图

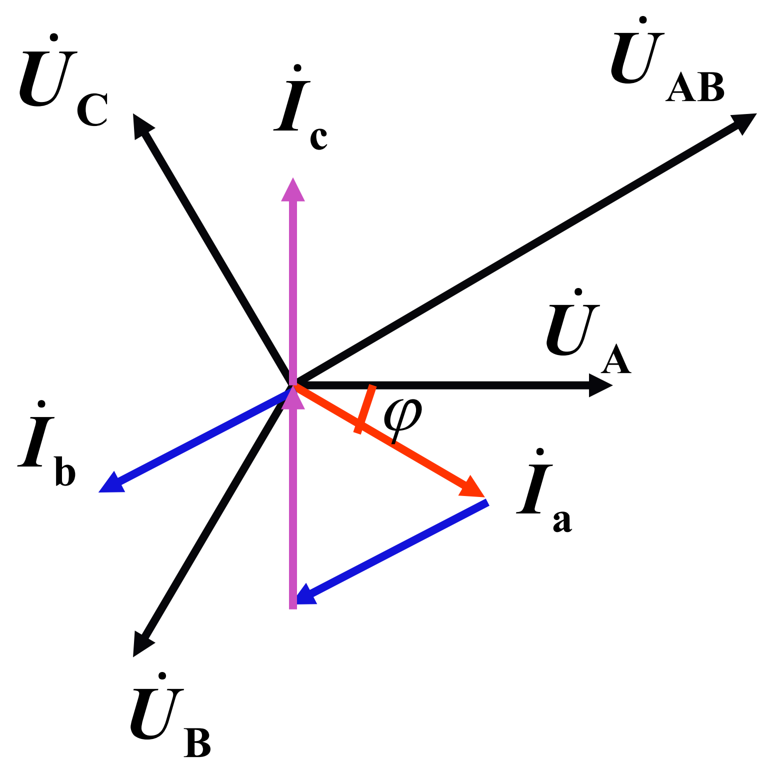


结论:

$$\dot{I}_{N}=\dot{I}_{a}+\dot{I}_{b}+\dot{I}_{c}\neq 0$$

三相负载对称

电压和电流的相量图



结论:

$$\dot{I}_{N}=\dot{I}_{a}+\dot{I}_{b}+\dot{I}_{c}=0$$

一、三相四线制系统

2. 当三相负载对称时，有： $Z_a = Z_b = Z_c = |Z|\angle\varphi$

$$\left.\begin{aligned}
\therefore \dot{I}_a &= \frac{\dot{U}_A}{Z_a} = \frac{U}{|Z|}\angle -\varphi \\
\dot{I}_b &= \frac{\dot{U}_B}{Z_b} = \frac{U}{|Z|}\angle(-\varphi - 120^\circ) \\
\dot{I}_c &= \frac{\dot{U}_C}{Z_c} = \frac{U}{|Z|}\angle(-\varphi + 120^\circ)
\end{aligned}\right\}$$

三相电路可计算一相电流，另两相电流可根据对称性而得

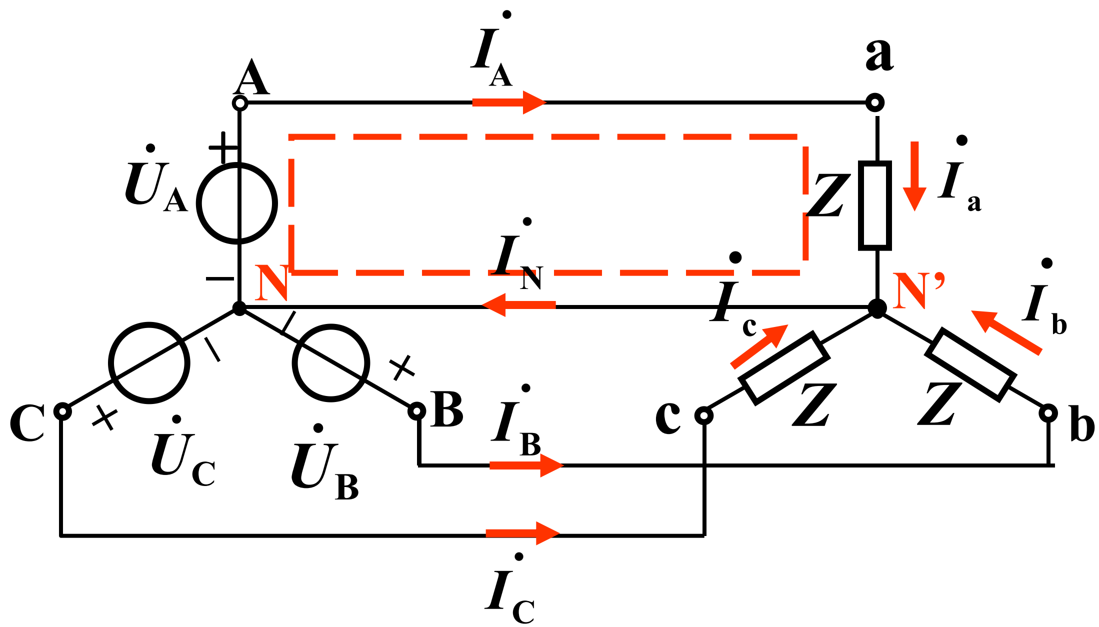
结论： 1) i_a、i_b、i_c为三相对称电流 ；

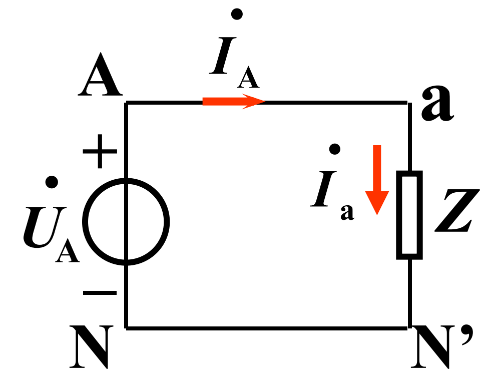
2) $I_a = I_b = I_c = U_P/|Z| = U_L/\sqrt{3}|Z|$

3) $\dot{I}_N = \dot{I}_a + \dot{I}_b + \dot{I}_c = 0$

一、三相四线制系统

可将三相电路的计算简化为单相电路的计算





由一相计算电路可得： $\dot{I}_A = \dot{I}_a = \dfrac{\dot{U}_{aN'}}{Z} = \dfrac{\dot{U}_A}{Z}$

同理 $\dot{I}_B = \dot{I}_b = \dfrac{\dot{U}_{bN'}}{Z} = \dfrac{\dot{U}_B}{Z}$ $\qquad \dot{I}_C = \dot{I}_c = \dfrac{\dot{U}_{cN'}}{Z} = \dfrac{\dot{U}_C}{Z}$

一、三相四线制系统

结论

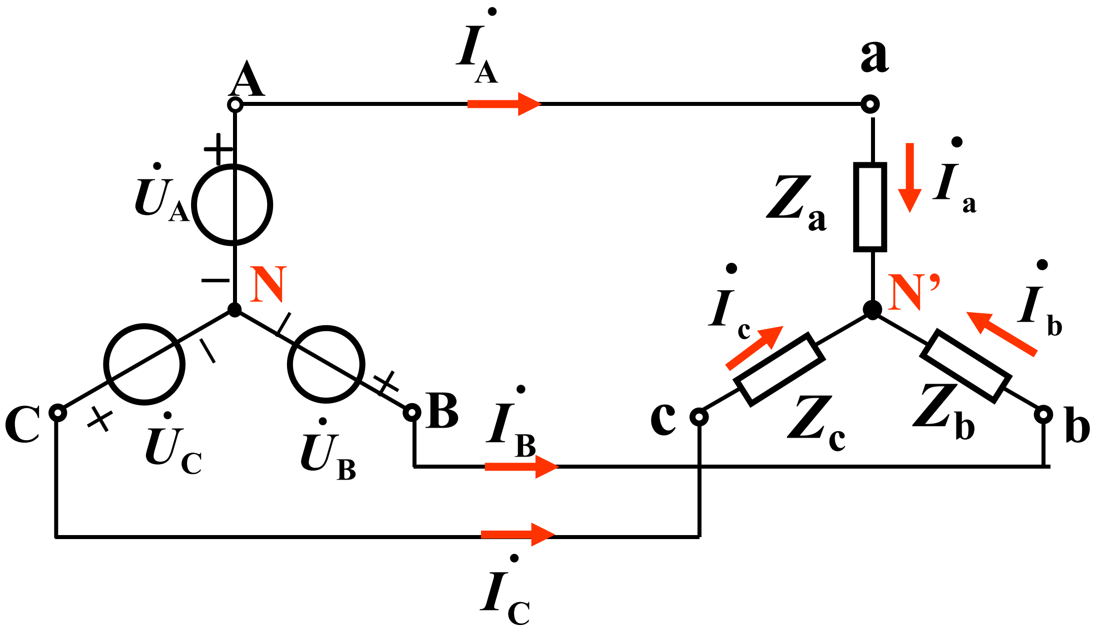
1. $U_{N'N}=0$，电源中点与负载中点等电位。有无中线对电路情况没有影响。

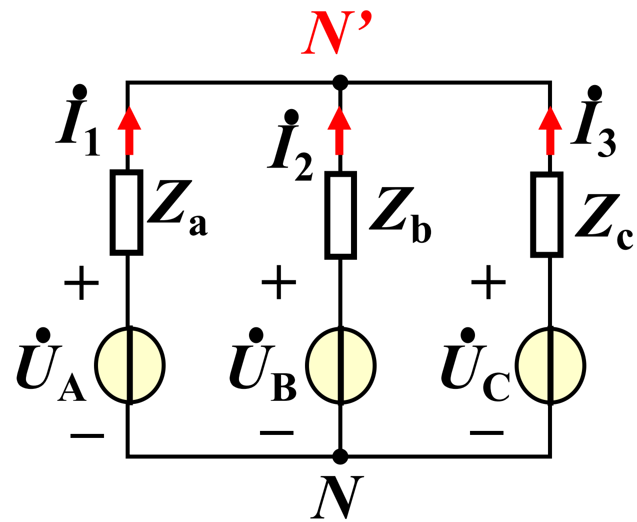
2. 对称情况下，各相电压、电流都是对称的，只要算出某一相的电压、电流，则其他两相的电压、电流可直接写出。

3. Y形联接的对称三相负载，其相、线电压、电流的关系为：

$$\dot{U}_{ab}=\sqrt{3}\dot{U}_{aN'}\angle 30^{\circ}\ \mathrm{V} \qquad \dot{I}_{A}=\dot{I}_{a}$$

二、三相三线制 (Y–Y)

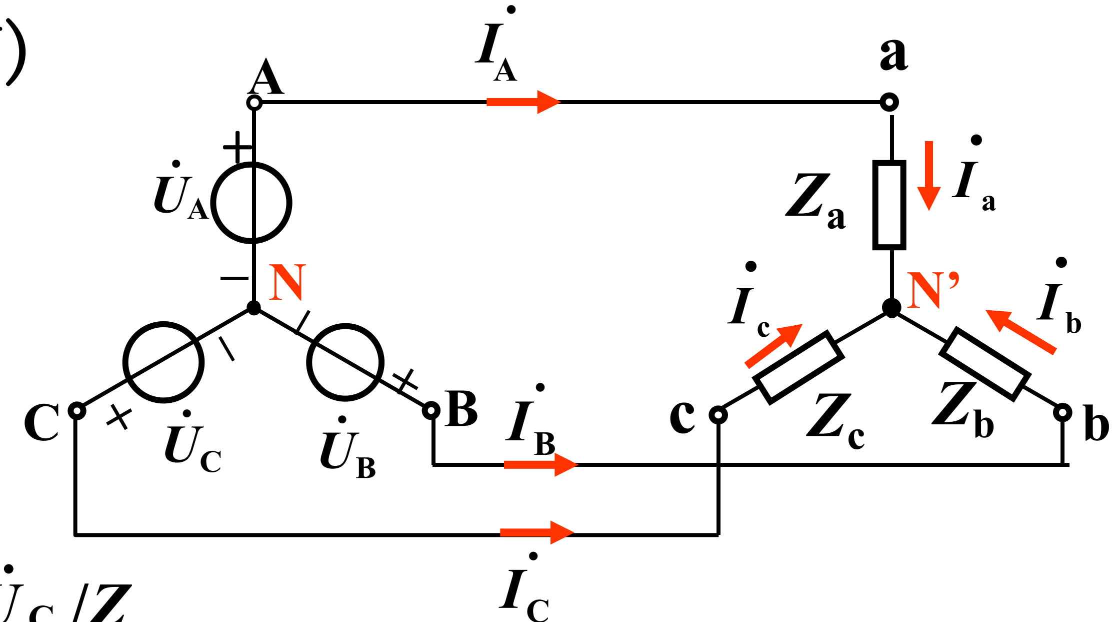




以N点为参考点，对N'点列写节点方程：

$$\dot{U}_{N'N} = \frac{\dfrac{\dot{U}_A}{Z_a} + \dfrac{\dot{U}_B}{Z_b} + \dfrac{\dot{U}_C}{Z_c}}{\dfrac{1}{Z_a} + \dfrac{1}{Z_b} + \dfrac{1}{Z_c}}$$

二、三相三线制（Y–Y）



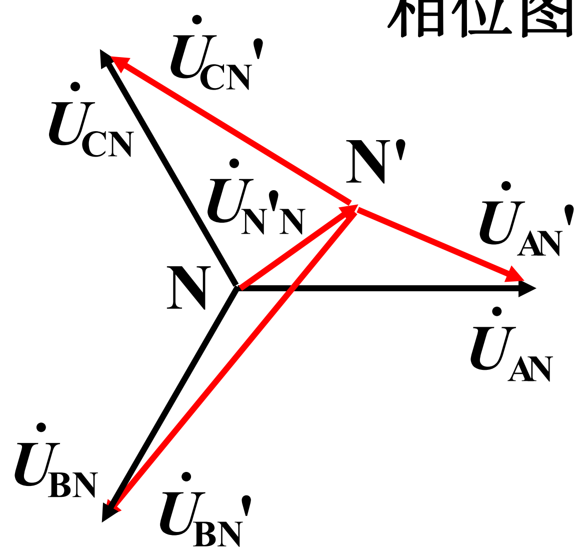
分析：

1. 三相负载不对称

$$Z_a \neq Z_b \neq Z_c \neq |Z|\angle\varphi$$

$$\dot{U}_{N'N} = \frac{\dot{U}_A/Z_a + \dot{U}_B/Z_b + \dot{U}_C/Z_c}{1/Z_a + 1/Z_b + 1/Z_c} \neq 0$$

相位图



负载各相电压：

$$\dot{U}_{AN'} = \dot{U}_{AN} - \dot{U}_{N'N}$$

$$\dot{U}_{BN'} = \dot{U}_{BN} - \dot{U}_{N'N}$$

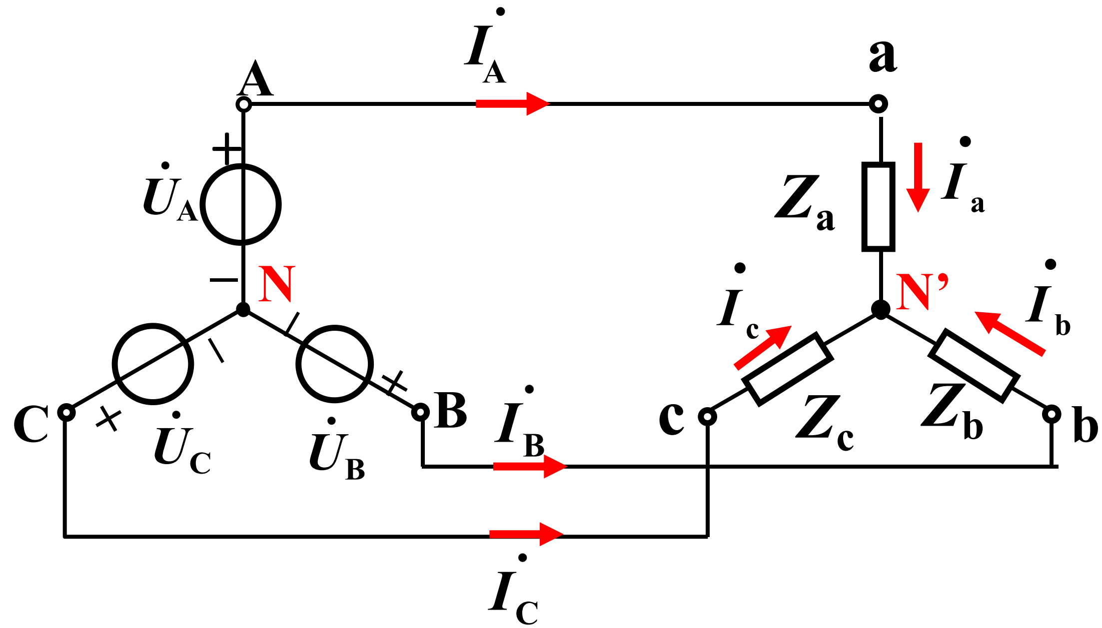
$$\dot{U}_{CN'} = \dot{U}_{CN} - \dot{U}_{N'N}$$

中性点位移 → 负载中点与电源中点不重合

二、三相三线制（Y–Y）

分析：

1. 三相负载不对称

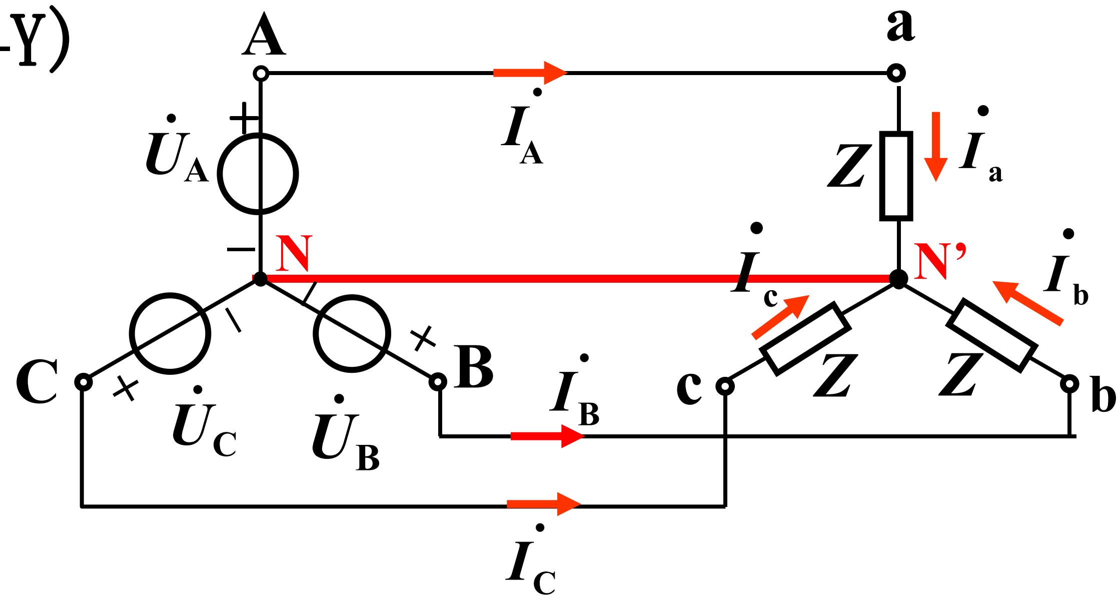


各相电流为

$$\dot{I}_A = \dot{I}_a = \frac{\dot{U}_A - \dot{U}_{N'N}}{Z_a}$$

$$\dot{I}_B = \dot{I}_b = \frac{\dot{U}_B - \dot{U}_{N'N}}{Z_b} \qquad \dot{I}_C = \dot{I}_c = \frac{\dot{U}_C - \dot{U}_{N'N}}{Z_c}$$

二、三相三线制（Y–Y）



分析：

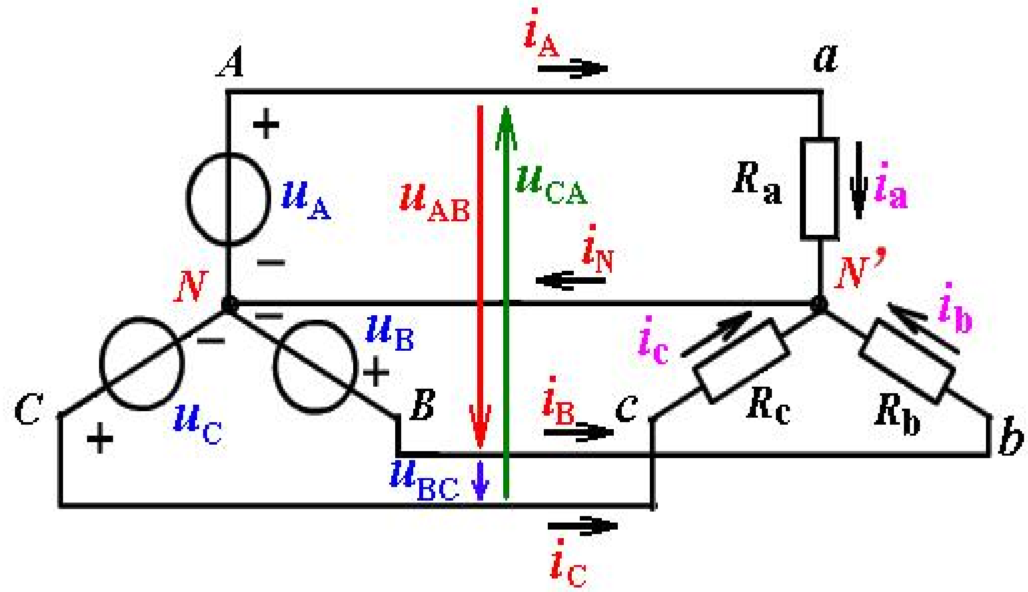
2. 三相负载对称

$$\because \dot{U}_{N'N} = \frac{\dfrac{\dot{U}_A}{Z_a}+\dfrac{\dot{U}_B}{Z_b}+\dfrac{\dot{U}_C}{Z_c}}{\dfrac{1}{Z_a}+\dfrac{1}{Z_b}+\dfrac{1}{Z_c}} = \frac{\dfrac{1}{Z}(\dot{U}_A+\dot{U}_B+\dot{U}_C)}{\dfrac{3}{Z}} = 0$$

$$\therefore \dot{I}_A = \dot{I}_a = \frac{\dot{U}_A}{Z} \qquad \dot{I}_B = \dot{I}_b = \frac{\dot{U}_B}{Z} \qquad \dot{I}_C = \dot{I}_c = \frac{\dot{U}_C}{Z}$$

可知 $\dot{I}_a$、$\dot{I}_b$、$\dot{I}_c$ 为三相对称电流

例1.已知对称三相四线制电源线电压为380V，相电压为 220V；负载为电灯组，在额定电压下其电阻分别为R_a=5Ω，R_b=10Ω，R_c=20Ω。试求负载相电压、负载电流及中性线电流。电灯的额定电压为220 V。



- 解：∵负载接成Y_0 有中性线

∴负载相电压为：

$$\dot{U}_a = \dot{U}_A = 220\angle 0^\circ \text{ V}$$

$$\dot{U}_b = \dot{U}_B = 220\angle -120^\circ \text{ V}$$

$$\dot{U}_c = \dot{U}_C = 220\angle 120^\circ \text{ V}$$

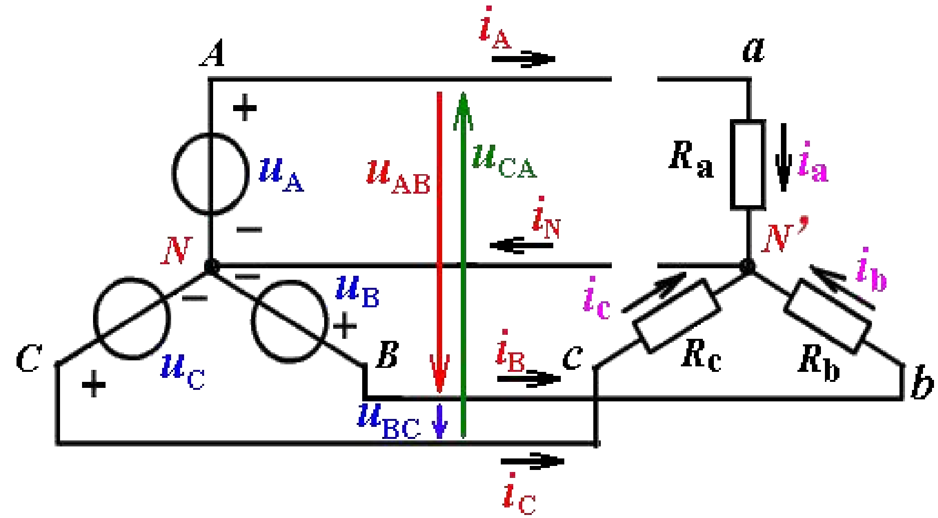
$$\therefore \dot{I}_a = \frac{\dot{U}_A}{R_a} = 44\angle 0^\circ \text{ A} \qquad \dot{I}_b = \frac{\dot{U}_B}{R_b} = 22\angle(-120^\circ)\text{A}$$

$$\dot{I}_c = \frac{\dot{U}_C}{R_c} = 11\angle 120^\circ \text{ A}$$

则：$\dot{I}_N = \dot{I}_a + \dot{I}_b + \dot{I}_c = 29.1\angle(-19^\circ)\text{A}$

• 例2. 在例1中，当A 相和中性线断开时，试求负载的端电压。

解：∵A 相和中性线断开



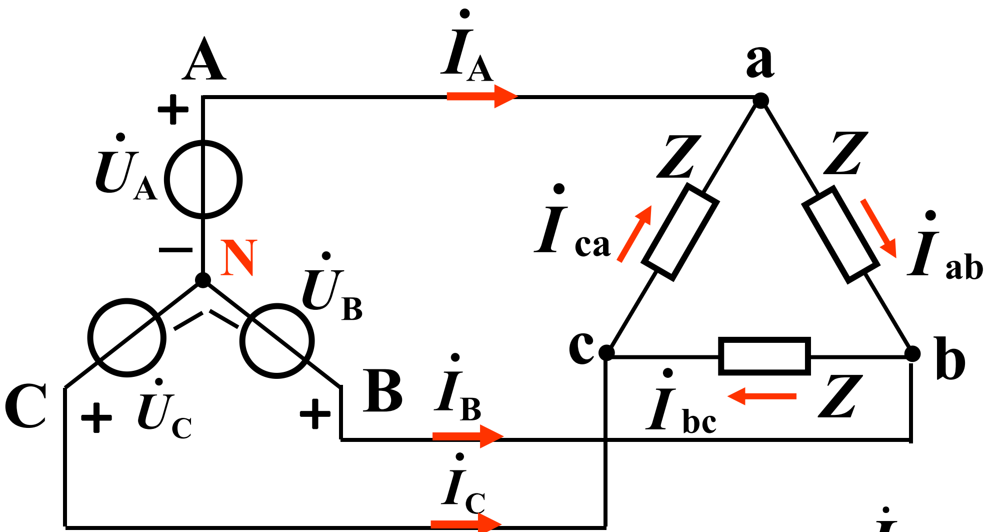
∴$U_{bc} = U_{BC} = 380\text{V}$

$$\therefore U_{bN'} = \frac{R_b}{R_b + R_c} U_{bc} = \frac{10}{10+20} \times 380 = 126.67 \quad \text{V}$$

$$U_{cN'} = \frac{R_c}{R_b + R_c} U_{bc} = \frac{20}{10+20} \times 380 = 253.33 \quad \text{V}$$

3 负载三角形联接的三相电路分析

- Y–△对称三相电路的计算



设：$\dot{U}_A = U\angle 0^\circ$ V

$\dot{U}_B = U\angle -120^\circ$ V

$\dot{U}_C = U\angle +120^\circ$ V

解法一

$$\dot{U}_{ab} = \dot{U}_{AB} = \sqrt{3}U\angle +30^\circ \text{ V}$$

$$\dot{U}_{bc} = \dot{U}_{BC} = \sqrt{3}U\angle -90^\circ \text{ V}$$

$$\dot{U}_{ca} = \dot{U}_{CA} = \sqrt{3}U\angle +150^\circ \text{ V}$$

$$\dot{I}_{ab} = \frac{\dot{U}_{ab}}{Z} = \frac{\sqrt{3}U}{|Z|}\angle 0^\circ + 30^\circ - \varphi \text{ A}$$

$$\dot{I}_{bc} = \frac{\dot{U}_{bc}}{Z} = \frac{\sqrt{3}U}{|Z|}\angle -90^\circ - \varphi \text{ A}$$

$$\dot{I}_{ca} = \frac{\dot{U}_{ca}}{Z} = \frac{\sqrt{3}U}{|Z|}\angle +150^\circ - \varphi \text{ A}$$

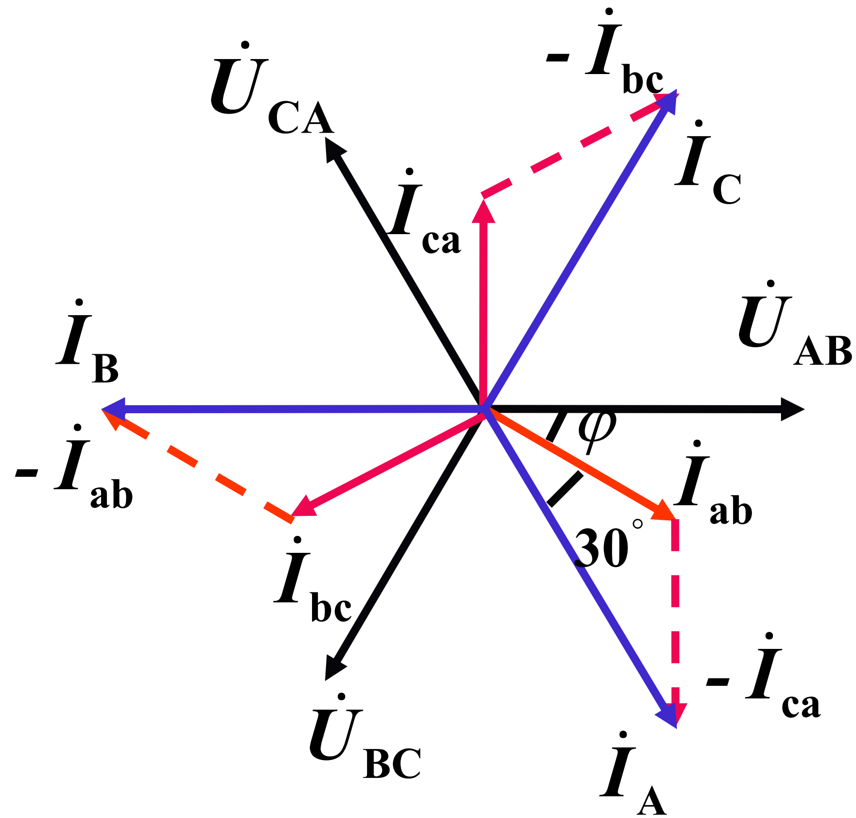
Y–△对称三相电路的计算

线电流：

$$\dot{I}_A = \dot{I}_{ab} - \dot{I}_{ca} = \sqrt{3}\dot{I}_{ab}\angle -30^o$$

$$\dot{I}_B = \dot{I}_{bc} - \dot{I}_{ab} = \sqrt{3}\dot{I}_{bc}\angle -30^o$$

$$\dot{I}_C = \dot{I}_{ca} - \dot{I}_{bc} = \sqrt{3}\dot{I}_{ca}\angle -30^o$$



结论

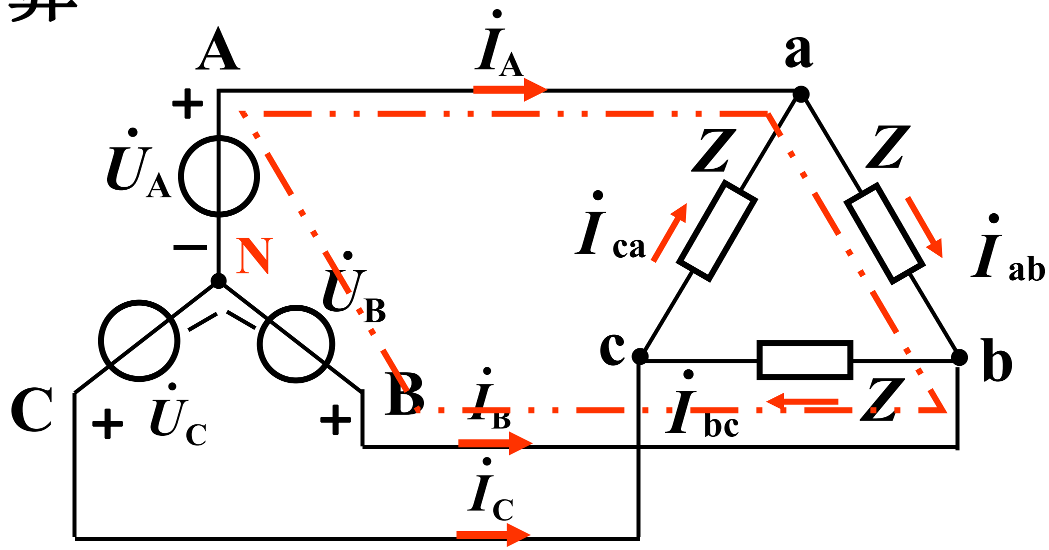
(1) 负载上相电压与线电压相等，且对称。

(2)线电流与相电流均为对称的。线电流大小是相电流的√3倍，相位落后相应相电流30°。

Y–△对称三相电路的计算

解法二

利用计算相电流的一相等效电路。



$$\because \dot{U}_{ab} = \dot{U}_{AB}$$

$$= \sqrt{3}U\angle +30^{\circ} \text{ V}$$

$$\therefore \dot{I}_{ab} = \frac{\dot{U}_{ab}}{Z} = \frac{\dot{U}_{AB}}{Z} = \frac{\sqrt{3}U}{|Z|}\angle +30^{\circ} - \varphi \text{ A}$$

$$\dot{I}_{bc} = \frac{\sqrt{3}U}{|Z|}\angle -90^{\circ} - \varphi \text{ A} \qquad \dot{I}_{ca} = \frac{\sqrt{3}U}{|Z|}\angle +150^{\circ} - \varphi \text{ A}$$

$$\dot{I}_A = \sqrt{3}\dot{I}_{ab}\angle -30^{\circ} = \frac{3U}{|Z|}\angle -\varphi \text{ A}$$

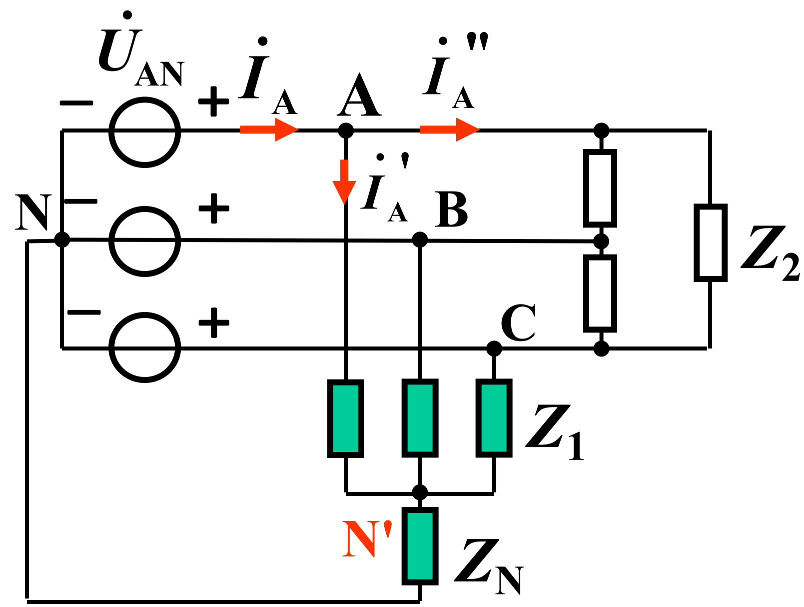
$$\dot{I}_B = \sqrt{3}\dot{I}_{bc}\angle -30^{\circ} \text{ A} \qquad \dot{I}_C = \sqrt{3}\dot{I}_{ca}\angle -30^{\circ} \text{ A}$$

- 例2. 如图对称三相电路，电源线电压为380V，$|Z_1|$=10Ω，

  $\cos\varphi_1$ =0.6(滞后)， Z_2= –j50Ω， Z_N=1+ j2Ω。

  求：线电流、相电流，并定性画出相量图(以A相为例)。

- 解：画出一相计算图如下图所示。



设 $\dot{U}_{AN} = 220\angle 0^{o}$ V

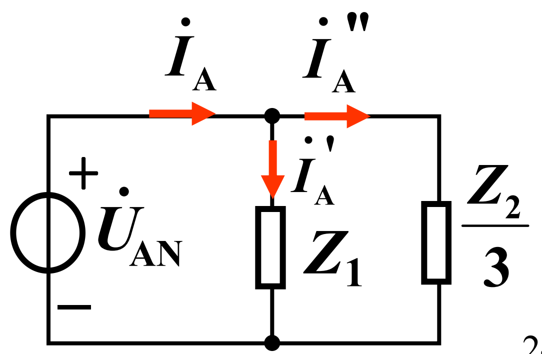
则 $\dot{U}_{AB} = 380\angle 30^{o}$ V

$\because\ Z_1 = 10\angle 53.13^{o} = 6 + j8\ \Omega$

$$Z_2' = \frac{1}{3} Z_2 = -j\frac{50}{3}\ \Omega$$

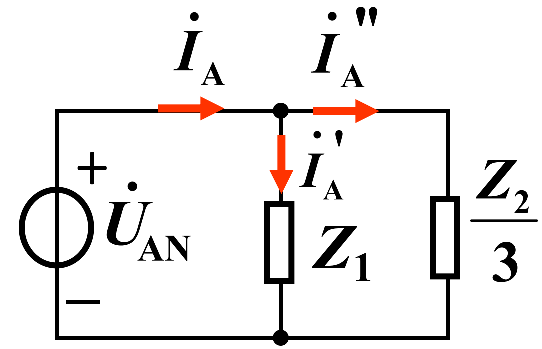
$$\therefore\ \dot{I}_A' = \frac{\dot{U}_{AN}}{Z_1} = \frac{220\angle 0^{o}}{10\angle 53.13^{o}}$$

$$= 22\angle -53.13^{o} = 13.2 - j17.6\text{A}$$



$$\dot{I}_A'' = \frac{\dot{U}_{AN}}{Z_2'} = \frac{220\angle 0^\circ}{-j50/3} = 13.2\angle 90^\circ\ \text{A}$$

$$\dot{I}_A = \dot{I}_A' + \dot{I}_A'' = 13.9\angle -18.4^\circ\ \text{A}$$



根据对称性，得*B*、*C*相的线电流、相电流：

$$\dot{I}_B = 13.9\angle -138.4^\circ\ \text{A} \qquad \dot{I}_C = 13.9\angle 101.6^\circ\ \text{A}$$

第一组负载的相电流　　　　第二组负载的相电流

$$\begin{cases} \dot{I}_A' = 22\angle -53.1^\circ\ \text{A} \\ \dot{I}_B' = 22\angle -173.1^\circ\ \text{A} \\ \dot{I}_C' = 22\angle 66.9^\circ\ \text{A} \end{cases}$$

$$\begin{cases} \dot{I}_{AB2} = \frac{1}{\sqrt{3}}\dot{I}_A''\ \angle 30^\circ = 7.6\angle 120^\circ\ \text{A} \\ \dot{I}_{BC2} = 7.6\angle 0^\circ\ \text{A} \\ \dot{I}_{CA2} = 7.6\angle -120^\circ\ \text{A} \end{cases}$$

依此作出相量图(略)：

4　三相电路的功率

- 一、三相电路的功率

1.　对称三相电路的瞬时功率 p

设对称三相电路中A相的电压、电流为

$$u_{\mathrm{A}} = \sqrt{2}U\sin\omega t \qquad i_{\mathrm{A}} = \sqrt{2}I\sin(\omega t - \varphi)$$

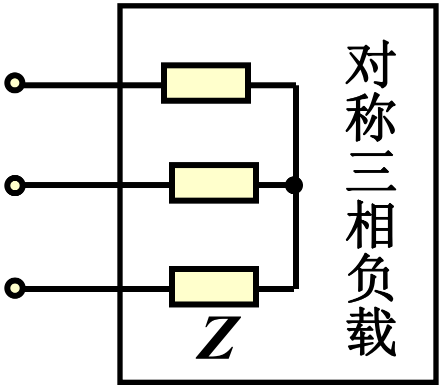
则 $$p_{\mathrm{A}} = u_{\mathrm{A}} i_{\mathrm{A}} = 2UI\sin\omega t\,\sin(\omega t - \varphi)$$
$$= UI\left[\cos\varphi - \cos(2\omega t - \varphi)\right]$$

$$p_{\mathrm{B}} = u_{\mathrm{B}} i_{\mathrm{B}} = UI\cos\varphi - UI\cos[(2\omega t - 120^{\circ}) - \varphi]$$

$$p_{\mathrm{C}} = u_{\mathrm{C}} i_{\mathrm{C}} = UI\cos\varphi - UI\cos[(2\omega t + 120^{\circ}) - \varphi]$$

$$\therefore p = p_{\mathrm{A}} + p_{\mathrm{B}} + p_{\mathrm{C}}$$

2. 对称三相电路的有功功率P



一相负载的功率：$U_p I_p \cos\varphi_{ph}$

且：$P_a = P_b = P_c = P_p = U_p I_p \cos\varphi_{ph}$

有：三相总有功功率 $P = 3P_p = 3U_p I_p \cos\varphi_{ph}$

对称三相负载$Z=|Z|\angle\varphi$

"Y"形负载：$U_L = \sqrt{3}U_{ph}$， $I_L = I_{ph}$

$$P = 3 \cdot \frac{1}{\sqrt{3}} U_L I_L \cos\varphi = \sqrt{3} U_L I_L \cos\varphi_{ph}$$

"Δ"形负载：$U_L = U_p$， $I_L = \sqrt{3} I_p$

$$P = 3U_L \frac{1}{\sqrt{3}} I_L \cos\varphi = \sqrt{3} U_L I_L \cos\varphi_{ph}$$

结论：对称三相电路总有功功率 $\boxed{P = \sqrt{3} U_L I_L \cos\varphi}$

3. 对称三相电路的无功功率Q

$$Q = Q_a + Q_b + Q_c = 3Q_p$$

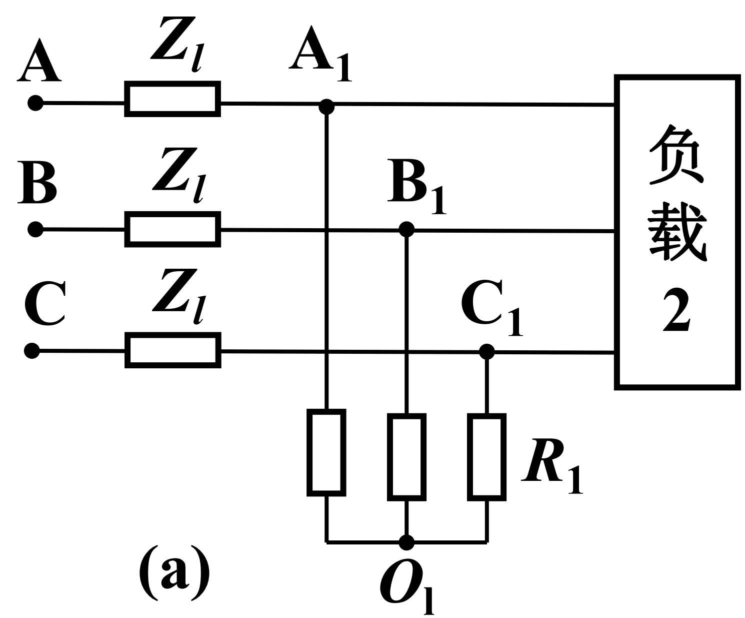
同理，三相总无功功率 $Q = 3Q_p = \sqrt{3} U_L I_L \sin\varphi$

4. 对称三相电路的视在功率S

$$S = \sqrt{3} U_L I_L = \sqrt{P^2 + Q^2}$$

功率因数可定义为： $\cos\varphi = P/S$

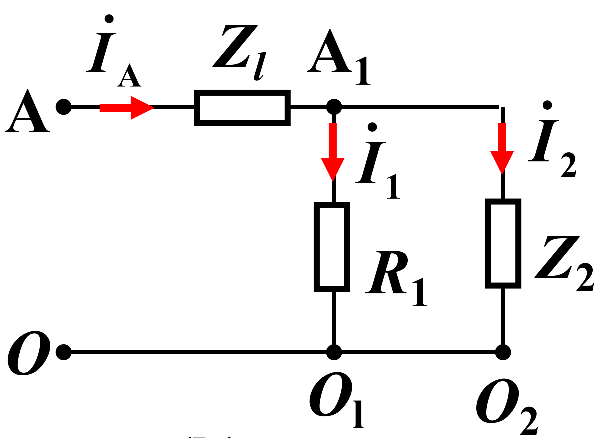
例1. 如图(a)对称三相电路，第一组负载R_1=110Ω，第二组负载平均功率P_2= 5280kw，$\cos\varphi_2$=0.8(滞后)，且两组负载的额定工作相电压有效值为220V，线路阻抗 Z_l=1+ j1Ω。试求负载在额定运行时对称三相电源的线电压U_L、线电流I_L及对称三相电路吸收的有功功率、无功功率、视在功率和功率因数。



(a)

解： 设第二组负载为Y接，

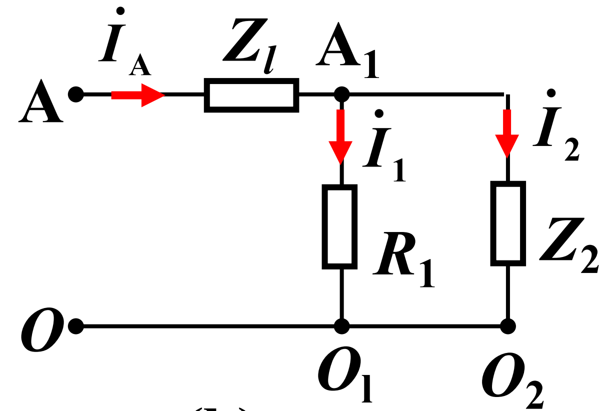
取A相计算电路，如图(b)



(b)

设 $\dot{U}_{A1}=220\angle 0^{\circ}$ V

由已知条件得



(b)

$$I_2=\frac{P_2}{\sqrt{3}U_{A_1B_1}\cos\varphi_2}=\frac{5280}{\sqrt{3}\times 380\times 0.8}=10\text{A}$$

$$\cos\varphi_2=0.8,\qquad \varphi=36.9^{\circ}$$

$$\therefore\quad \dot{I}_2=10\angle-36.9^{\circ}\ \text{A}\qquad\qquad \dot{I}_1=\frac{\dot{U}_{A1}}{R_1}=\frac{220\angle 0^{\circ}}{110}=2\angle 0^{\circ}\,\text{A}$$

$$\dot{I}_A=\dot{I}_1+\dot{I}_2=2+10\angle-36.9^{\circ}=10-j6=11.66\angle-30.96^{\circ}\,\text{A}$$

$$\dot{U}_{AO}=Z_l\dot{I}_A+\dot{U}_{A_1}=(1+j1)\times 11.66\angle-30.96^{\circ}+220\angle 0^{\circ}$$
$$=236\angle 0.97^{\circ}\ \text{V}$$

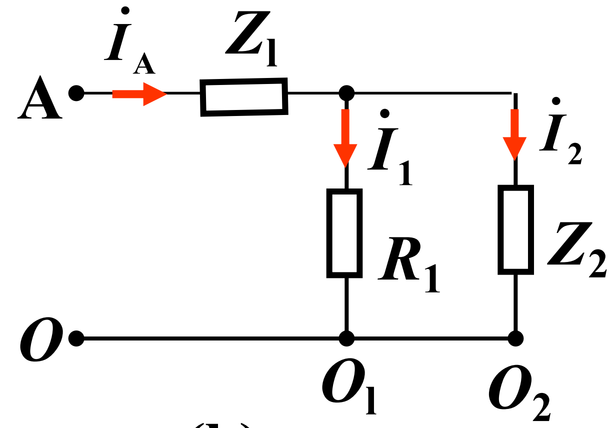
$$\dot{U}_{AB}=\sqrt{3}\,\dot{U}_A\angle 30^{\circ}=\sqrt{3}\times 236\angle(0.97^{\circ}+30^{\circ})$$
$$=408.8\angle 30.97^{\circ}\ \text{V}$$

$$\because\ \dot{U}_{AB} = 408.8\angle 30.97^{\circ}\ \text{V}$$

$$\dot{U}_{A} = 236\angle 0.97^{\circ}\ \text{V}$$

$$\dot{I}_{A} = 11.66\angle -30.96^{\circ}\ \text{A}$$

$$\therefore\ U_{L} = 408.8\ \text{V},\qquad I_{L} = 11.66\text{A}$$



(b)

$$P = \sqrt{3}U_{L}I_{L}\cos\varphi$$

$$= \sqrt{3}\times 408.8\times 11.66\cos\left[0.97^{\circ} - (-30.97^{\circ})\right] = 7.007\text{kW}$$

$$Q = \sqrt{3}U_{L}I_{L}\sin\varphi$$

$$= \sqrt{3}\times 408.8\times 11.66\sin 31.93^{\circ} = 4.367\text{kvar}$$

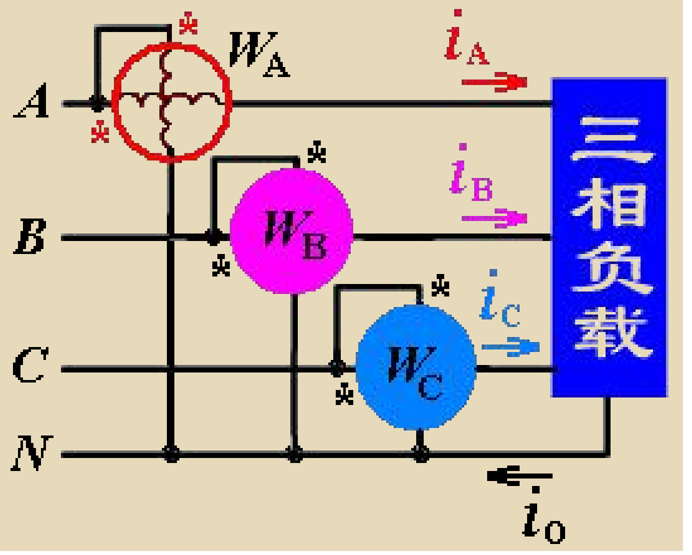
$$S = \sqrt{3}U_{L}I_{L} = \sqrt{3}\times 408.8\times 11.66 = 8.256\text{kVA}$$

$$\cos\varphi = \cos\left[0.97^{\circ} - (-30.96^{\circ})\right] = \cos 31.93^{\circ} = 0.85$$

- **二、三相电路功率的测量(对称，不对称)**

1. 三表法： 适用于三相四线制的电路测量

(1)若负载不对称，则



$$p = u_{AN} i_A + u_{BN} i_B + u_{CN} i_C$$

$$P = P_A + P_B + P_C$$

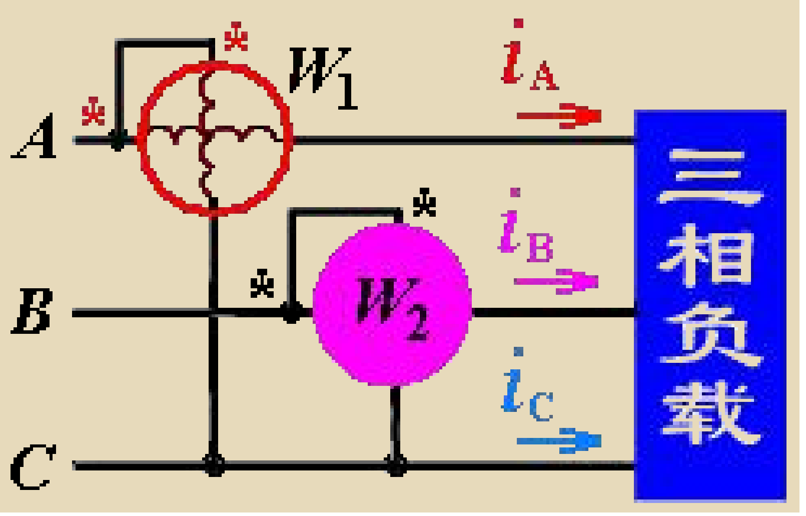
(2) 若负载对称，则

$$P = 3P_A = 3P_B = 3P_C = 3U_{ph} I_{ph} \cos \varphi_{ph}$$

需一块表，读数乘以3。即为一表法

- **二、三相电路功率的测量(对称，不对称)**

2. 二表法：适用于三相三线制的电路测量



若：W_1的读数为P_1，W_2的读数为P_2，

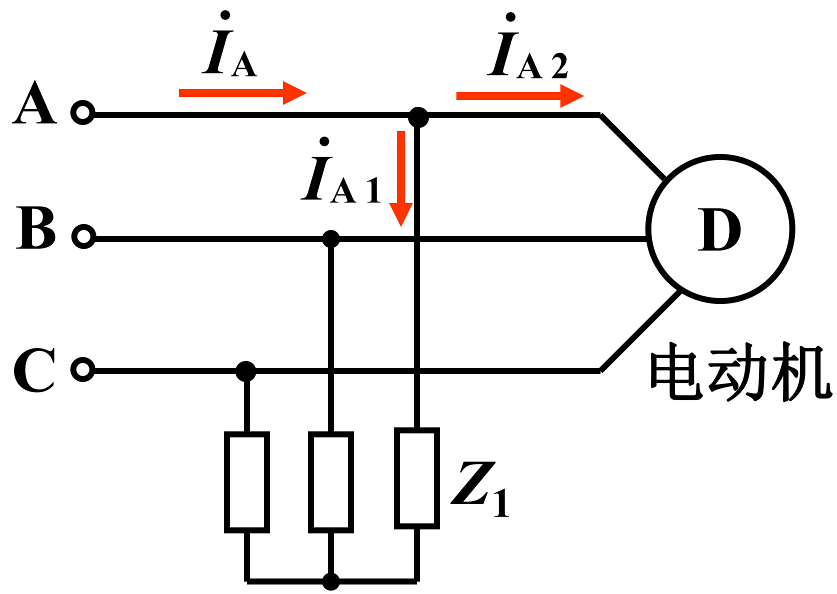
则：$P = P_1 + P_2$ 即为三相总功率。

证明：(参见书本)

例：U_l =380V，Z_1=30+j40Ω，电动机 P=1700W，cosφ=0.8(滞后)。

求：(1) 线电流和电源发出总功率；

(2) 用两表法测电动机负载的功率，画接线图，求两表读数。



解：(1) $\dot{U}_{AN} = 220\angle 0^\circ$ V

$$\dot{I}_{A1} = \frac{\dot{U}_{AN}}{Z_1} = \frac{220\angle 0^\circ}{30 + j40}$$

$$= 4.41\angle -53.1^\circ \text{ A}$$

电动机负载：

$$P = \sqrt{3} U_l I_{A2} \cos\varphi = 1.7 \text{ kW}$$

$$I_{A2} = \frac{P}{\sqrt{3} U_l \cos\varphi} = \frac{P}{\sqrt{3} \times 380 \times 0.8} = 3.23\text{A}$$

$$\therefore \dot{I}_{A2} = 3.23\angle -36.9^\circ \text{ A}$$

总电流： $\dot{I}_A = \dot{I}_{A1} + \dot{I}_{A2}$

$$= 4.41\angle -53.1^\circ + 3.23\angle -36.9^\circ$$

$$= 7.56\angle -46.2^\circ \ \mathrm{A}$$

$$P_{总} = \sqrt{3}U_l I_A \cos\varphi_{总}$$

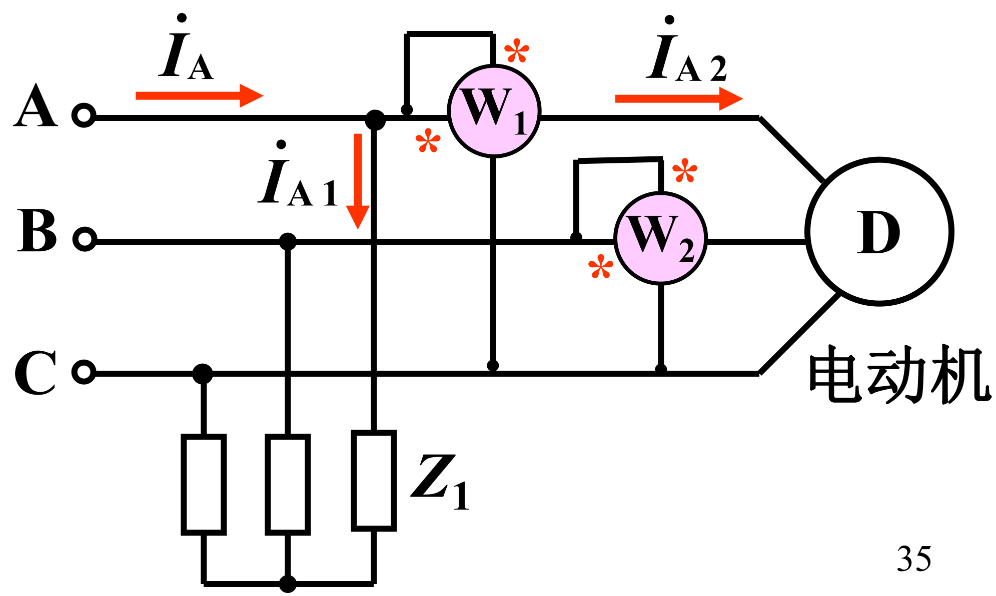
$$= \sqrt{3} \times 380 \times 7.56\cos 46.2^\circ = 3.44 \ \mathrm{kW}$$

$$P_{Z_1} = 3 \times I_{A1}^2 \times R_1 = 3 \times 4.41^2 \times 30 = 1.74 \ \ \mathrm{kW}$$

(2) 两表的读数如图

$$\dot{I}_{A2} = 3.23\angle -36.9^\circ \ \mathrm{A}$$

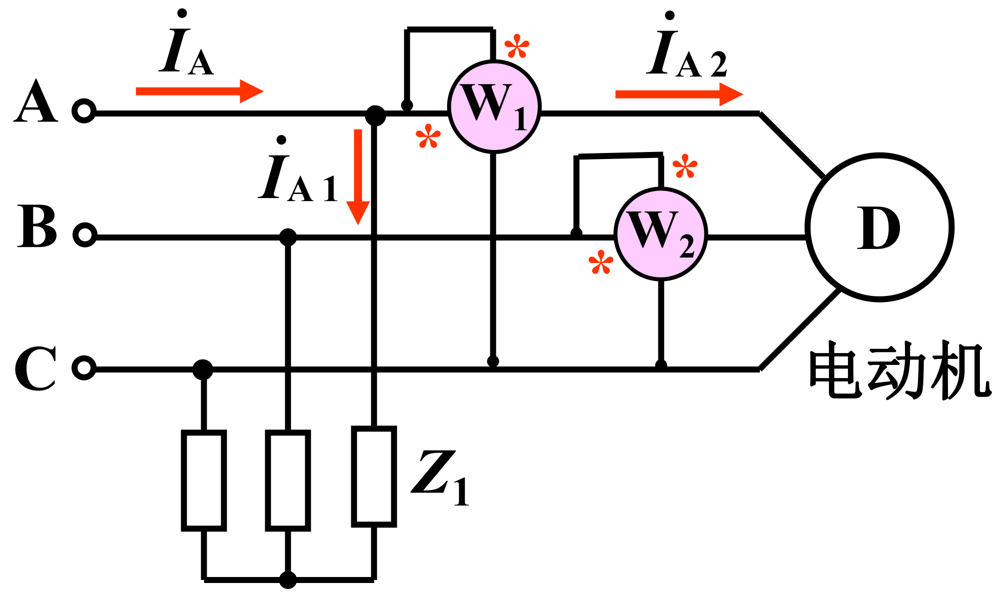
$$\dot{I}_{B2} = 3.23\angle -156.9^\circ \ \mathrm{A}$$



$\because\quad \dot{U}_{AB} = 380\angle 30^\circ\ \text{V}$

$\therefore\quad \dot{U}_{BC} = 380\angle -90^\circ\ \text{V}$

$$\dot{U}_{AC} = -\dot{U}_{CA}$$
$$= -380\angle 150^\circ\ \text{V}$$
$$= 380\angle -30^\circ\ \text{V}$$



表W_1的读数P_1： $P_1 = U_{AC} I_{A2} \cos\varphi_1$

$$= 380 \times 3.23 \cos(-30^\circ + 36.9^\circ)$$

$$= 1218.5\text{W}$$

表W_2的读数P_2： $P_2 = U_{BC} I_{B2} \cos\varphi_2$

$$= 380 \times 3.23 \cos(-156.9^\circ + 90^\circ)$$

$$= 481.6\text{W}$$

第七章作业

12-6， 12-8，12-29