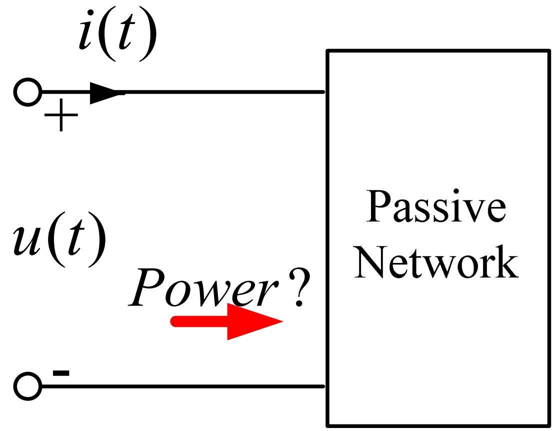
第11章
正弦稳态电路的功率

11.2 瞬时功率（Instantaneous power）

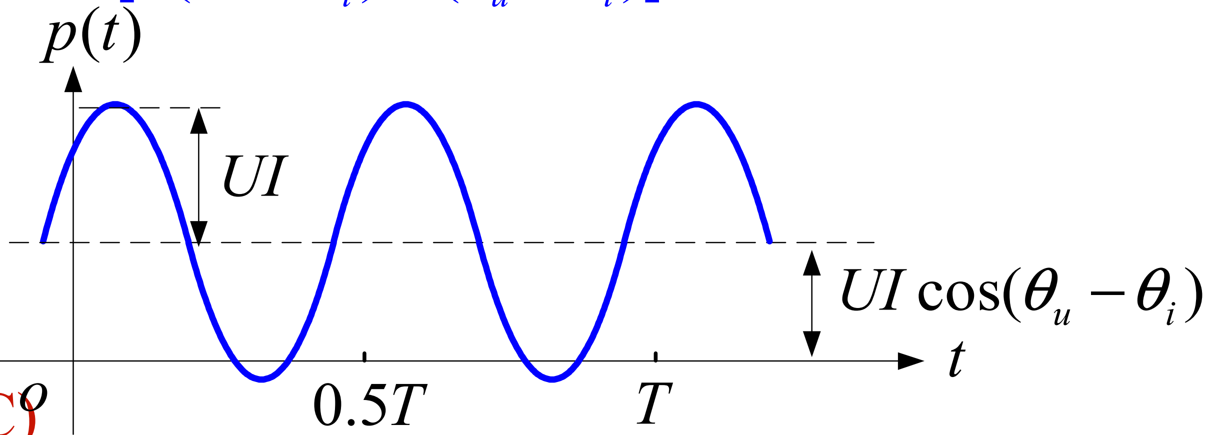


$$u=\sqrt{2}U\cos(\omega t+\theta_u),\quad i=\sqrt{2}I\cos\cos(\omega t+\theta_i)$$

$$p(t)=u(t)i(t)=2UI\cos(\omega t+\theta_u)\cos(\omega t+\theta_i)$$

$$=UI\cos(\theta_u-\theta_i)+UI\cos(2\omega t+\theta_u+\theta_i)$$

$$=UI\cos(\theta_u-\theta_i)+UI\cos[2(\omega t+\theta_i)+(\theta_u-\theta_i)]$$



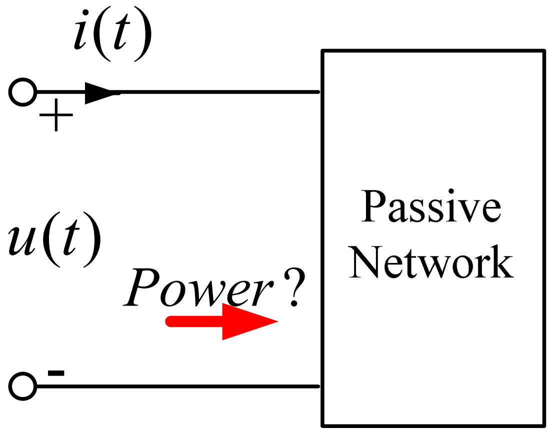
2 元件的瞬时功率(RLC)

R $\quad p(t)=UI+UI\cos 2(\omega t+\theta_i)\geq 0$

L $\quad p(t)=UI\cos(90°)+UI\cos[2(\omega t+\theta_i)+90°]$ $\boxed{=-UI\sin 2(\omega t+\theta_i)}$

C $\quad p(t)=UI\cos(-90°)+UI\cos[2(\omega t+\theta_i)-90°]$ $\boxed{=UI\sin 2(\omega t+\theta_i)}$

11.2 瞬时功率（Instantaneous power）



3 RLC支路的瞬时功率

$$p(t)=u(t)i(t)=2UI\cos(\omega t+\theta_u)\cos(\omega t+\theta_i)$$

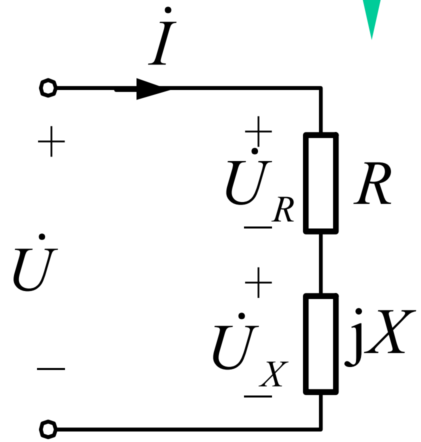
$$=UI\cos(\theta_u-\theta_i)+UI\cos(2\omega t+\theta_u+\theta_i)$$

$$=UI\cos(\theta_u-\theta_i)+UI\cos[2(\omega t+\theta_i)+(\theta_u-\theta_i)]$$

$$=UI\cos(\theta_u-\theta_i)+UI\cos(\theta_u-\theta_i)\cos 2(\omega t+\theta_i)-UI\sin(\theta_u-\theta_i)\sin 2(\omega t+\theta_i)$$

$$=\underbrace{UI\cos(\theta_u-\theta_i)[1+\cos 2(\omega t+\theta_i)]}_{\text{消耗功率}}-\underbrace{UI\sin(\theta_u-\theta_i)\sin 2(\omega t+\theta_i)}_{\text{交换功率}}$$

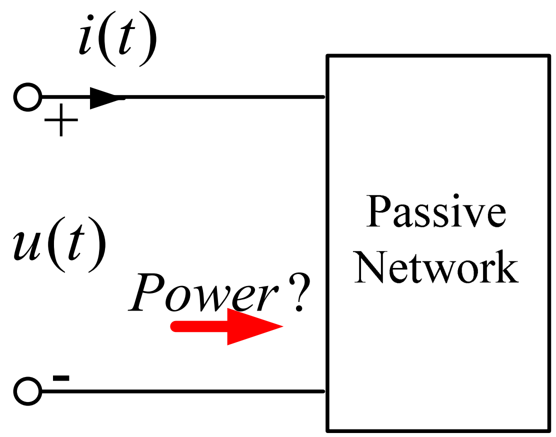
$$=p_R(t)+p_X(t)$$



无源一端口网络的瞬时功率等于:

- 恒为正的消耗功率$p_R(t)$,
- 和平均值为0的交换功率$p_X(t)$之和。

11.3 有功功率与无功功率



1 有功功率 real power

$$p(t)=u(t)i(t)=2UI\cos(\omega t+\theta_u)\cos(\omega t+\theta_i)$$

$$=UI\cos(\theta_u-\theta_i)+UI\cos(2\omega t+\theta_u+\theta_i)$$

$$=\underbrace{UI\cos(\theta_u-\theta_i)[1+\cos 2(\omega t+\theta_i)]}_{\text{消耗功率}}-UI\sin(\theta_u-\theta_i)\sin 2(\omega t+\theta_i)$$

平均功率 Average power

$$\boxed{P=\frac{1}{T}\int_0^T p(t)dt=UI\cos(\theta_u-\theta_i)=UI\cos\varphi}$$

单位：W 瓦

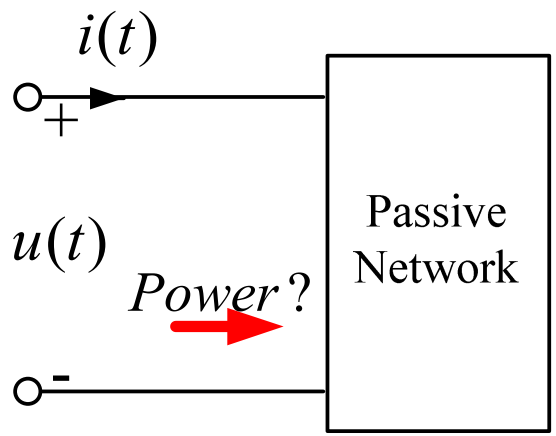
φ： 功率因数角。对无源网络，为其等效阻抗的阻抗角，即

$P=UI\cos\varphi=(|Z|I)I\cos\varphi=RI^2$

$\cos\varphi$：功率因数

$$\cos\varphi\begin{cases}1, & \text{纯电阻}\\0, & \text{纯电抗}\end{cases}$$

11.3 有功功率与无功功率



1 有功功率　real power

$$p(t)=u(t)i(t)=2UI\cos(\omega t+\theta_u)\cos(\omega t+\theta_i)$$

$$=UI\cos(\theta_u-\theta_i)+UI\cos(2\omega t+\theta_u+\theta_i)$$

$$=UI\cos(\theta_u-\theta_i)[1+\cos 2(\omega t+\theta_i)]-\underline{UI\sin(\theta_u-\theta_i)\sin 2(\omega t+\theta_i)}$$

交换功率

2 无功功率 reactive power

交换功率的幅值 Exchanged maximum power

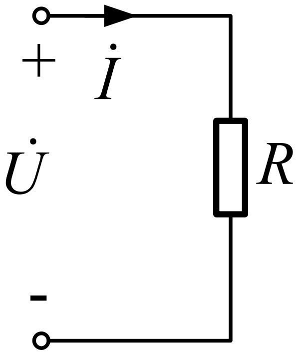
$Q=UI\sin(\theta_u-\theta_i)=UI\sin\varphi$　单位：var 乏　吸收还是发出?

Q 的大小反映网络与外电路交换功率的幅值。是由储能元件L、C的性质决定的;

Q>0，表示网络吸收无功功率;

Q<0，表示网络发出无功功率。

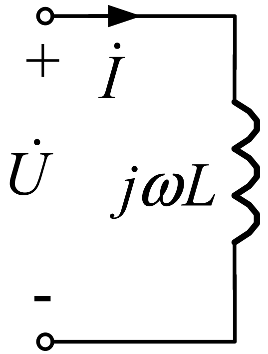
讨论1：R、L、C元件的有功功率和无功功率?



$P_R = UI\cos\varphi = UI\cos 0° = UI = I^2R = U^2/R$

$Q_R = UI\sin\varphi = UI\sin 0° = 0$

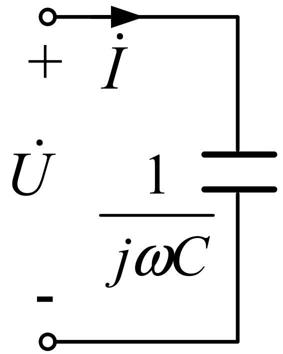
电阻只吸收(消耗)功率，无功功率为0。



$P_L = UI\cos\varphi = UI\cos 90° = 0$

$Q_L = UI\sin\varphi = UI\sin 90° = UI$

电感不消耗有功功率，吸收无功功率。

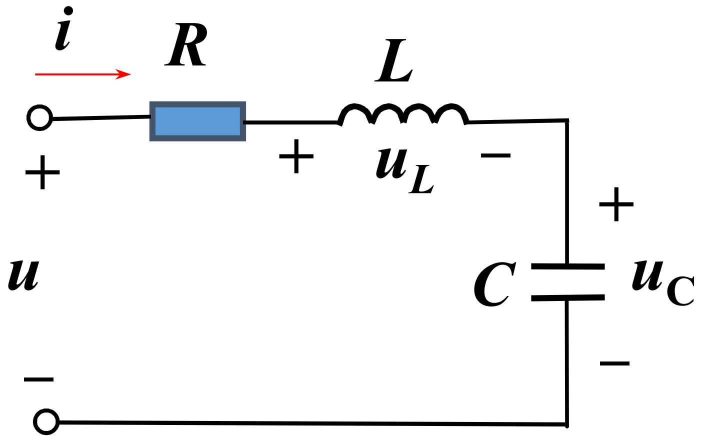


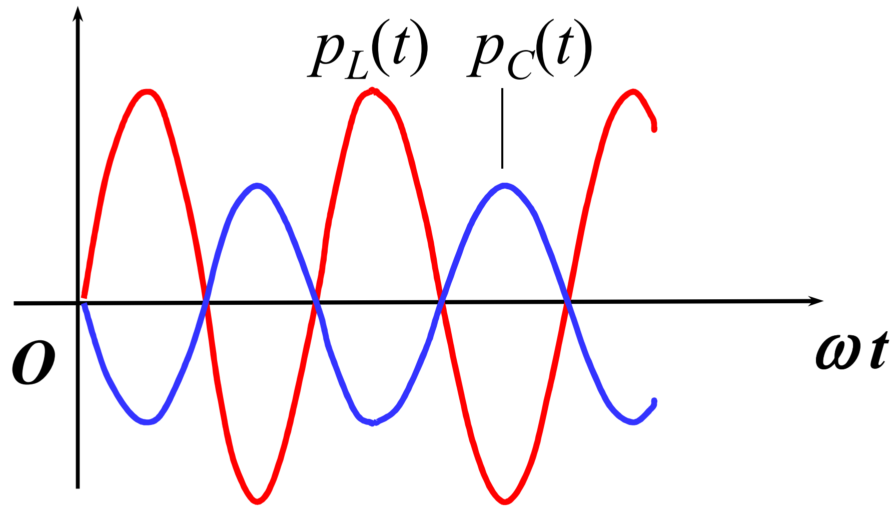
$P_C = UI\cos\varphi = UI\cos(-90°) = 0$

$Q_C = UI\sin\varphi = UI\sin(-90°) = -UI$

电容不消耗功率；电容发出无功功率。

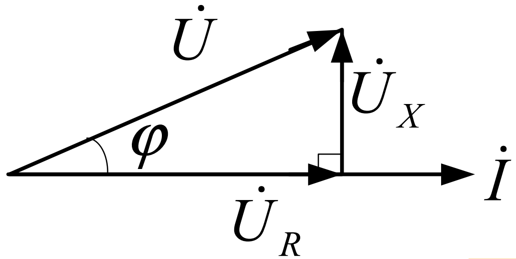
讨论2：电感、电容的无功补偿作用?

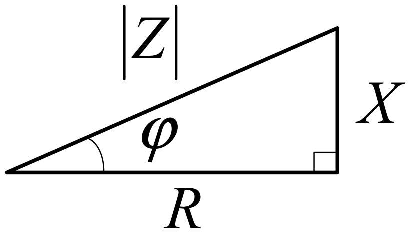


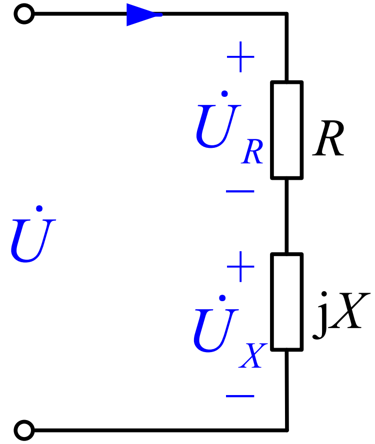


当L发出功率时，C刚好吸收功率，则与外电路交换功率为p_L+p_C，因此，L、C的无功具有互相补偿的作用。

讨论3：计算以下各电路的平均功率和无功功率？



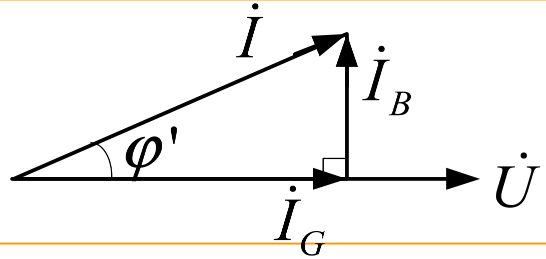


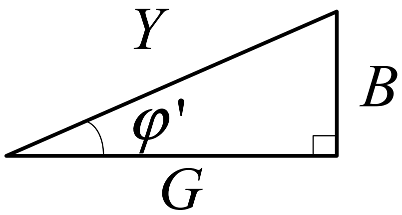


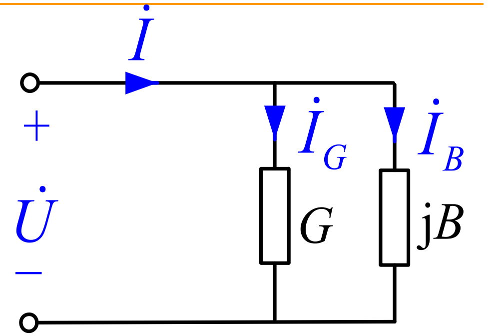
$$P = UI\cos\varphi = U_R I \boxed{= RI^2}$$

$$Q = UI\sin\varphi = U_X I \boxed{= XI^2}$$

设为感性电路





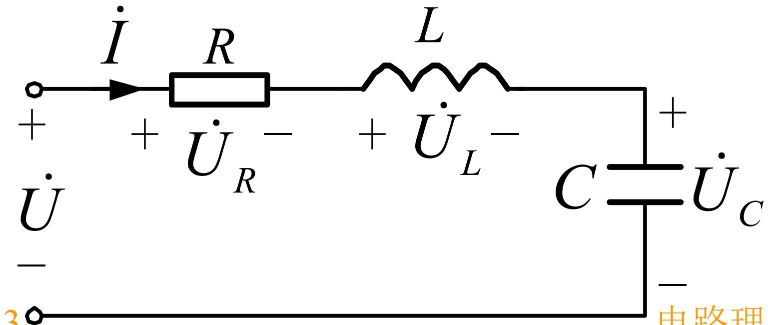


$$\boxed{P = UI\cos\varphi = UI_G = GU^2}$$

$$\boxed{Q = UI\sin\varphi = UI\sin(-\varphi') = -UI_B = -BU^2}$$

设为容性电路

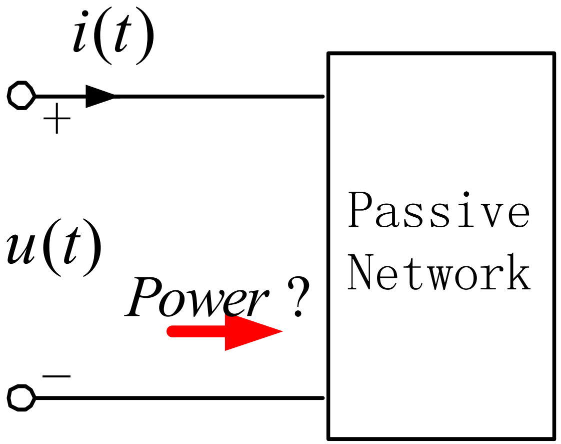
推论：



$$P = UI\cos\varphi = RI^2$$

$$Q = UI\sin\varphi = (\omega L - \frac{1}{\omega C})I^2$$

11.4 视在功率及功率因数

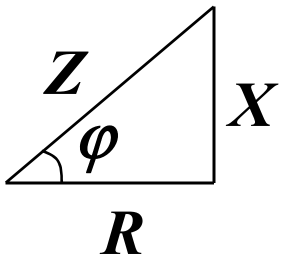


视在功率　Apparent power

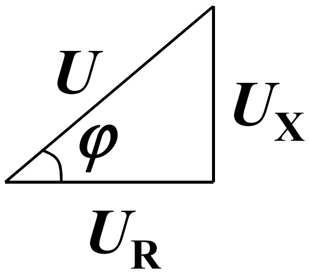
$$S = UI = \sqrt{P^2 + Q^2}$$ 单位：VA

反映电气设备的容量。

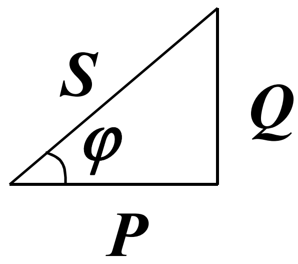
有功，无功，视在功率的关系：



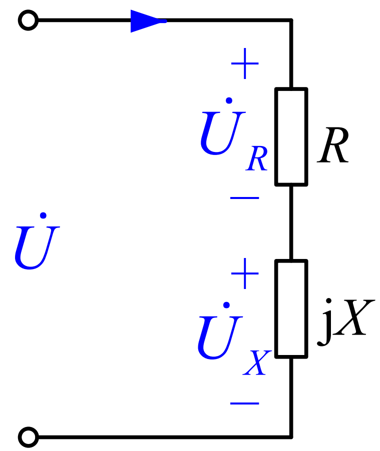
阻抗三角形



电压三角形



功率三角形

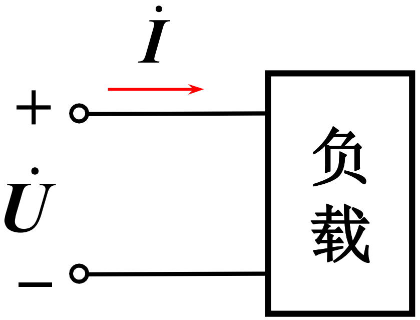


设为感性电路

11.5 复功率及功率守恒

1. 复功率Complex power

电力系统分析中，为了方便分析计算，将P、Q、S合成一个物理量，引入“复功率”。



$$\dot{U}=U\angle\theta_u \quad , \qquad \dot{I}=I\angle\theta_i$$

$$P=UI\cos(\theta_u-\theta_i)=UI\mathrm{Re}[e^{\mathrm{j}(\theta_u-\theta_i)}]$$

$$=\mathrm{Re}(\underbrace{U\mathrm{e}^{\mathrm{j}\theta_u}}_{\dot{U}}\cdot\underbrace{I\mathrm{e}^{-\mathrm{j}\theta_i}}_{\dot{I}^*})$$

$$\boxed{P=\mathrm{Re}[\dot{U}\cdot\dot{I}^*]}$$

$$\boxed{\text{定义}\quad \bar{S}=\dot{U}\dot{I}^*\quad\text{为复功率，单位}\quad \mathrm{VA}}$$

则 $\bar{S}=\dot{U}\dot{I}^*=UI\angle(\theta_u-\theta_i)=UI\angle\varphi=S\angle\varphi$

$$=UI\cos\varphi+\mathrm{j}UI\sin\varphi$$

$$=P+\mathrm{j}Q$$

推论：无源网络中

$$\bar{S}=\dot{U}\dot{I}^*=Z\dot{I}\cdot\dot{I}^*=ZI^2$$

$$\bar{S}=\dot{U}\dot{I}^*=\dot{U}(\dot{U}Y)^*$$

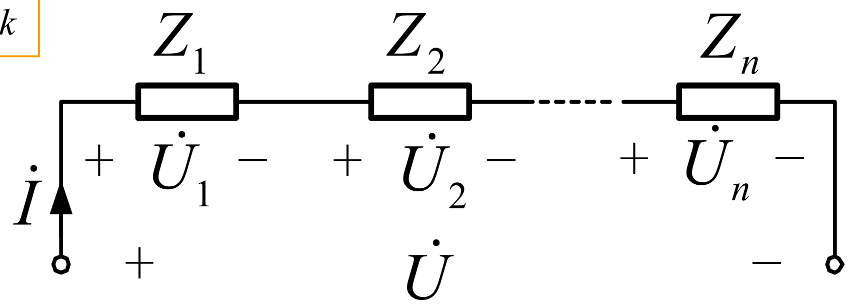
$$=\dot{U}\cdot\dot{U}^*Y^*=U^2Y^*$$

11.5 复功率及功率守恒

2 复功率守恒 Conservation of power

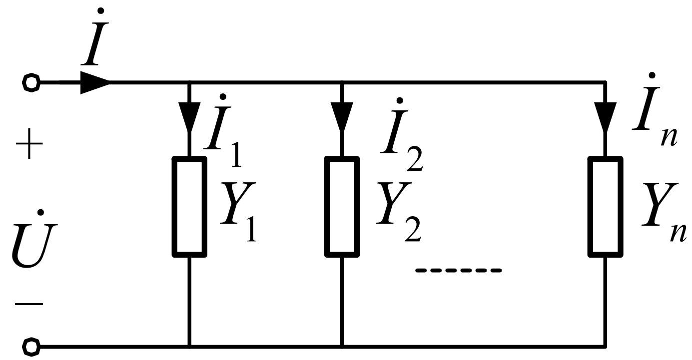
在正弦稳态下，任一电路激励源发出的复功率等于各支路吸收的复功率之和。即

$$\boxed{\overline{S}=\sum \overline{S}_k}$$



$$\overline{S}=\dot{U}\dot{I}^*=\left(\sum_{k=1}^{n}\dot{U}_k\right)\dot{I}^*=\sum_{k=1}^{n}(\dot{U}_k\dot{I}^*)$$

$$\boxed{\overline{S}=\sum \overline{S}_k}$$



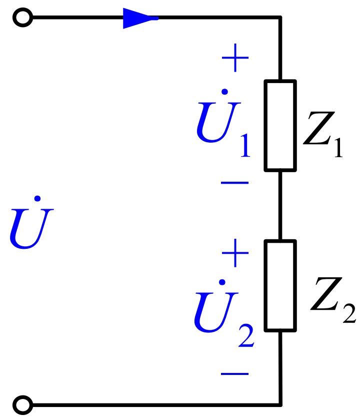
$$\overline{S}=\dot{U}\dot{I}^*=\dot{U}\left(\sum_{k=1}^{n}\dot{I}_k^*\right)=\left(\sum_{k=1}^{n}\dot{U}\dot{I}_k^*\right)$$

$$\boxed{\overline{S}=\sum \overline{S}_k}$$

$$\boxed{\overline{S}=\sum \overline{S}_k=\sum P_k+j\sum Q_k}$$

11.5 复功率及功率守恒

2 复功率守恒　Conservation of power



复功率守恒，有功功率、无功功率守恒。

视在功率不守恒。 $\boxed{S \neq \sum_{k=1}^{b} S_k}$

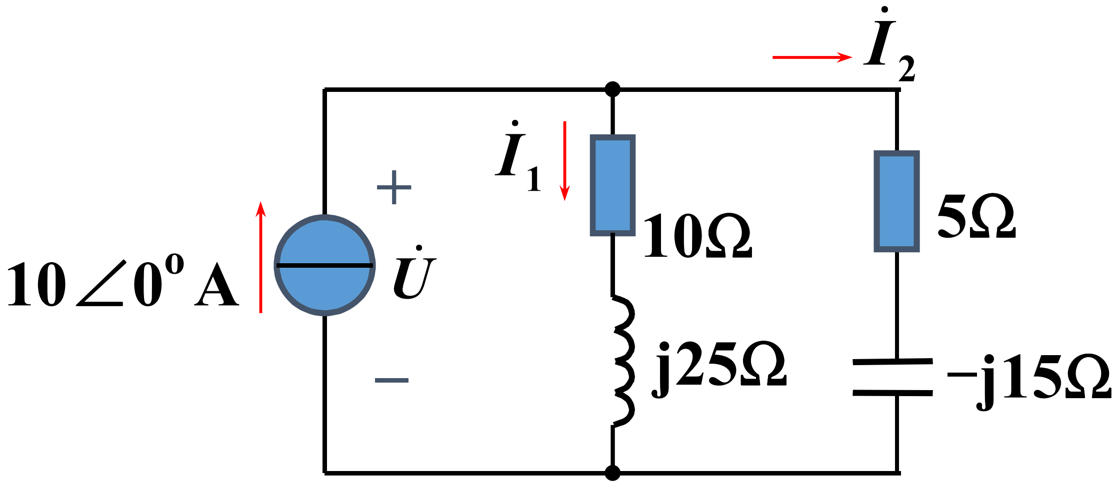
证明：

$$U = U_1 + U_2 \ ?$$

$$U \neq U_1 + U_2$$

$$UI \neq U_1 I + U_2 I \qquad \boxed{S \neq S_1 + S_2}$$

【例1】.已知如图，求各支路的复功率。



解：

$$\dot{U}=10\angle 0^{\circ}\times[(10+j25)//(5-\mathrm{j}15)]=236\angle(-37.1^{\circ})\quad \mathrm{V}$$

$$\overline{S}_{发}=\dot{U}\dot{I}^{*}=236\angle(-37.1^{\circ})\times 10\angle 0^{\circ}=1882-\mathrm{j}1424\quad \mathrm{VA}$$

$$\overline{S}_{1吸}=U^{2}Y_{1}^{*}=236^{2}\left(\frac{1}{10+j25}\right)^{*}=768+\mathrm{j}1920\quad \mathrm{VA}$$

$$\overline{S}_{2吸}=U^{2}Y_{2}^{*}=1113-\mathrm{j}3345\quad \mathrm{VA}$$ 复功率守恒。

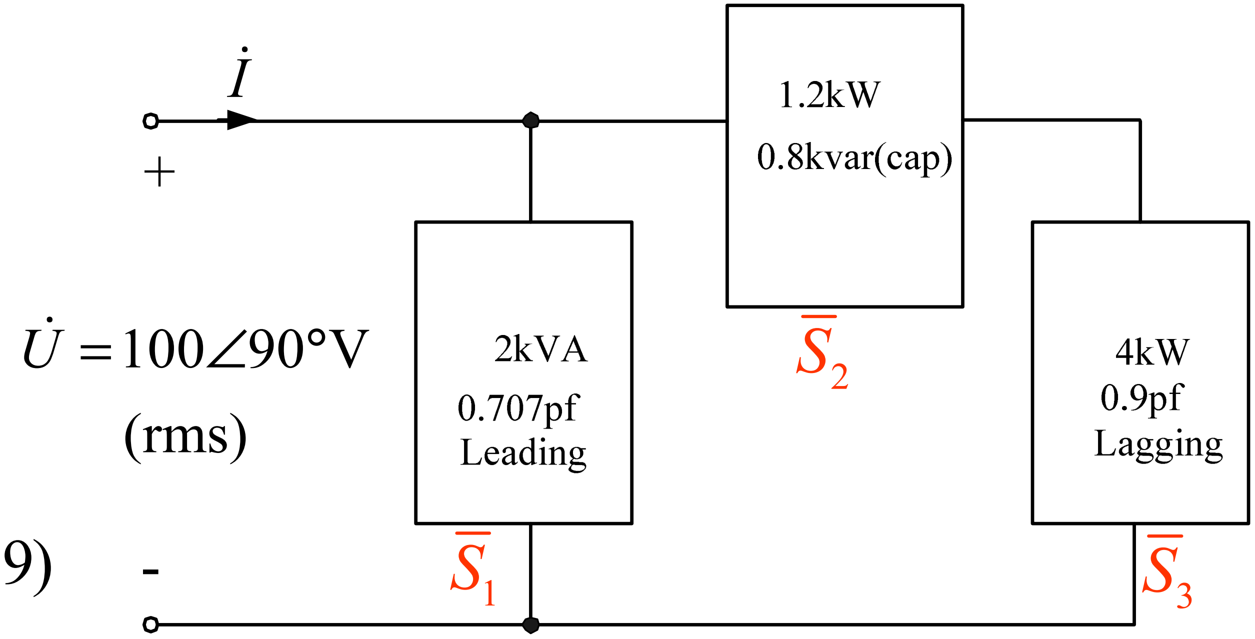
思考：感性网络和容性网络，复功率虚部（Q）正负？

【例2】确定电源提供的复功率及端口电流.（p456，例11-5-1）

$$\overline{S}_1 = 2\times(0.707 - j0.707)$$
$$= 1.414 - j1.414$$

$$\overline{S}_2 = 1.2 - j0.8$$

$$\overline{S}_3 = 4 + j4\times\frac{\sin\varphi}{\cos\varphi}$$
$$= 4 + j4\times\tan(\arccos 0.9)$$
$$= 4 + j1.937$$

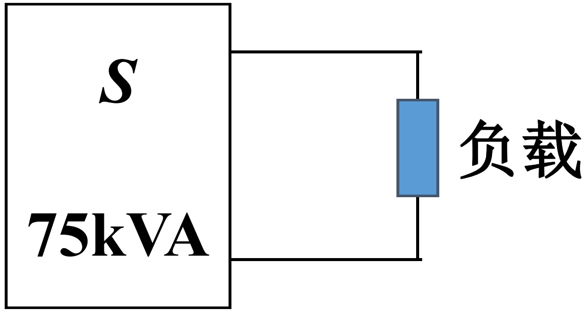


$$\overline{S} = \overline{S}_1 + \overline{S}_2 + \overline{S}_3 = 6.614 - j0.277 = 6.62\angle -2.4°\text{kVA}$$

$$\dot{I} = \left(\frac{\overline{S}}{\dot{U}}\right)^* = \left(\frac{6.62\angle -2.4°}{100j}\right)^* = 66.2\angle 92.4°\text{A}$$

11.6 功率因数校正

设备容量 S (额定)向负载送多少有功要由负载的阻抗角决定。



$\cos\varphi=0.7$, $P=0.7S=52.5\text{kW}$

一般用户：

异步电机 :空载$\cos\varphi=0.2\sim0.3$

日光灯 :$\cos\varphi=0.45\sim0.6$

功率因数低带来的问题：

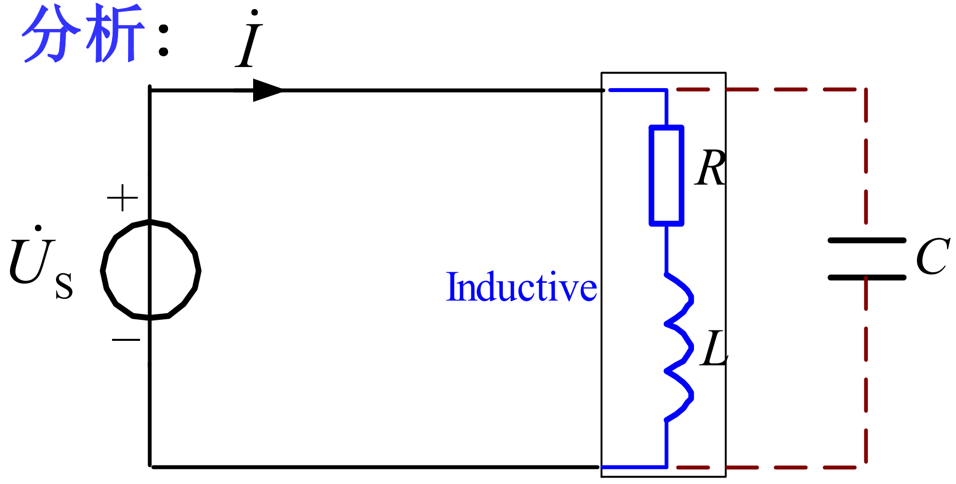
- 设备不能充分利用，电流到了额定值，但功率容量还有；
- 当输出相同的有功功率时，线路上电流大$I=P/(U\cos\varphi)$，线路压降损耗大。

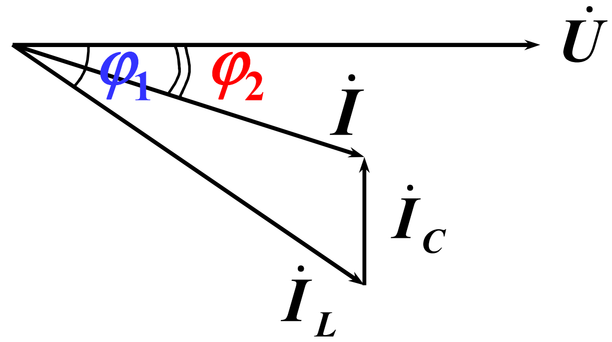
解决办法：并联电容，提高功率因数 (改进自身设备)。

思考：能否用串联电容提高$\cos\varphi$?

单纯从提高$\cos\varphi$看是可以，但是负载上电压改变了。在电网与电网连接上有用这种方法的，一般用户采用并联电容。

分析：



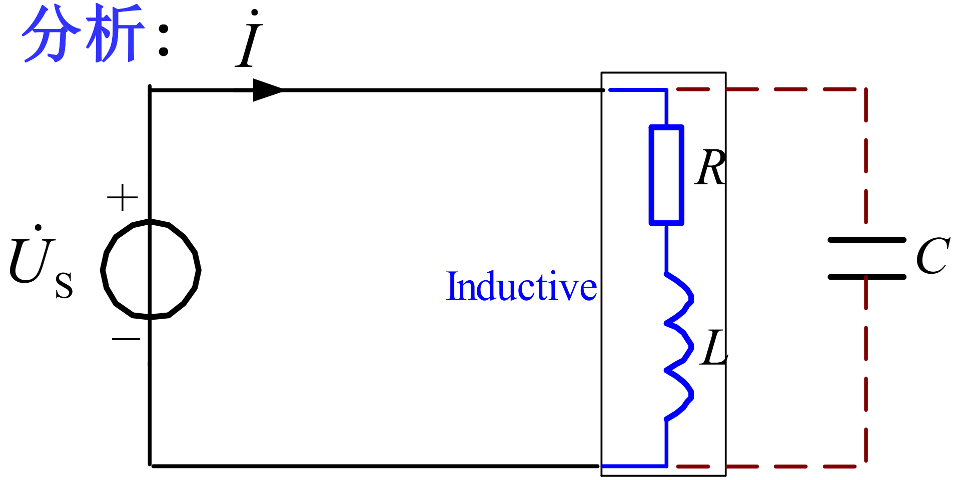


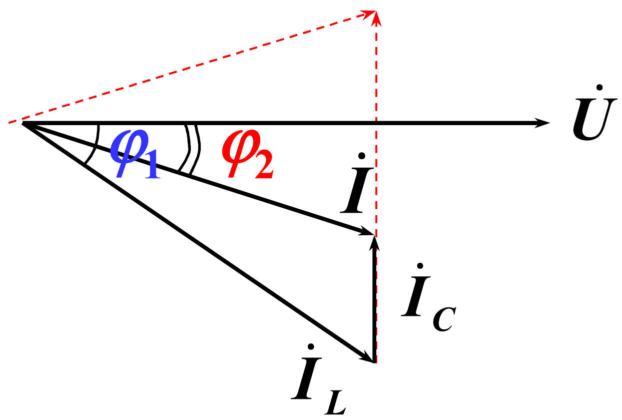
- 并联电容后，原感性负载的电流、吸收的有功无功都不变，即负载的工作状态没有发生任何变化；

- 由于并联电容的电流超前端口电压90°，使得端口总电流减少。从相量图上，端口电压和端口电流的夹角减小了，从而提高了功率因数。

- 功率因数提高后，线路上电流减少，就可以带更多的负载，充分利用设备的能力。

分析：





$$I_C = I_L \sin\varphi_1 - I\sin\varphi_2$$

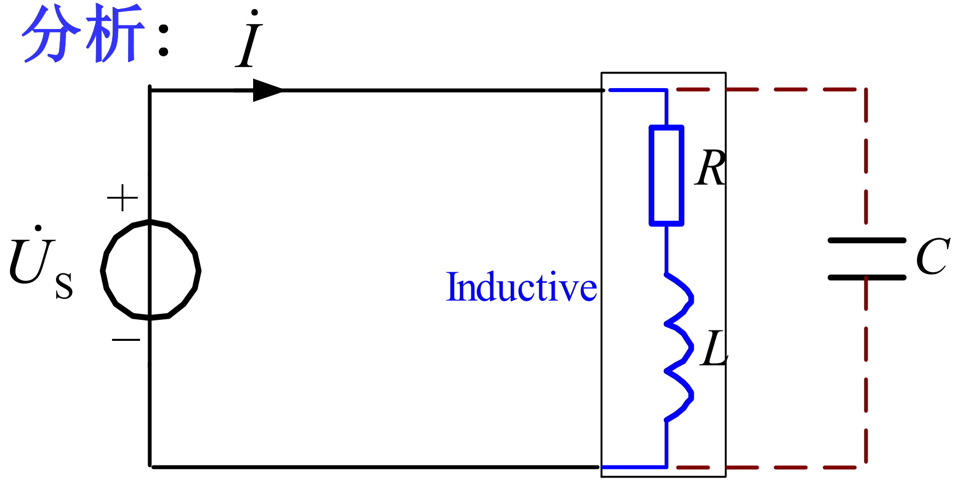
将 $I_L = \dfrac{P}{U\cos\varphi_1}$ ，$I = \dfrac{P}{U\cos\varphi_2}$ 代入上式得

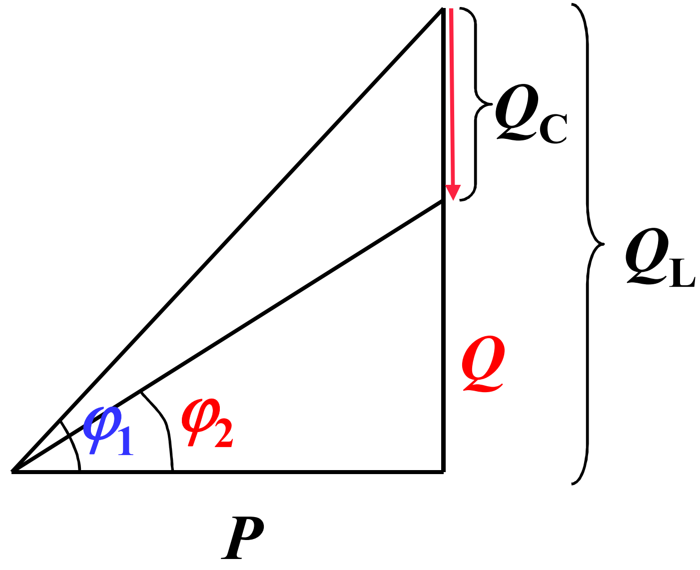
$$I_C = \frac{P}{U}(\tan\varphi_1 - \tan\varphi_2) = \omega CU \quad \Rightarrow \quad C = \frac{P}{\omega U^2}(\tan\varphi_1 - \tan\varphi_2)$$

补偿容量不同
- 欠
- 全——不要求(电容设备投资增加,经济效果不明显)
- 过——使功率因数又由高变低(性质不同)

综合考虑，提高到适当值为宜(0.9 左右)。

分析：





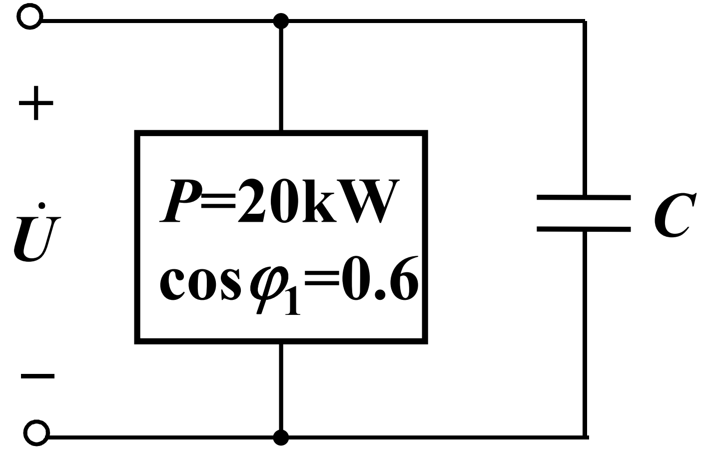
补偿容量也可以用功率三角形确定：

$$|Q_c| = |Q_L - Q| = P\frac{\sin\varphi_1}{\cos\varphi_1} - P\frac{\sin\varphi_2}{\cos\varphi_2} = P(\tan\varphi_1 - \tan\varphi_2)$$

$$|Q_C| = UI = \omega C U^2$$

$$\boxed{C = \frac{P}{\omega U^2}(\tan\varphi_1 - \tan\varphi_2)}$$

【例1】已知：f=50Hz, U=380V, P=20kW, $\cos\varphi_1$=0.6(滞后)。要使功率因数提高到0.9，求并联电容C。



解：

由$\cos\varphi_1 = 0.6$ 得 $\varphi_1 = 53.13°$

由$\cos\varphi_2 = 0.9$ 得 $\varphi_2 = 25.84°$

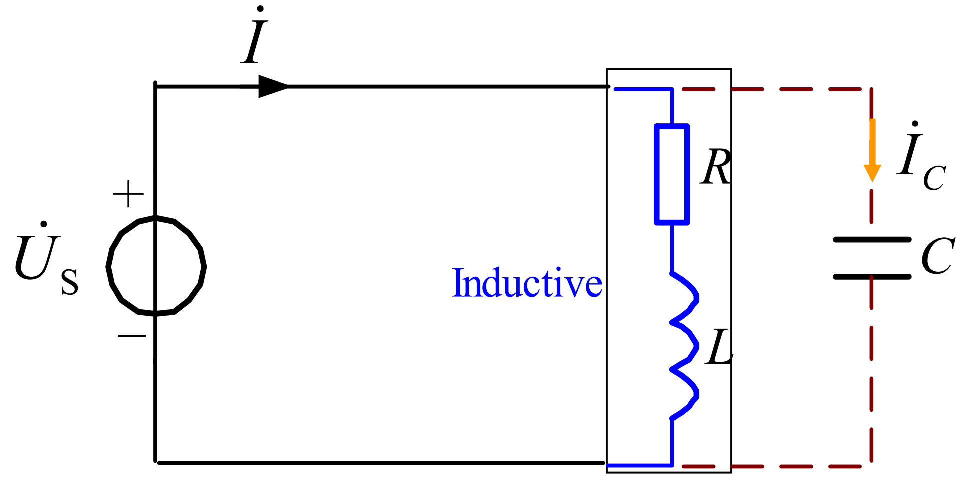
$$Q_L = P\frac{\sin\varphi_1}{\cos\varphi_1} = P\tan\varphi_1 = 20\times\tan 53.13° = 26.67k\,\text{var}$$

$$Q = P\frac{\sin\varphi_2}{\cos\varphi_2} = P\tan\varphi_2 = 20\times\tan 25.84° = 9.69k\,\text{var}$$

$$Q_c = Q - Q_L = -\omega C U^2$$

$$C = \frac{Q_L - Q}{\omega U^2} = \frac{(26.67\text{-}9.69)\times 10^3}{314\times 380^2} = 375\ \mu\text{F}$$

【课下练习】



电压源:

2500VA, 220V (rms), 50Hz

感性负载:

1210W ,0.5 （滞后）. → 0.85

$$\dot{U}_s = 220\angle 0°$$

$$\dot{I}_L = \frac{P}{U_s \cos\varphi_1}\angle -\varphi_1 = \frac{1210}{220\times 0.5}\angle -60° = 11\angle -60°$$

降低线路电流

$$\dot{I} = \frac{P}{U_s \cos\varphi_2}\angle -\varphi_2 = \frac{1210}{220\times 0.85}\angle -31.8° = 6.5\angle -31.8°$$

$$\dot{I}_C = \frac{\dot{U}_s}{-\mathrm{j}X_C} = \frac{220}{-\mathrm{j}X_C} \qquad \dot{I} = \dot{I}_C + \dot{I}_L \Rightarrow 6.5\angle -31.8° = 11\angle -60° + \frac{220}{-\mathrm{j}X_C}$$

$$X_C = 36.1\Omega \Rightarrow C = 88.2\mu F$$

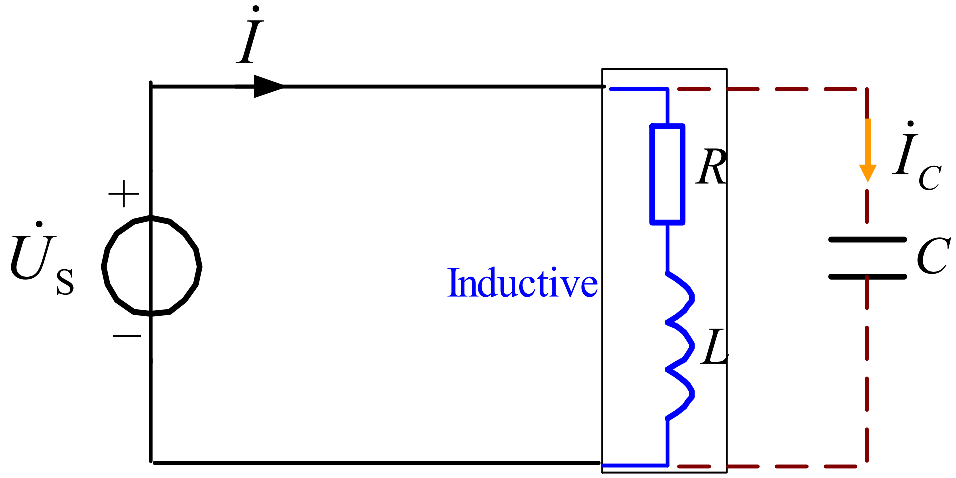
【课下练习】

电压源:

2500VA, 220V (rms), 50Hz

感性负载:

1210W ,0.5 （滞后） . → 0.85



$$\dot{U}_s = 220\angle 0°$$

方法2 功率三角形

$$Q_1 = 1210\,\text{tg}\arccos 0.5 = 1210\sqrt{3}\text{Var}$$

$$S_1 = \sqrt{1210^2 + (1210\sqrt{3})^2} = 1210/0.5 = 2420\text{VA}$$

$$Q_2 = 1210\,\text{tg}\arccos 0.85 = 745\text{Var}$$

$$S_2 = \sqrt{1210^2 + (745)^2} = 1210/0.85 = 1423.5\text{VA}$$

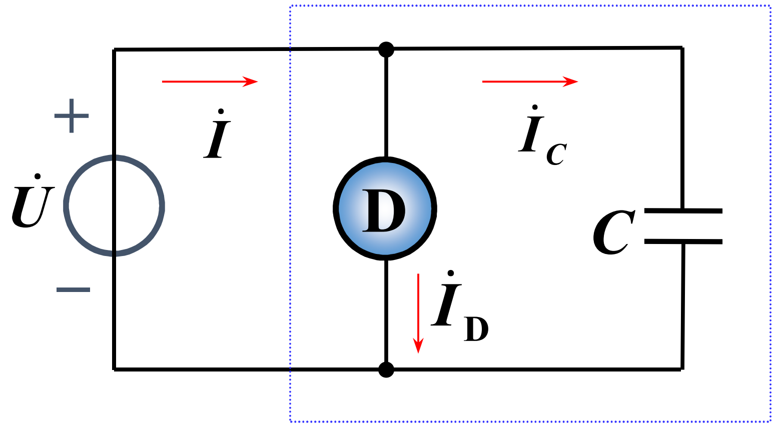
$$Q_C = Q_1 - Q_2 = \omega C U_s^2 = 2\pi \times 50 \times 220^2 C$$

$$\boxed{C = 88.5\mu\text{F}}$$

提高电源容量利用率

【例2】已知：电动机 P_D=1000W，功率因数为0.8（滞后）U=220V，f=50Hz，C=30μF。求负载电路的功率因数。

解：



$$I_D=\frac{P_D}{U\cos\varphi_D}=\frac{1000}{220\times0.8}=5.68\text{A}$$

由 $\cos\varphi_D=0.8$(滞后)，得 $\varphi_D=36.8°$

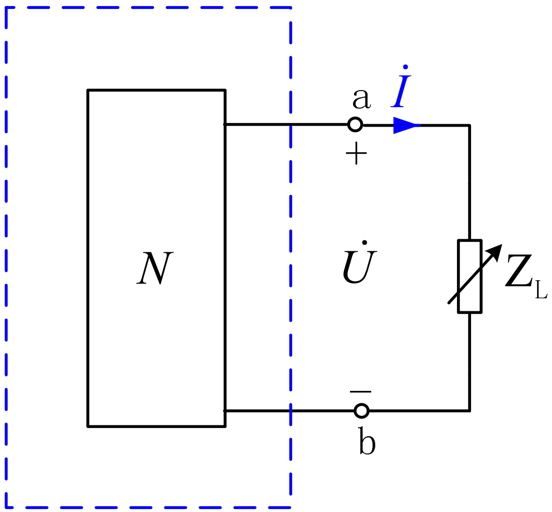
设 $\dot{U}=220\angle0^o$，则 $\dot{I}_D=5.68\angle-36.8^o$

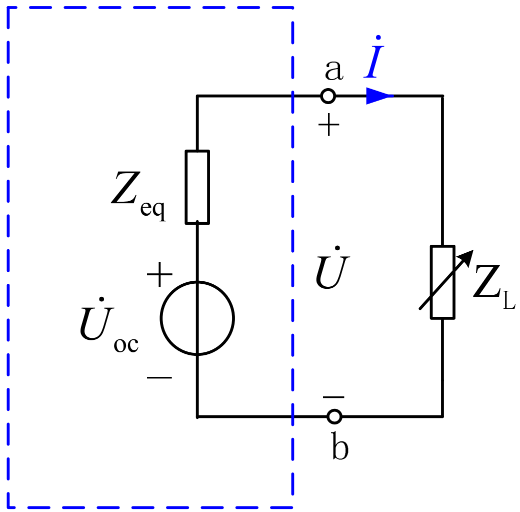
$$\dot{I}_C=\dot{U}\times j\omega C=220\angle0°\times j\omega C=j2.08$$

$$\dot{I}=\dot{I}_D+\dot{I}_C=4.54-j1.33=4.73\angle-16.3^o$$

则 $\cos\varphi=\cos[0^o-(-16.3^o)]=0.96$

11.7 最大功率传输 Maximum power transfer





$$Z_{eq} = R_{eq} + jX_{eq}$$

$$Z_L = R_L + jX_L$$

$$Z_L = ?$$

$$P_{Z_L} = \max?$$

$$\dot{I} = \frac{\dot{U}_{oc}}{Z_{eq} + Z_L}, \quad I = \frac{U_{oc}}{\sqrt{(R_{eq} + R_L)^2 + (X_{eq} + X_L)^2}}$$

$$P_Z = I^2 R_L$$

$$= \frac{U_{oc}^2 R_L}{(R_L + R_{eq})^2 + (X_L + X_{eq})^2}$$

$$\begin{cases} \dfrac{\partial P_Z}{\partial X_L} = 0 \\ \dfrac{\partial P_Z}{\partial R_L} = 0 \end{cases} \Rightarrow \begin{cases} X_L + X_{eq} = 0 \\ R_L = R_{eq} \end{cases}$$

$$\boxed{Z_L = Z_{eq}^* \qquad P_{Z\max} = \frac{U_{oc}^2}{4R_{eq}}}$$

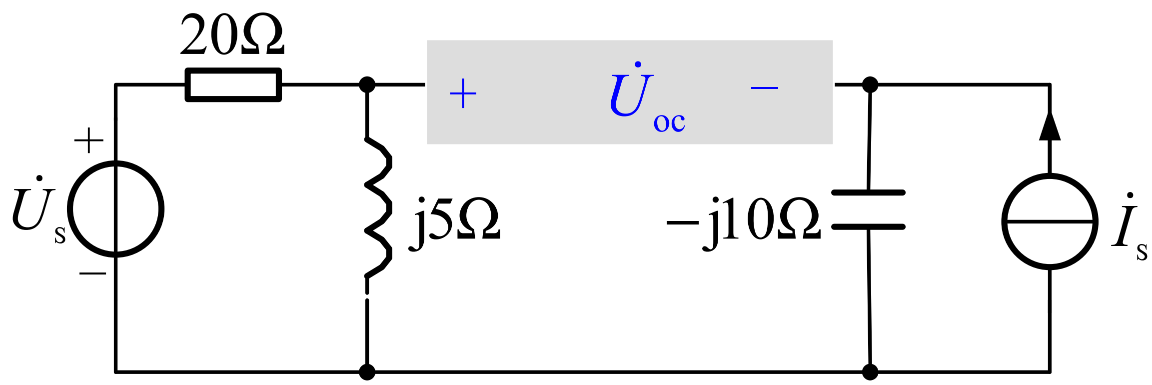
The load is matched to the network/source. 共轭匹配

11.7 最大功率传输 Maximum power transfer

【练习】：Z为何值时，Z获得最大功率？

$$\dot{U}_s = (100 - j50)\text{V}$$

$$\dot{I}_s = (20 + j30)\text{A}$$



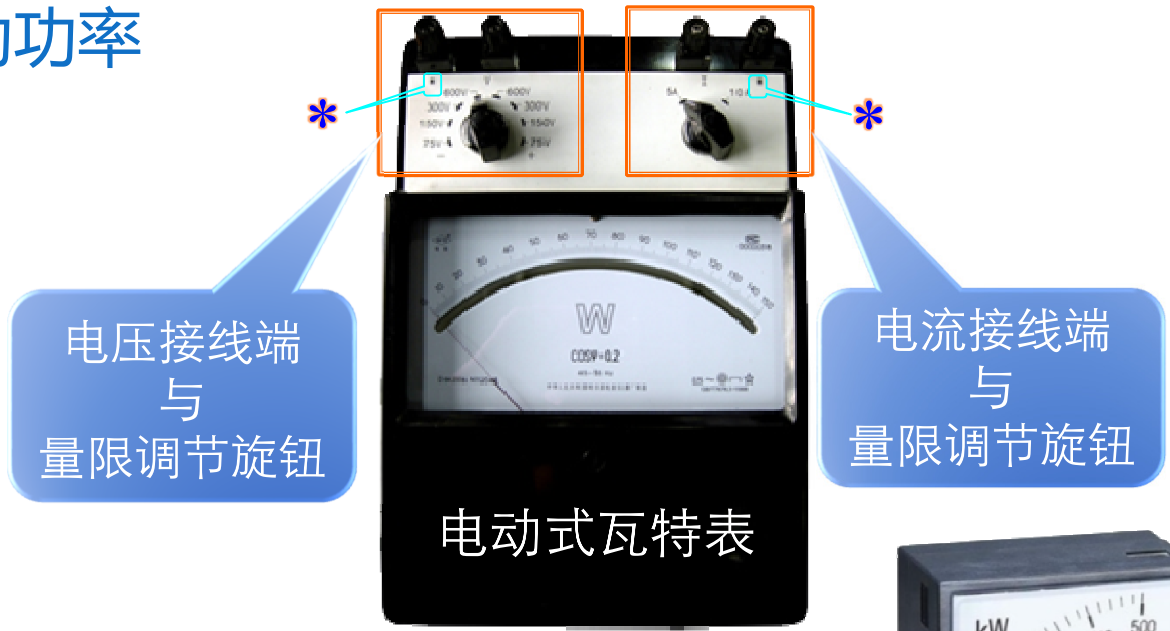
$$\dot{U}_{oc} = \dot{U}_s \times \frac{j5}{20 + j5} - (-j10)\dot{I}_s$$

$$Z_{eq} = \frac{20 \times j5}{20 + j5} + (-j10)$$

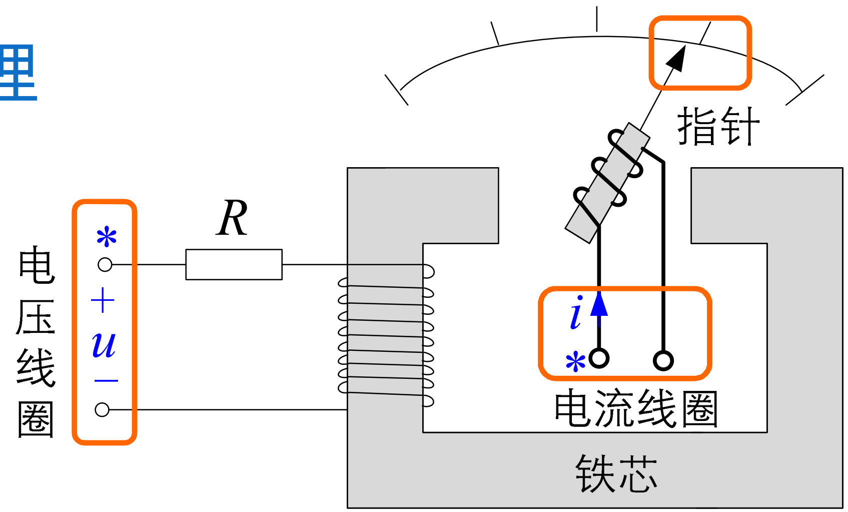
$$Z = Z_{eq}^{\ *} \qquad P_{Z\max} = \frac{U_{oc}^2}{4\,\text{Re}[Z_{eq}]}$$

11.8 有功功率测量

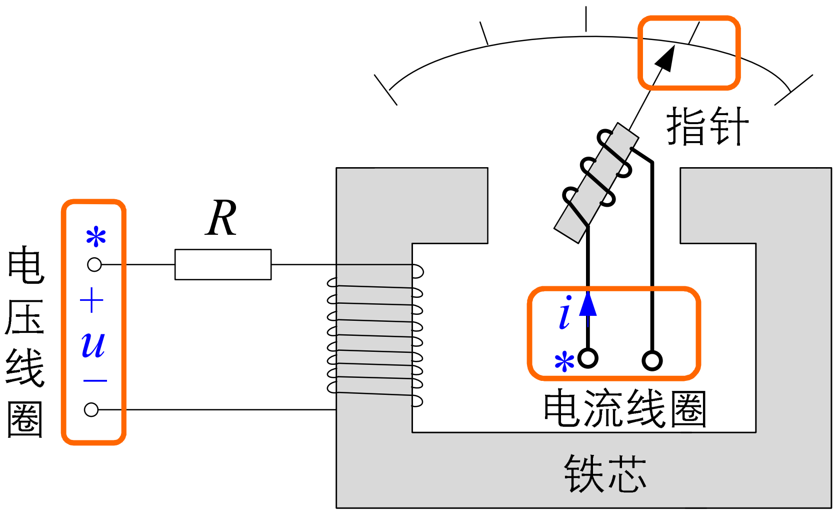
☞ 瓦特表测量有功功率



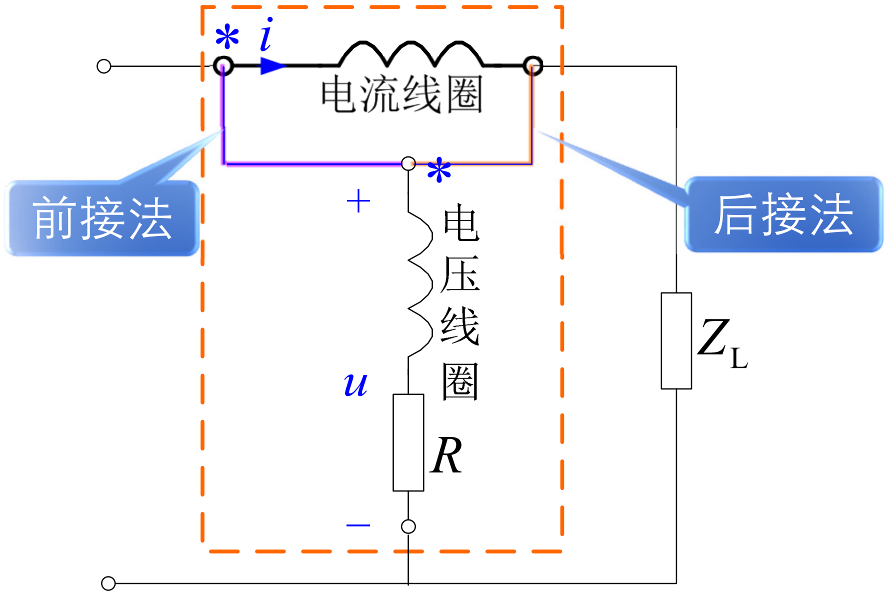
☞ 电动式瓦特表原理



11.8 有功功率测量



☞瓦特表的接线方式



电流线圈与负载串联

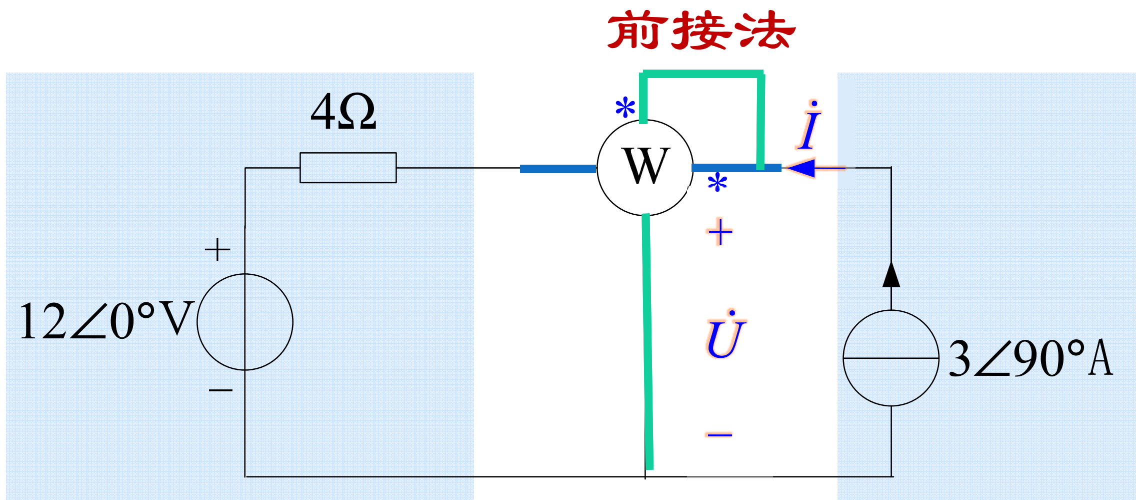
电压线圈与负载并联

☞瓦特表的读数

$$\boxed{P} = \frac{1}{T}\int_0^T ui\mathrm{d}t = \boxed{\mathrm{Re}[\dot{U}\times\dot{I}^*]}$$

11.8 有功功率测量

练习　**确定瓦特表的读数，及读数的物理含义。**



瓦特表的读数 $P = \mathrm{Re}[\dot{U} \times \dot{I}^*]$

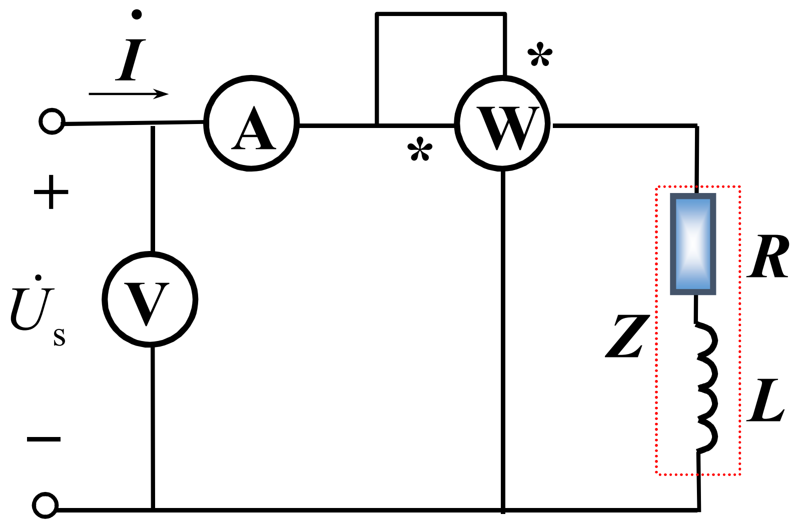
$$\dot{U} = 4 \times 3\angle 90° + 12\angle 0° = 12\sqrt{2}\angle 45° \text{ V}$$

$$P = \mathrm{Re}[12\sqrt{2}\angle 45° \times 3\angle -90°] = 36\text{W}$$

是电流源发出的有功功率，

也是电压源和电阻吸收的有功功率之和。

【例1】三表法测线圈参数(R、L)与电源的复功率。已知f=50Hz，且测得U=50V，I=1A，P=30W。



解：设 $\dot{U} = 50\angle 0°\text{V}$

$$P = UI\cos\varphi = 30$$

$$\cos\varphi = \frac{3}{5} \qquad \varphi = 53.13° \ \text{(lagging)}$$

则 $\dot{I} = 1\angle -53.13°\text{A}$

$$Z = \frac{\dot{U}}{\dot{I}} = 50\angle 53.13° = (30 + j40)\Omega$$

$$Z = 30 + j40 = R + \text{j}2\pi fL$$

$$R = 30\Omega \qquad L = 127\text{mH}$$

$$\bar{S} = \dot{U}\dot{I}^* = (30 + \text{j}40)\ \text{VA}$$

$$(\bar{S} = UI\angle\varphi = 50\angle 53.13°)$$

Method 2

$$P = I^2R \Rightarrow R = \frac{P}{I^2} = \frac{30}{1^2} = 30\Omega$$

$$|Z| = \frac{U}{I} = \frac{50}{1} = 50\Omega$$

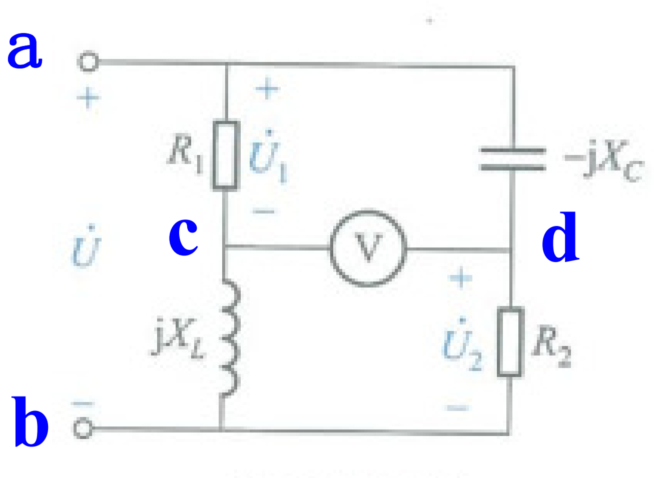
$$|Z| = \sqrt{R^2 + (\omega L)^2}$$

$$L = \frac{1}{\omega}\sqrt{|Z|^2 - R^2} = \frac{40}{314} = 0.127\text{H}$$

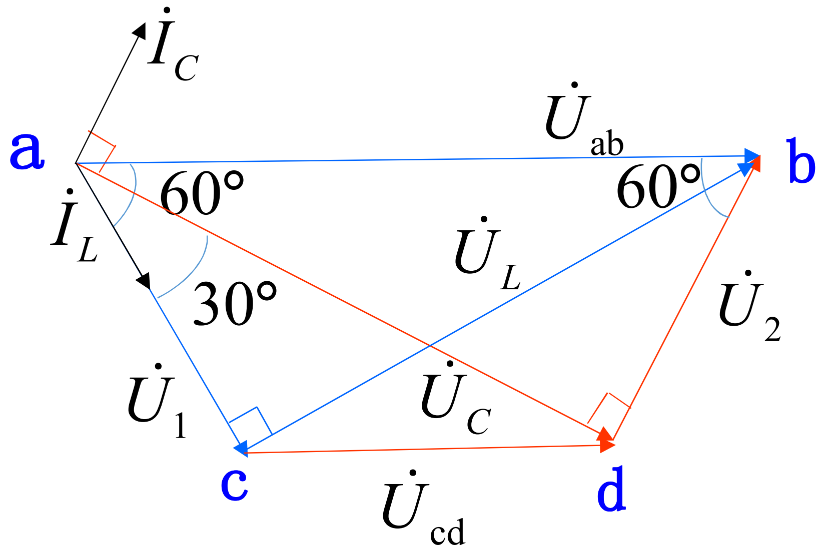
计划学时：4学时；课后学习8学时

作业：
11-2/ 功率
11-7/ 复功率
11-9/功率因数校正
11-13/最大功率
11-20/功率测量
11-26 /综合应用

11-25　图示电路中，端口电压U的有效值为100V，U_1、U_2的有效值均为50V，求电压表的读数。



题 11-25 图



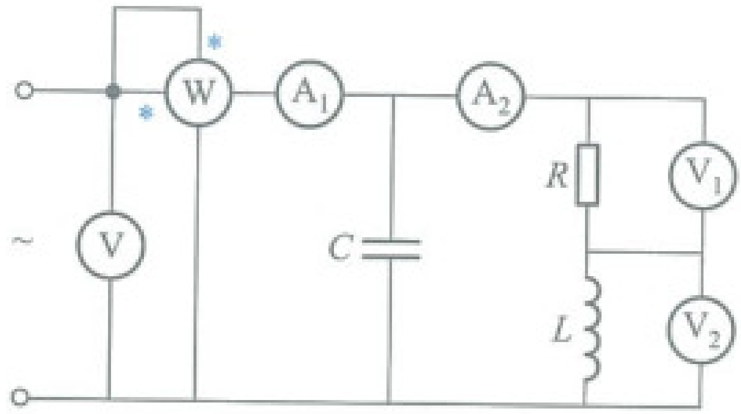
解：设端口电压U为参考相量　$\dot{U}=100\angle 0°\text{V}$

$U_1 = 50\text{V}$可以得出：　$U_L = 50\sqrt{3}\text{V}$

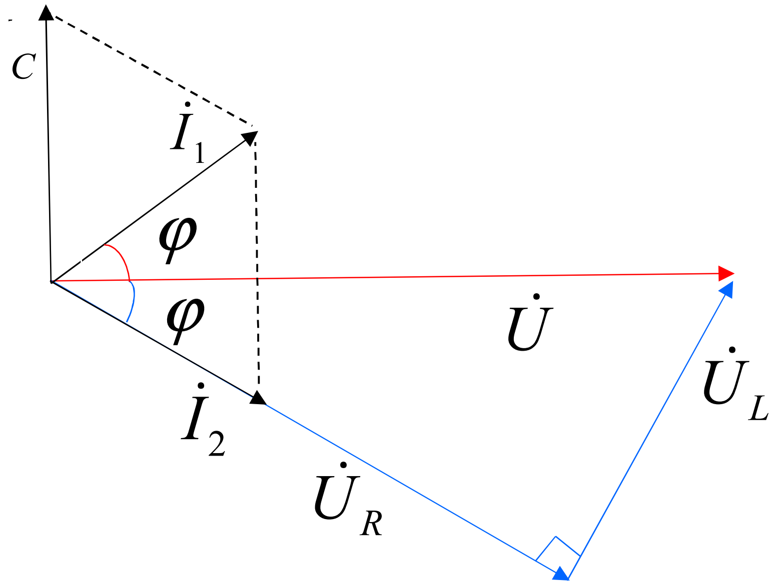
$$U_{cd}{}^2 = U_1{}^2 + U_L{}^2 - 2U_1 \times U_L \cos 30°$$
$$= 50^2 + (50\sqrt{3})^2 - 2\times 50\times 50\sqrt{3}\times\frac{\sqrt{3}}{2}$$

$$U_{cd} = 50\text{V}$$

11-26　图示电路中，功率表读数为100W，电压表读数为100V，电流表A_1A_2的读数相等，电压表V_2的读数是V_1的一半，求参数R, X_L, X_C的值。



题 11-26 图



解：设端口电压U为参考相量　$\dot{U}=100\angle 0°\text{V}$

$U_R = 2U_L$可以得出：$\cos\varphi = \dfrac{2}{\sqrt{5}}, \sin\varphi = \dfrac{1}{\sqrt{5}}$　$U_R = U\cos\varphi = 100\times\dfrac{2}{\sqrt{5}} = 40\sqrt{5}\text{V}$，$U_L = 20\sqrt{5}\text{V}$

$P=UI_1\cos\varphi$可以得出：$I_1 = \dfrac{P}{U\cos\varphi} = \dfrac{100}{100\times\cos\varphi} = \dfrac{\sqrt{5}}{2}\text{A}$　　$I_2 = I_1 = \dfrac{\sqrt{5}}{2}\text{A}$

$I_C = 2I_1\sin\varphi = 2\times\dfrac{\sqrt{5}}{2}\times\dfrac{1}{\sqrt{5}} = 1\text{A}$　　$\boxed{R = \dfrac{U_R}{I_2} = \dfrac{40\sqrt{5}}{\frac{\sqrt{5}}{2}} = 80\Omega}$ $\boxed{X_L = 40\Omega}$ $\boxed{X_C = \dfrac{U}{I_C} = \dfrac{100}{1} = 100\Omega}$