1.

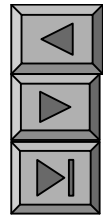
2.

3. —

4.

5.

6.



+

10 11 12

9 1

1. Z

(1)

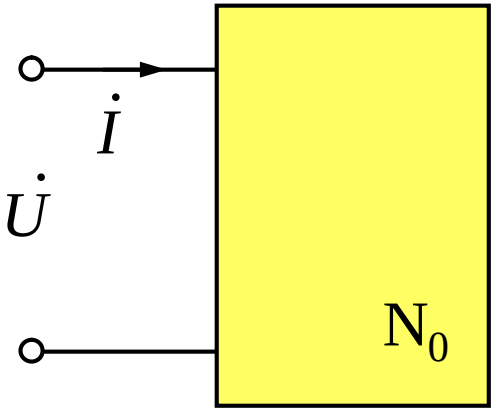
$\dot{U}$ $U\angle u$ $\dot{I}$ $I\angle i$

$Z \overset{\text{def}}{=\!=} \dfrac{\dot{U}}{\dot{I}}$ $\dfrac{U}{I}\angle u\ \ i$ $|Z|\angle z$

$|Z|$ $\dfrac{U}{I}$

z u i

z



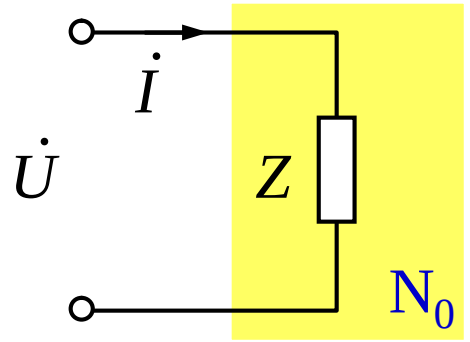
(2)

$$Z = |Z| e^{j\varphi_z}$$

$$: \quad Z = |Z| \angle \varphi_z$$

$$Z = |Z|\cos\varphi_z + j|Z|\sin\varphi_z$$

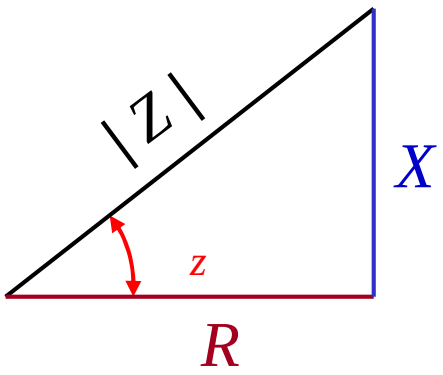
$$Z = R + jX$$



Z — R — Z — X — ____

$$\begin{cases} R = |Z|\cos\varphi_z \\ X = |Z|\sin\varphi_z \end{cases} \qquad \begin{cases} |Z| = \sqrt{R^2 + X^2} \\ \varphi_z = \operatorname{arctg}\dfrac{X}{R} \end{cases}$$

$|Z|$ — R — X



(3)

$$Z \quad \frac{\dot{U}}{\dot{I}} \quad R$$

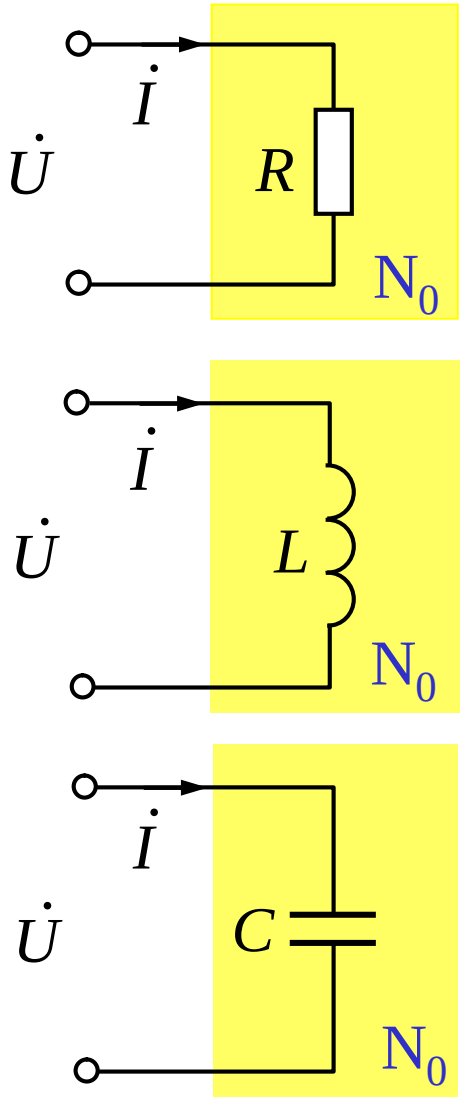
$$Z \quad \frac{\dot{U}}{\dot{I}} \quad \mathrm{j} \quad L \quad \mathrm{j} X_L$$

$X_L \quad L$ —— $X_L \quad f$

$$Z \quad \frac{\dot{U}}{\dot{I}} \quad \frac{1}{\mathrm{j} \quad C} \quad \mathrm{j}\frac{1}{C} \quad \mathrm{j} X_C$$

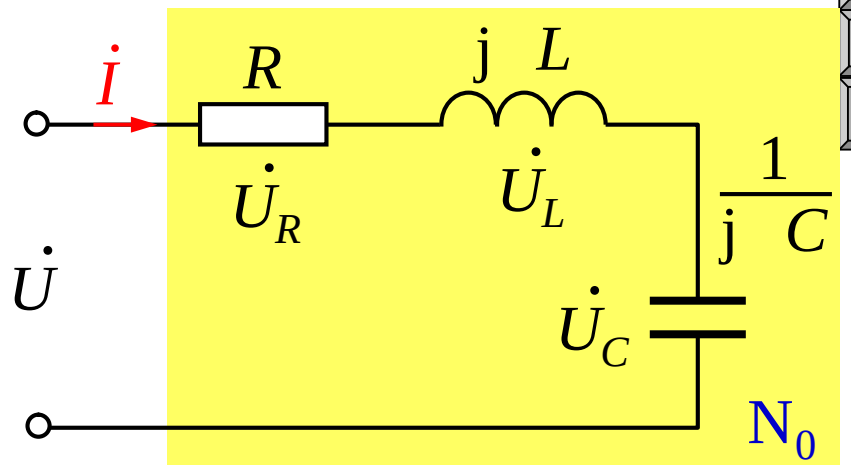
$X_C \quad \frac{1}{C}$ —— $X_C \quad (1/f)$!

Z



(4)*RLC*

KVL VCR



$$\dot{U} \quad R\dot{I} \quad \mathrm{j}\ L\dot{I} \quad \mathrm{j}\frac{1}{C}\dot{I}$$

$$\left(R \quad \mathrm{j}\ L \quad \mathrm{j}\frac{1}{C}\right)\dot{I} \quad R \quad \mathrm{j}(X_L \quad X_C)]\ \dot{I}$$

$$R \quad \mathrm{j}X\ \dot{I} \quad Z\ \dot{I}$$

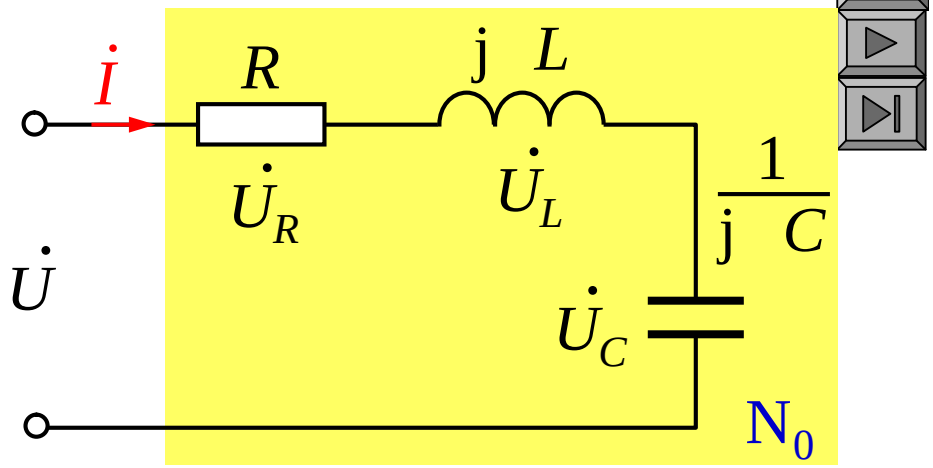
$$Z \quad \frac{\dot{U}}{\dot{I}} \quad R \quad \mathrm{j}\ X \quad |Z| \angle_{z}$$

$$X \quad X \qquad L \quad \frac{1}{C}$$

$$Z \quad \frac{\dot{U}}{\dot{I}} \quad R \quad \mathrm{j}\,X \quad |Z| \angle_{z}$$

$$X \quad X_L \quad X_C \qquad L \quad \frac{1}{C}$$

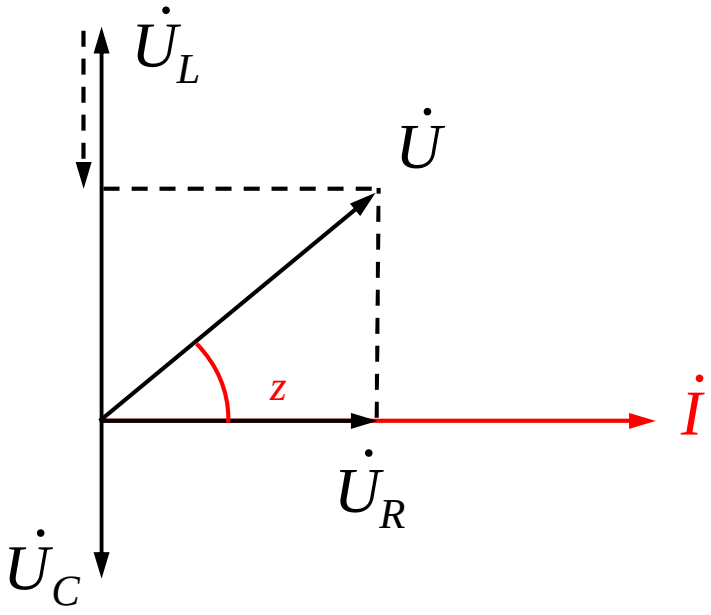
$$z \quad \operatorname{arctg} \frac{X}{R}$$



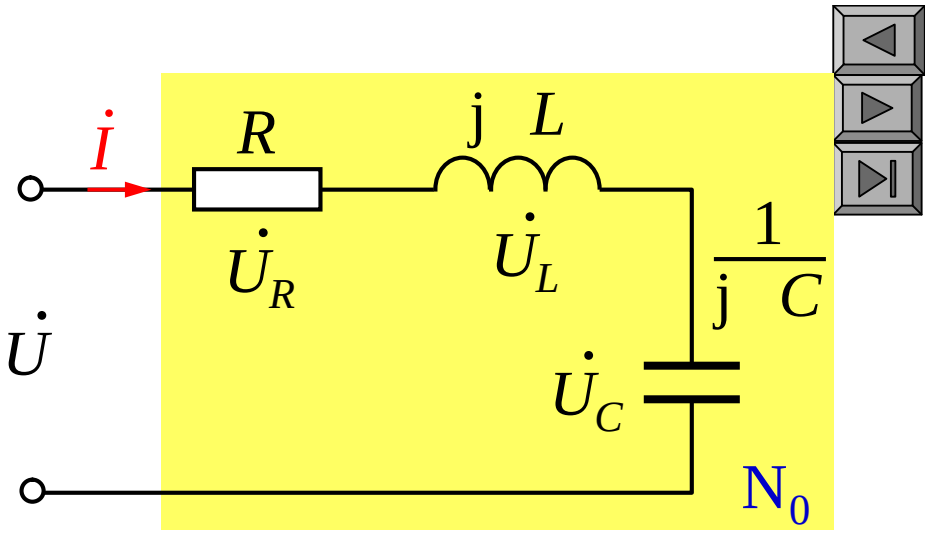
$$L \quad \frac{1}{C}$$

$$X \quad 0 \qquad z \quad 0$$

$$Z$$



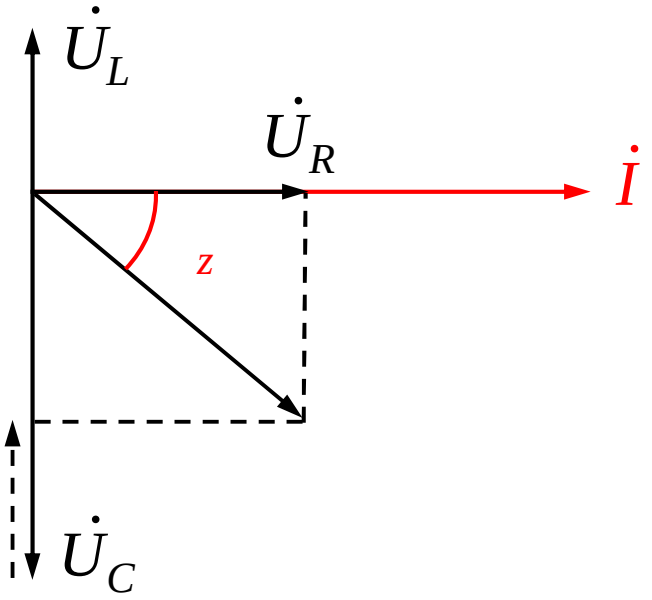
$Z \quad \frac{\dot{U}}{\dot{I}} \quad R \quad \mathrm{j}$



$L \quad \frac{1}{C}$

$X \quad 0 \qquad z \quad 0$

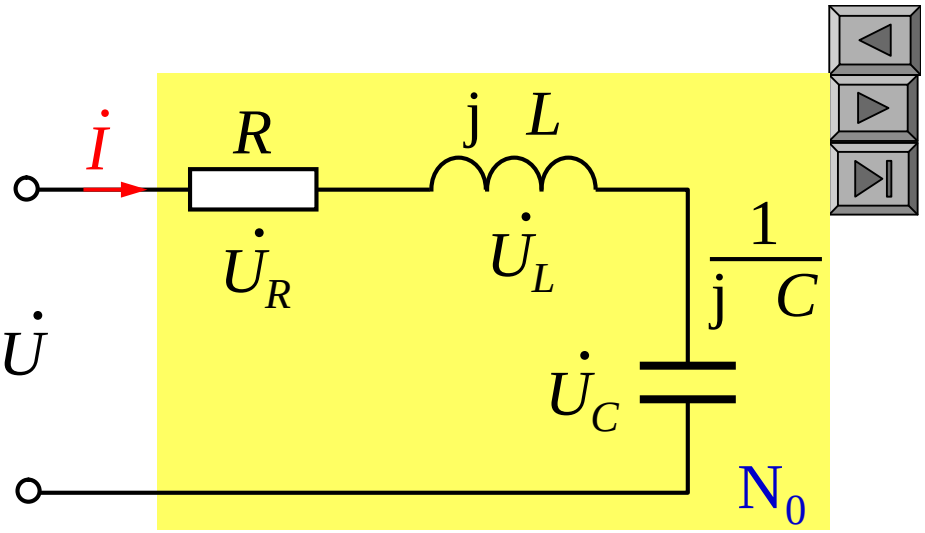
Z



$Z \quad \frac{\dot{U}}{\dot{I}} \quad R \quad \mathrm{j}\,X \quad |Z| \angle_{z}$

$X \quad X_L \quad X_C \quad L \quad \frac{1}{C}$

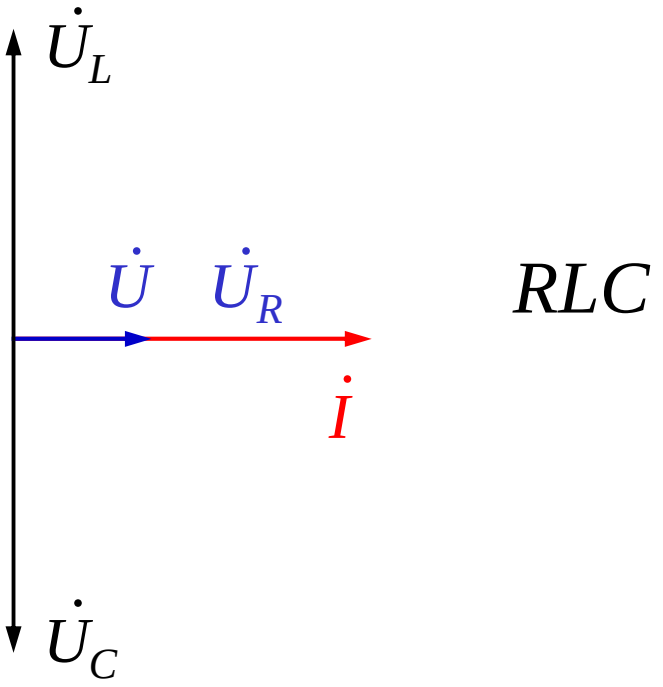
$_{z} \quad \arctg \frac{X}{R}$



$L \quad \frac{1}{C}$

$X \quad 0 \quad _{z} \quad 0$

Z

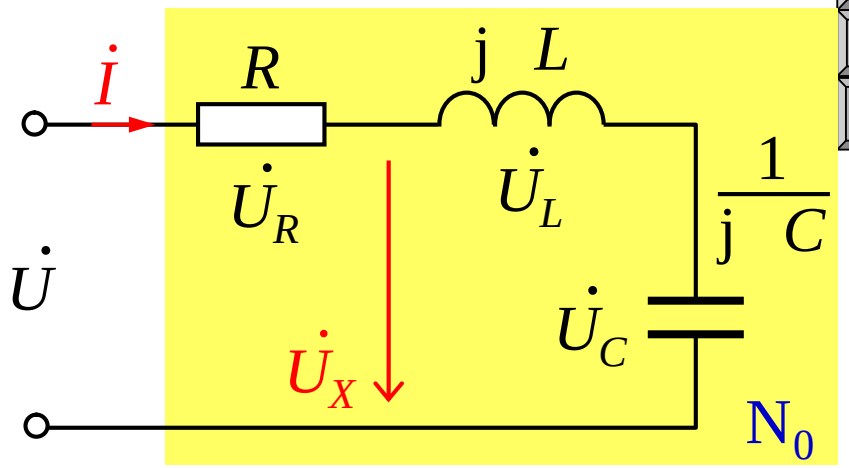


RLC

$Z \quad \frac{\dot{U}}{\dot{I}} \quad R \quad \mathrm{j}\,X \quad |Z|\angle_{z}$

$X \quad X_L \quad X_C \qquad L \quad \frac{1}{C}$

$z \quad \operatorname{arctg}\frac{X}{R}$



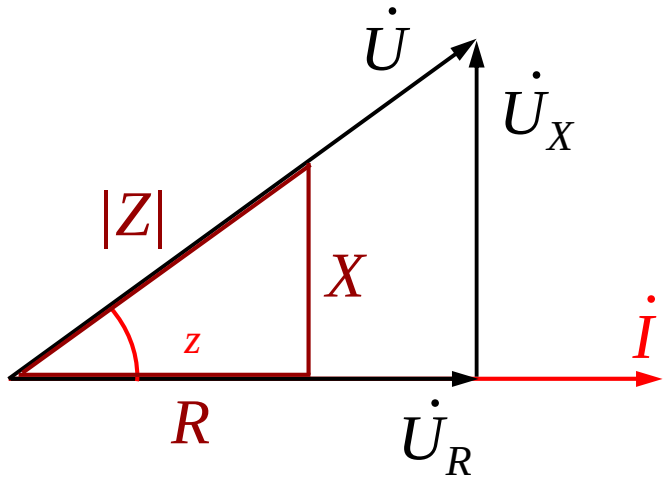
$R \quad 0 \quad X>0 \qquad Z$

$R \quad 0 \quad X<0 \qquad Z$

RLC $\qquad U_R$

$U_X \quad U$

$U \quad \sqrt{U_R^2 \quad U_X^2}$



2. Y

(1) Z Y Y $\frac{1}{Z}$

Y $\frac{\dot{I}}{\dot{U}}$ $\frac{I}{U}\angle_{i\quad u}$ $|Y|\angle_{Y}$ [S]

$|Y|$ $\frac{I}{U}$ ———

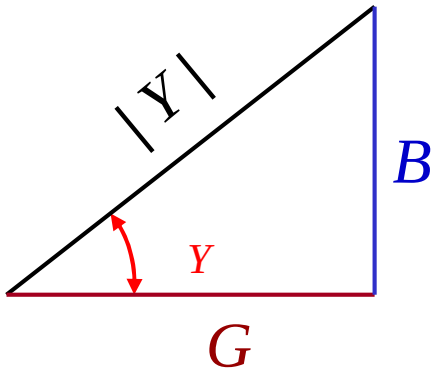
Y i u ———

Y G j B

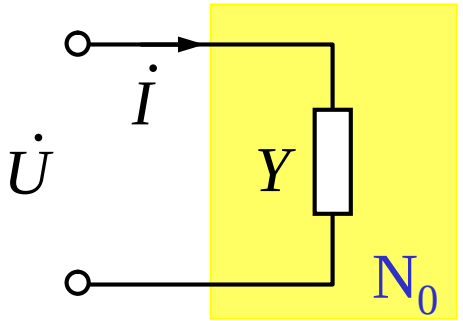
G B ——

G、B $|Y|$ Y

$$\left.\begin{array}{l} G\ |Y|\cos\ _{Y} \\ B\ |Y|\sin\ _{Y} \end{array}\right\} \qquad \left.\begin{array}{l} |Y|\ \sqrt{G^2\ \ B^2} \\ \ _{Y}\ \ \mathrm{arctg}\frac{B}{G} \end{array}\right\}$$



(2) R L C



Y $\dfrac{\dot{I}}{\dot{U}}$ $\dfrac{1}{R}$ G ——

Y $\dfrac{\dot{I}}{\dot{U}}$ $\dfrac{1}{\mathrm{j}\ L}$ $\mathrm{j}B_L$

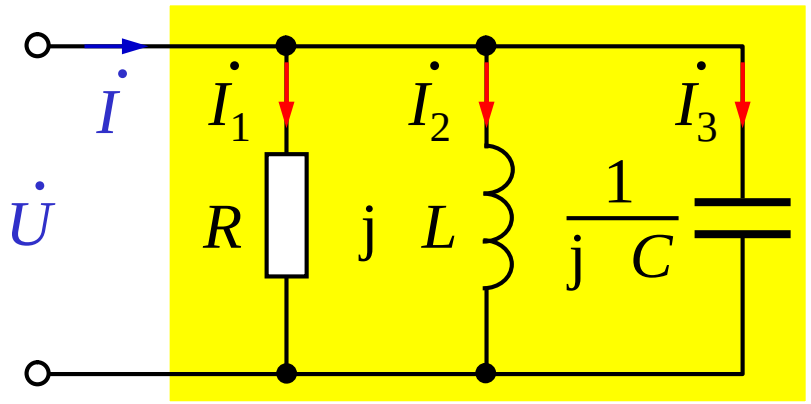
B_L $\dfrac{1}{L}$ ——

Y $\dfrac{\dot{I}}{\dot{U}}$ j C $\mathrm{j}B_C$ Y

B_C C ——

(3)*RLC*

VCR KCL

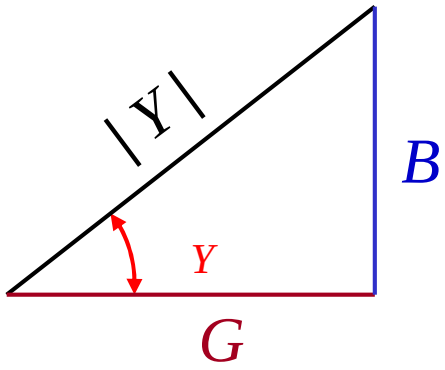


$$\dot{I} \quad G\dot{U} \quad \frac{1}{\text{j}\ L}\dot{U} \quad \text{j}\ C\dot{U}$$

$$\left[G \quad \text{j}\frac{1}{L} \quad \text{j}\ C\right]\dot{U} \quad G \quad \text{j}(B_L \quad B_C)]\dot{U}$$

$$G \quad \text{j}B\ \dot{U} \quad Y\dot{U}$$

$$Y \quad \frac{\dot{I}}{\dot{U}} \quad G \quad \text{j}\,B \quad |Y|\angle_{\ Y}$$



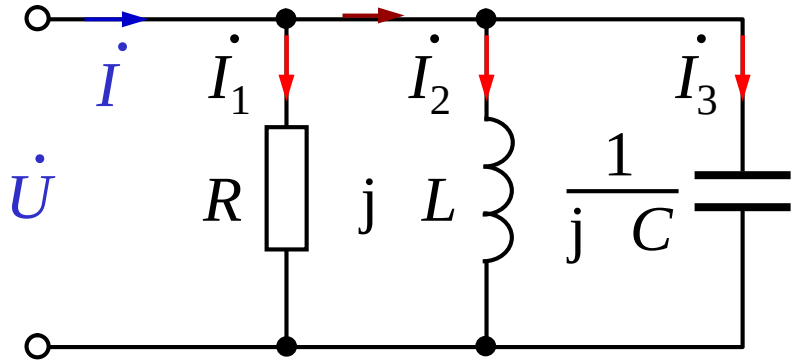
$$B \quad B_L \quad B_C \qquad \frac{1}{L} \qquad C$$

$$|Y| \quad \sqrt{G^2 \quad B^2} \qquad _Y \quad \text{arctg}\frac{B}{G}$$

$Y \quad \frac{\dot{I}}{\dot{U}} \quad G \quad jB \quad |Y| \angle \quad Y$

$B \quad B_L \quad B_C \quad \frac{1}{L} \quad C$

$|Y| \quad \sqrt{G^2 \quad B^2} \quad Y \quad \text{arctg} \frac{B}{G}$



RLC

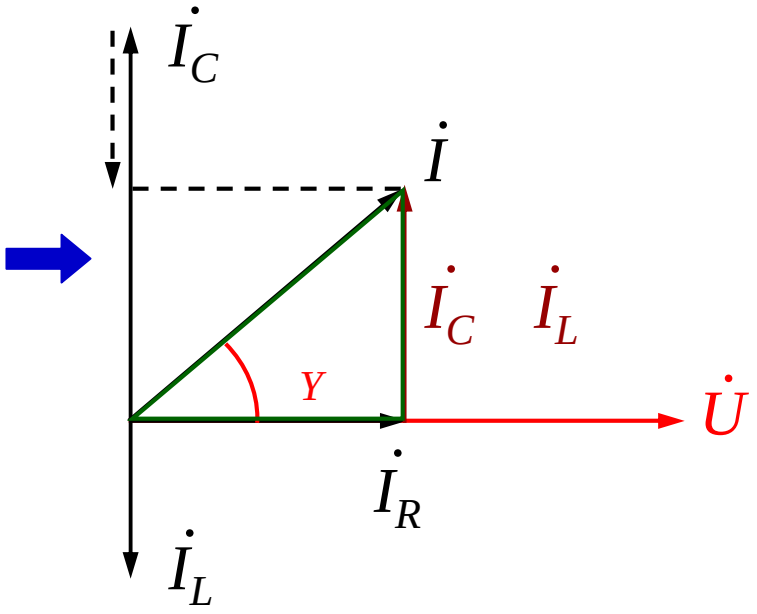
$B \quad 0 \quad Y \quad 0, \quad Y$

$B \quad 0 \quad Y \quad 0, \quad Y$

$B \quad 0 \quad Y \quad 0, \quad Y$

$G \quad 0, \quad B \quad 0, \quad Y$

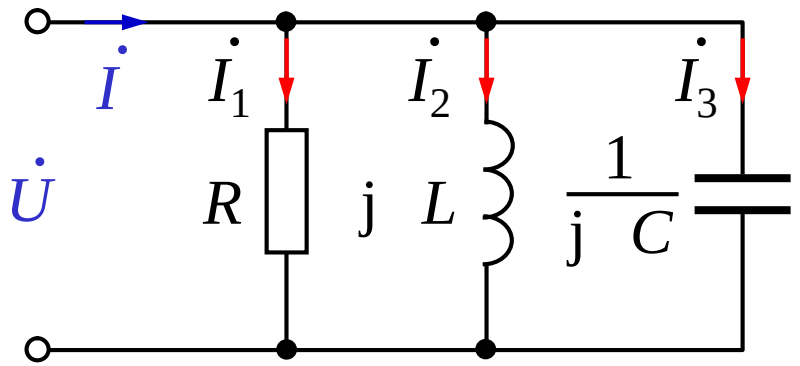
$G \quad 0, \quad B \quad 0, \quad Y$

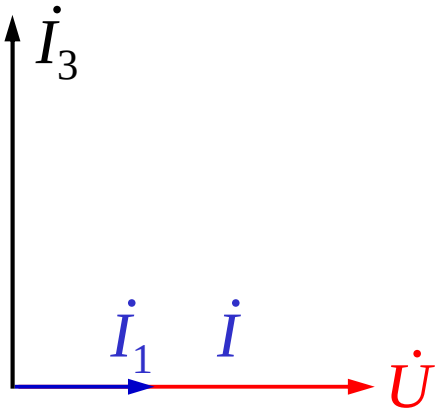


$Y \quad \frac{\dot{I}}{\dot{U}} \quad G \quad jB \quad |Y| \angle_{Y}$

$B \quad B_L \quad B_C \quad \frac{1}{L} \quad C$

$|Y| \quad \sqrt{G^2 \quad B^2} \quad {}_{Y} \quad \text{arctg}\frac{B}{G}$



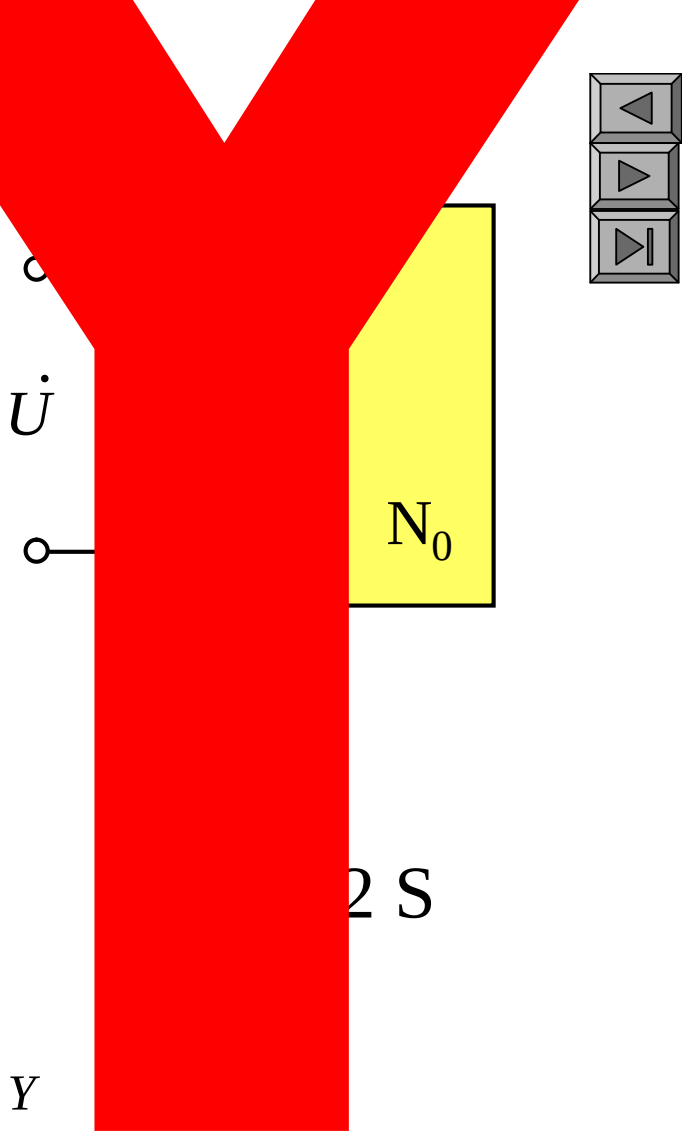


$\dot{I}_2$

3.

N_0 ( )

( ) ( )



Z(j) R( ) jX( )

Y(j) G( ) jB( )

Z(j) Y(j) 1

| Z |

Y 0.2 − S

$Z \quad R \quad jX \qquad\qquad Y \quad G \quad jB$

$$Y \quad \frac{1}{Z} \quad \frac{1}{R \quad jX} \quad \frac{(R \quad jX)}{(R \quad jX)(R \quad jX)}$$

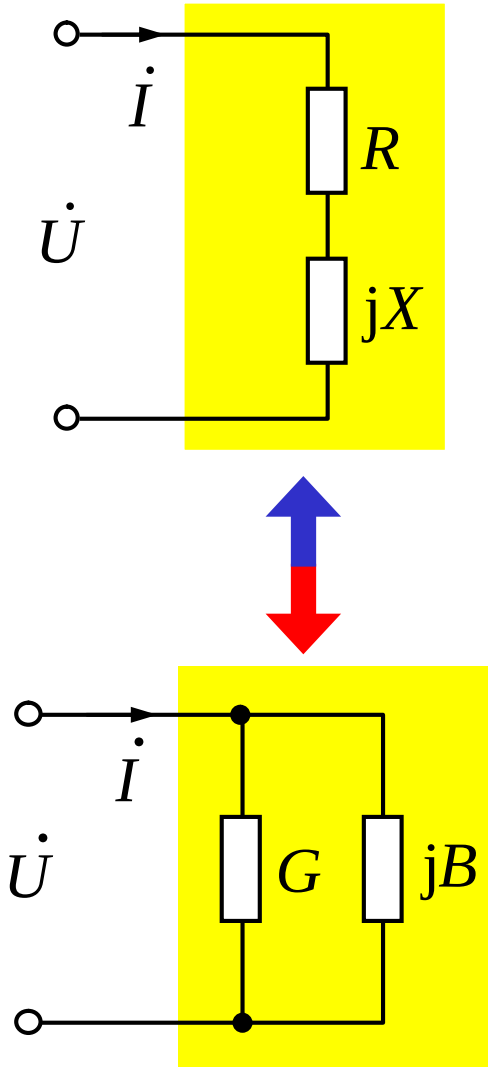
$$\frac{R}{R^2 \quad X^2} + j\frac{X}{R^2 \quad X^2} \quad G \quad jB$$

$$G \quad \frac{R}{|Z|^2} \qquad B \quad \frac{X}{|Z|^2}$$

$$Y \quad G \quad jB$$

$$Z \quad R \quad jX$$

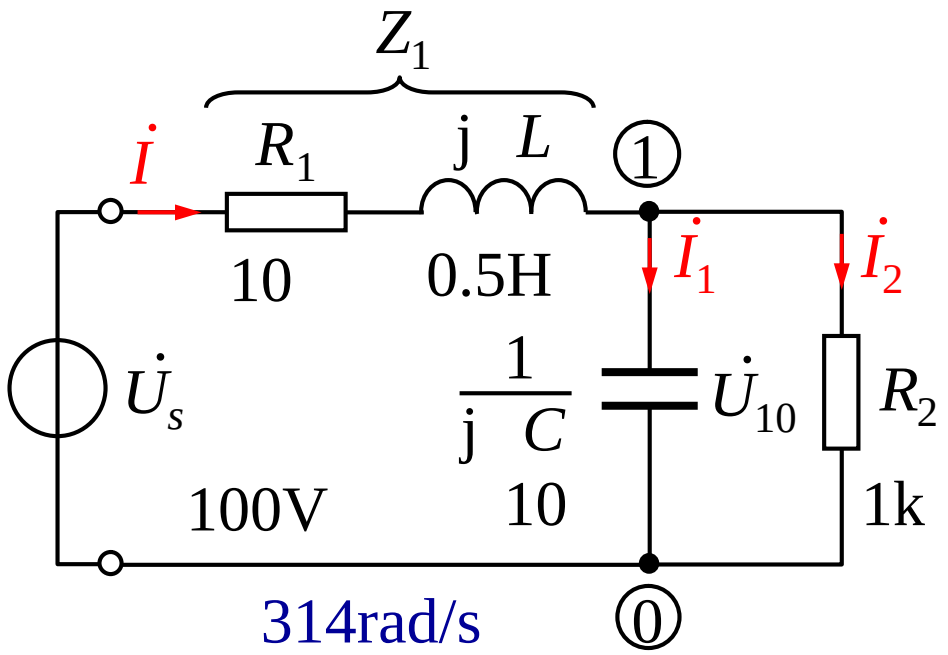
$$R \quad \frac{G}{|Y|^2} \qquad X \quad \frac{B}{|Y|^2}$$



$\dot{U}_{10}$

$\dot{U}_{10}$

$\dot{U}_{10}$ $U_{10}\angle 0^{o}$ V



Z_1

Y_{10}

Z_1 10 j157

Y_{10} $\frac{1}{R_2}$ j C 10^{-3} j3.14 10^{-3}

3.2954 $10^{-3}\angle 72.33^{o}$ S

Z_{10} $\frac{1}{Y_{10}}$ $303.45\angle 72.33^{o}$ 92.11 j289.13

$\dot{U}_{10}$

Z_1 10 j157

Z_{10} 92.11 j289.13

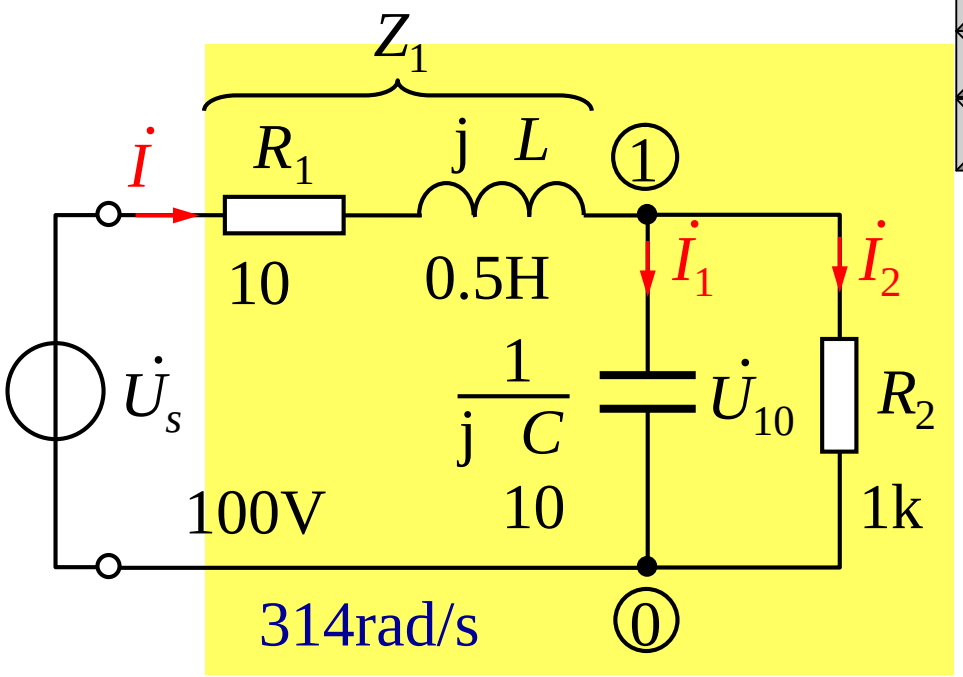
$303.45 \angle 72.33^{o}$

Z_{eq} Z_1 Z_{10}

(92.11 10) j(157 289.13)

102.11 j132.13

$166.99 \angle -52.30^{o}$

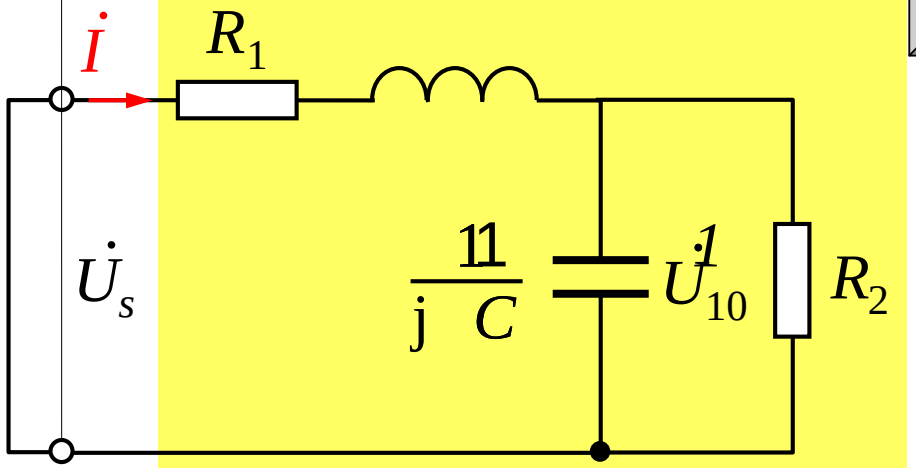


$$\dot{I} \quad \frac{\dot{U}_S}{Z_{eq}} \quad \frac{100}{166.99 \angle -52.30^{o}}$$

$0.6 \angle 52.30^{o}$ A

$\dot{U}_{10}$

2 2



$\dot{U}_{10}$ $Z_{10}\ \dot{I}$ 1 303.45 0.6 $\angle$ 72.33° 52.30°

=182.07 $\angle$ −20.03° V

$\dot{I}_1$ j $C\dot{U}_{10}$ 182.07 0.00314 $\angle$ 90° − 20.03° A

0.57 $\angle$ 69.97° A

$\dot{I}_2$ $\frac{\dot{U}_{10}}{R_2}$ 0.182 $\angle$ −20.03° A

9 2

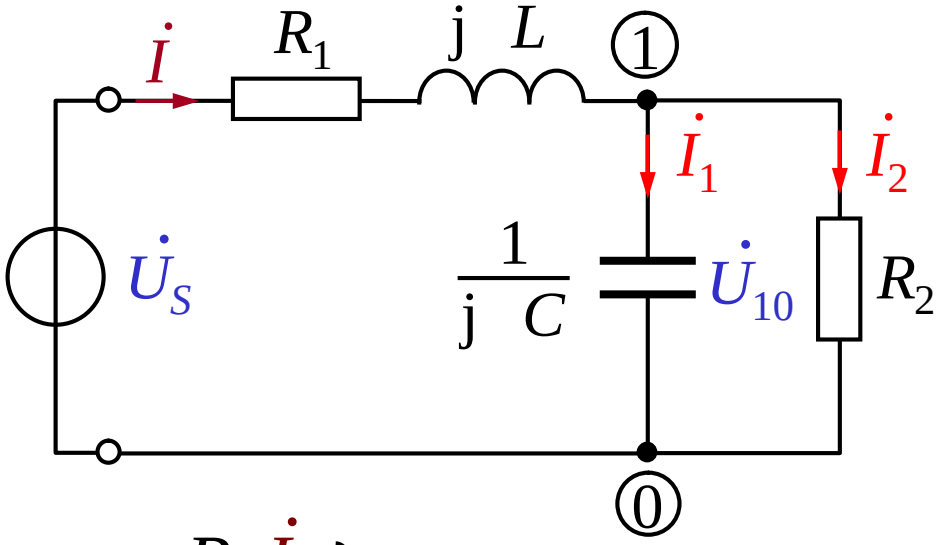
“ ”

VCR

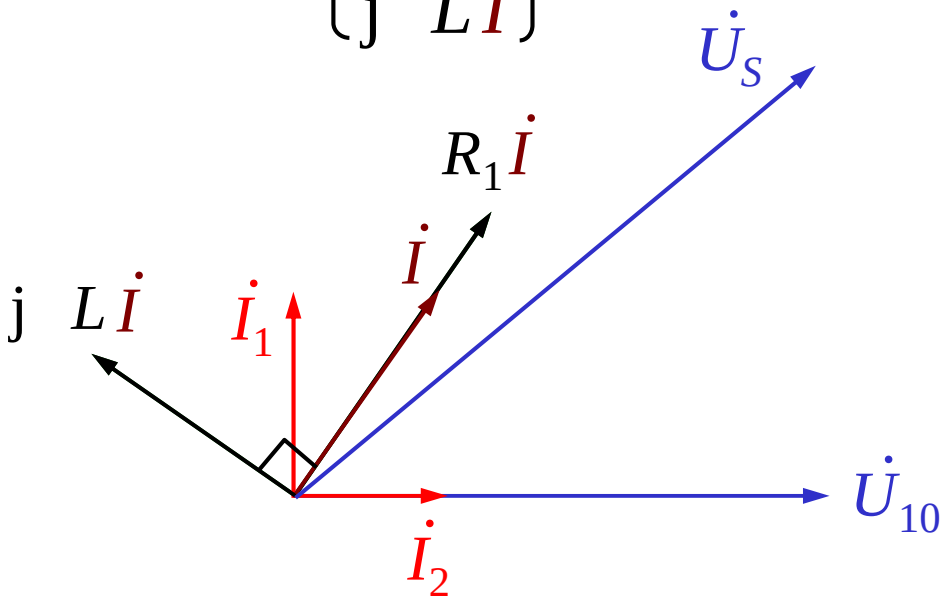
KCL

VCR

KVL



$$\dot{U}_{10} \xrightarrow{\text{VCR}} \begin{Bmatrix} \dot{I}_1 \\ \dot{I}_2 \end{Bmatrix} \xrightarrow{\text{KCL}} \dot{I} \xrightarrow{\text{VCR}} \begin{Bmatrix} R_1\dot{I} \\ \mathrm{j}\ L\dot{I} \end{Bmatrix} \xrightarrow{\dot{U}_{10}\quad \text{KVL}} \dot{U}_S$$



$\dot{U}$ $\dot{I}$

I R X_C X_L

: $\dot{U}_{ab}$

$\dot{I}_1$ $\dot{U}_{ab}$ 90°

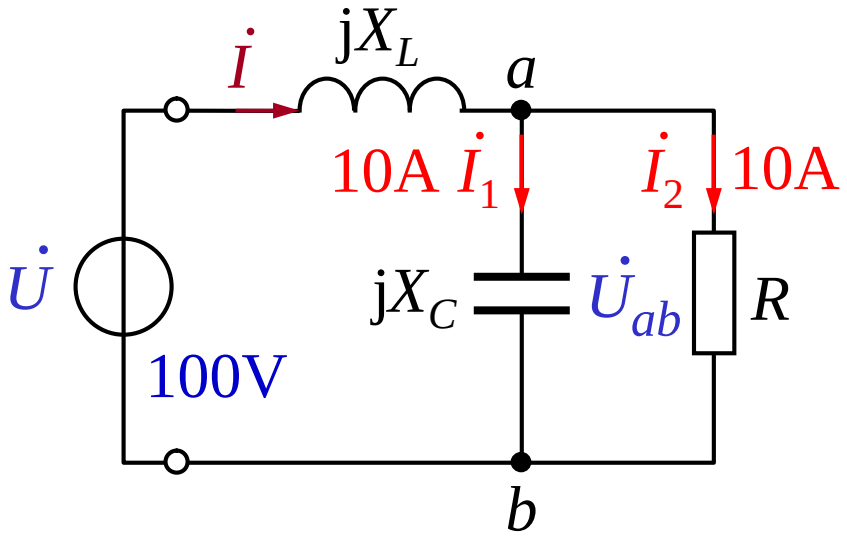
$\dot{I}_2$ $\dot{U}_{ab}$

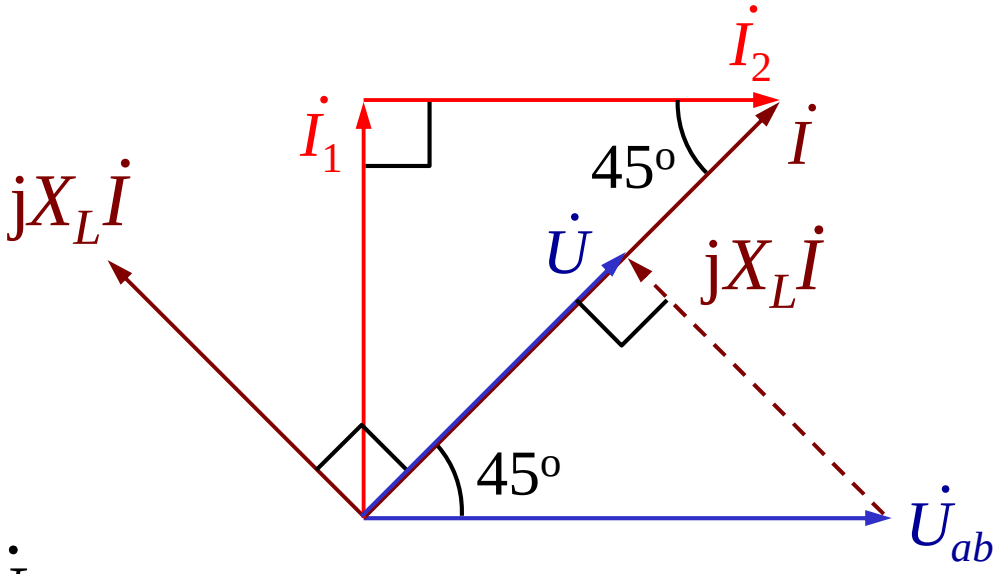
KCL $\dot{I}$ $\dot{I}_1$ $\dot{I}_2$

I $\sqrt{I_1^2 \quad I_2^2}$ 14.14 A

$\mathrm{j}X_L\dot{I}$ $\dot{I}$ 90°

KVL $\dot{U}$ $\mathrm{j}X_L\dot{I}$ $\dot{U}_{ab}$





$\dot{U}$ $\dot{I}$

I R X_C X_L

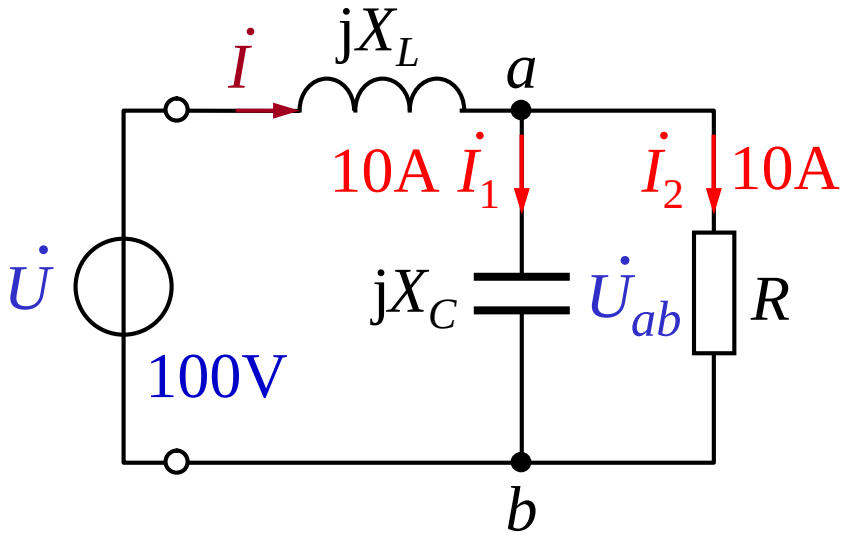
$X_L I$ U 100V

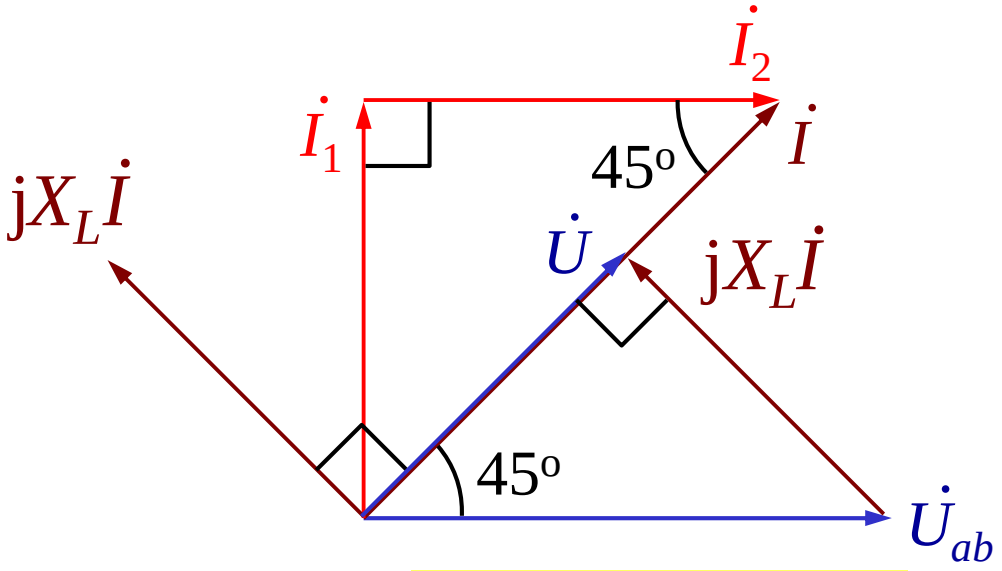
X_L $\dfrac{U}{I}$ $\dfrac{100}{14.14}$ 7.07

U_{ab} $\sqrt{2}\,U$ 141.4V

R $\dfrac{U_{ab}}{I_2}$ 14.14

X_C $\dfrac{U_{ab}}{I_1}$ 14.14

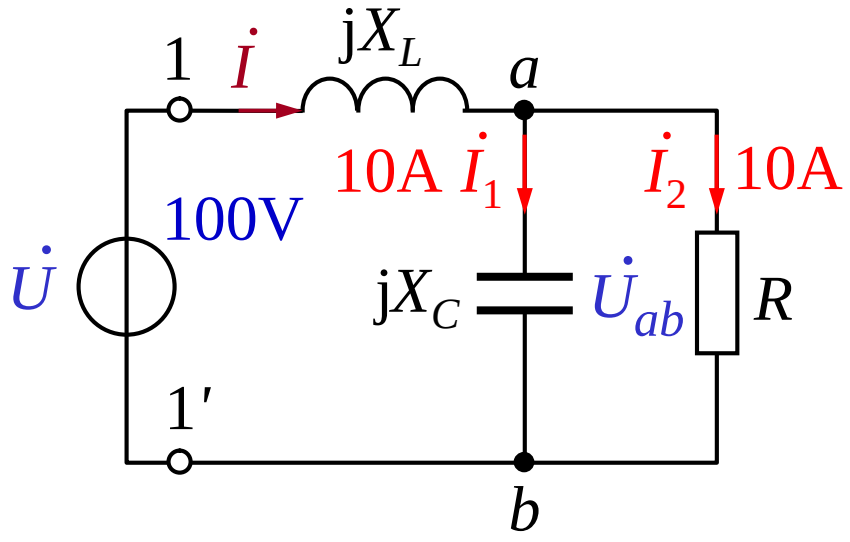




L C I 14.14 A

$\dot{U}$ $\dot{I}$

I R X_C X_L



$\dot{U}_{ab}$

$\dot{U}_{ab}$ $U_{ab}\angle 0^{o}$ V

$\dot{I}_1$ j10 A $\dot{I}_2$ 10 A

$\dot{I}$ $\dot{I}_1$ $\dot{I}_2$ (10 j10) A

14.14$\angle 45^{o}$ A

I_1 I_2 ⟶ R X_C

$Z_{11'}$ jX_L $\dfrac{R(\ \mathrm{j}X_C)}{R\ \ \mathrm{j}X_C}$

jX_L $\dfrac{\mathrm{j}X_C}{1-\mathrm{j}}$

jX_L $\dfrac{\mathrm{j}X_C(1+\mathrm{j})}{2}$

$0.5X_C$ j (X_L $0.5X_C$)

$\dot{U}$ $\dot{I}$

I R X_C X_L

$Z_{11'}$ $0.5X_C$ j $(X_L$ $0.5X_C)$

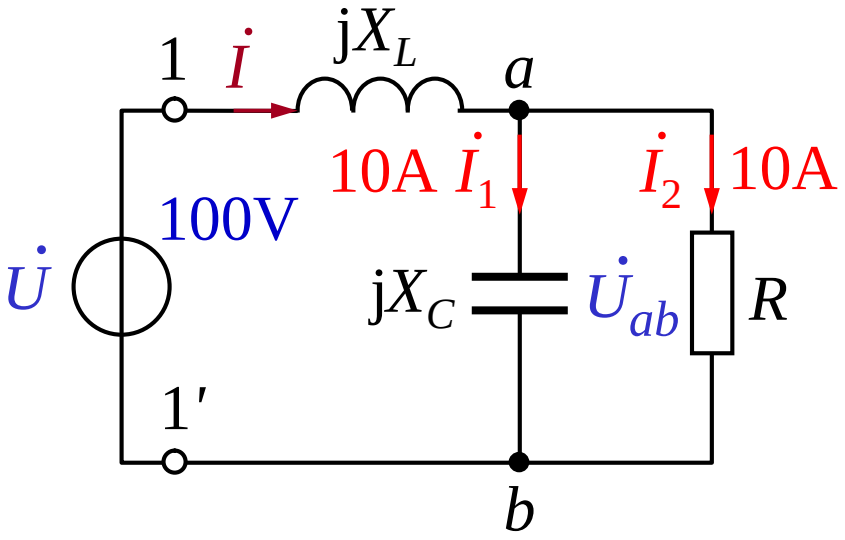
$\dot{U}$ $\dot{I}$ $\longrightarrow$ $Z_{11'}$

X_L $0.5X_C$ 0

$$Z_{11'} \quad \frac{\dot{U}}{\dot{I}} \quad \frac{100}{14.14} \quad 7.07 \quad 0.5X_C$$

X_C 14.14 R

X_L $0.5X_C$ 0 X_L $0.5X_C$ 7.07



9 3

KCL KVL VCR

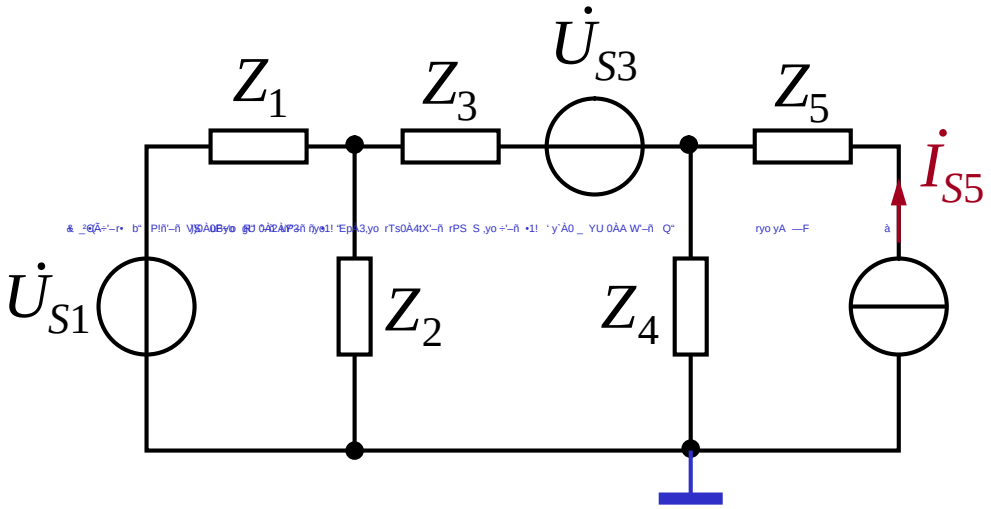
KCL	$i \quad 0$	$\dot{I} \quad 0$
KVL	$u \quad 0$	$\dot{U} \quad 0$
VCR	$u \quad Ri$	$\dot{U} \quad Z\dot{I}$

R_{eq}

( )

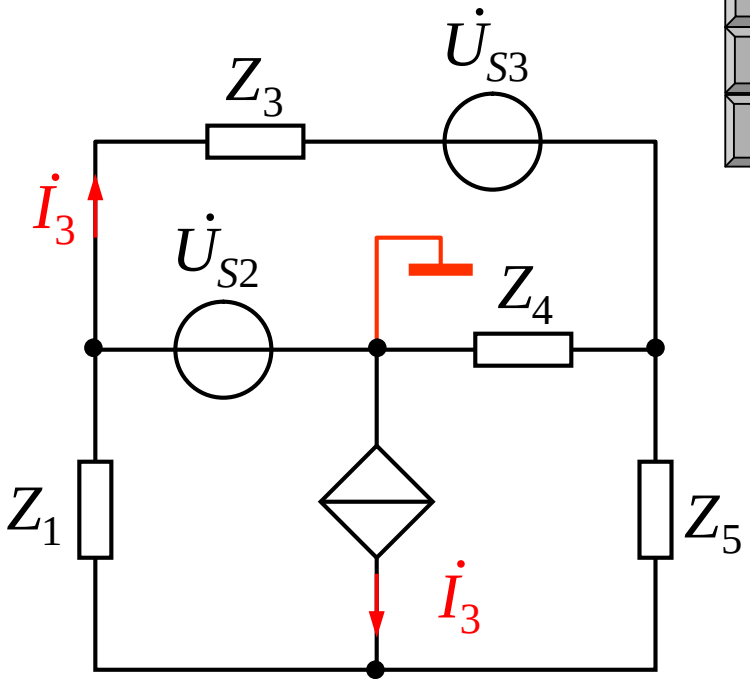
p ui

( )



$(Y_1 \quad Y_2 \quad Y_3)$

2



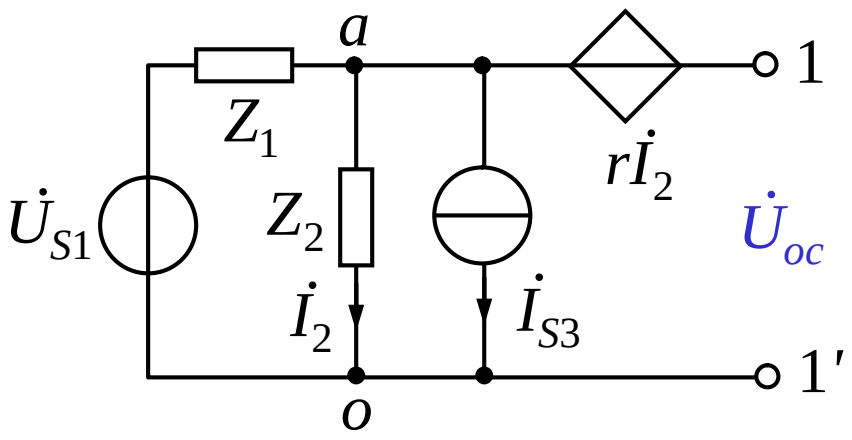
$\dot{U}_{n1}$ $\dot{U}_{S2}$

$Y_3\dot{U}_{n1}$ $(Y_3$ Y_4 $Y_5)\dot{U}_{n3}$ $Y_5\dot{U}_{n4}$ $Y_3\dot{U}_{S3}$

$Y_1\dot{U}_{n1}$ $Y_5\dot{U}_{n3}$ $(Y_1$ $Y_5)\dot{U}_{n4}$ $\dot{I}_3$

$\dot{I}_3$ $\dfrac{(\dot{U}_{n1}\ \dot{U}_{n3})\ \dot{U}_{S3}}{Z_3}$ $Y_3(\dot{U}_{n1}\ \dot{U}_{n3}\ \dot{U}_{S3})$

3



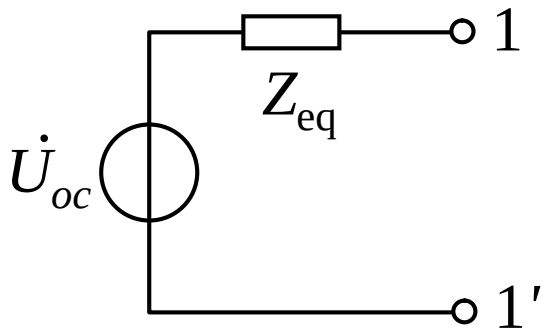
$$\dot{U}_{oc} \quad r\dot{I}_2 + \dot{U}_{ao}$$

$$\dot{I}_2 \quad Y_2\dot{U}_{ao}$$

$$\dot{U}_{oc} \quad rY_2\dot{U}_{ao} \quad \dot{U}_{ao} \quad (1 \quad rY_2)\dot{U}_{ao}$$

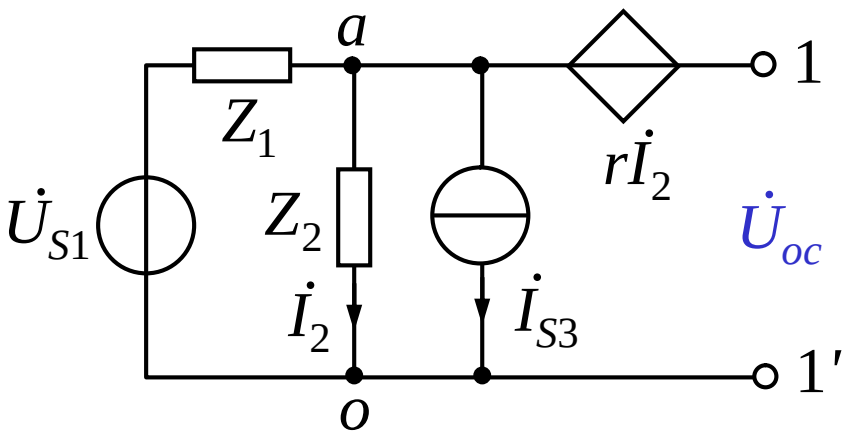
$$\dot{U}_{ao} \quad \frac{Y_1\dot{U}_{S1} \quad \dot{I}_{S3}}{Y_1 \quad Y_2}$$

$$\dot{U}_{oc} \quad \frac{(1 \quad rY_2)(Y_1\dot{U}_{S1} \quad \dot{I}_{S3})}{Y_1 \quad Y_2}$$



3

$$\dot{U}_{oc} = \frac{(1 + rY_2)(Y_1\dot{U}_{S1} - \dot{I}_{S3})}{Y_1 + Y_2}$$

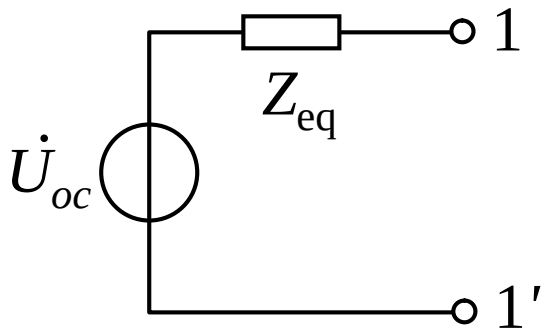


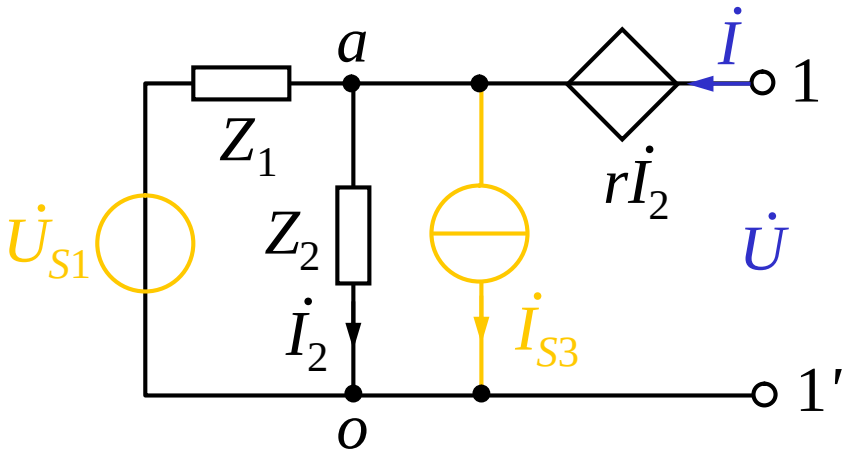
$$\dot{I}_2 = \frac{Z_1}{Z_1 + Z_2}\dot{I}$$

$$\dot{I} = \frac{Z_1 + Z_2}{Z_1}\dot{I}_2 + (1 + Y_1Z_2)\dot{I}_2$$

$$\dot{U} = r\dot{I}_2 + Z_2\dot{I}_2 + (Z_2 + r)\dot{I}_2$$

$$Z_{eq} = \frac{\dot{U}}{\dot{I}} = \frac{Z_2 + r}{1 + Y_1Z_2}$$





4 U_S 380V f 50Hz C

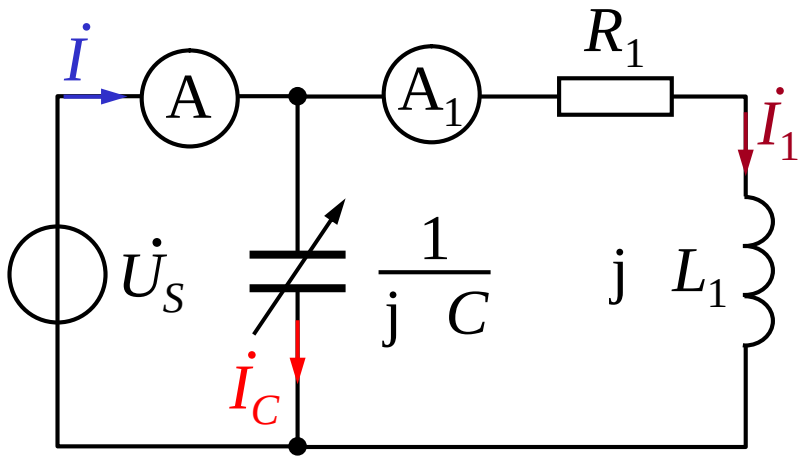
C 80.95 F A 2.59A

A_1

1

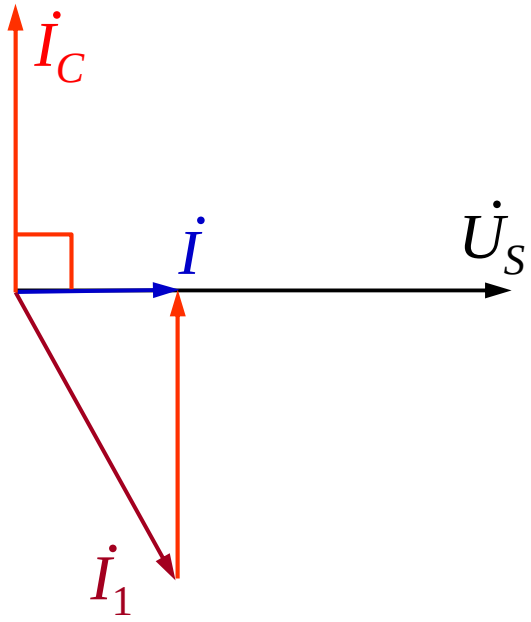
$\dot{U}_S$

C I_C $\dot{I}$ $\dot{I}_1$ $\dot{I}_C$



$\dot{I}_1$ $\dot{I}_C$ $\dot{U}_S$

$\dot{I}$ $\dot{U}_S$



I_C 2 fCU_S 9.66A

I_1 $\sqrt{9.66^2 \quad 2.59^2}$ 10 A

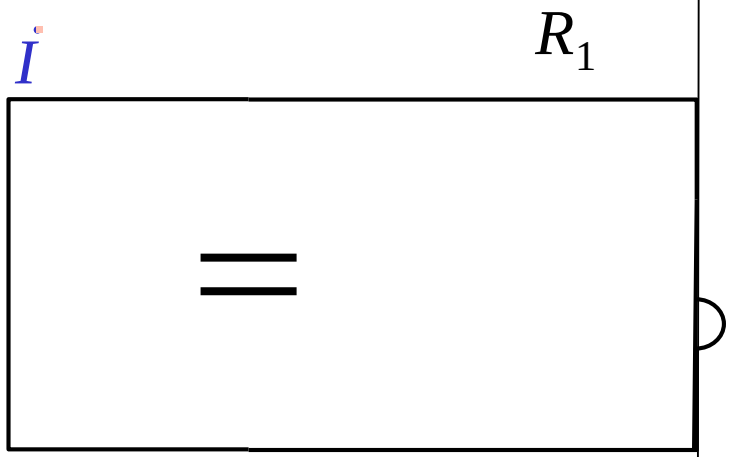
4 U_S 380V f 50Hz C

C 80.95 F A 2.59A

A_1 1 1

2

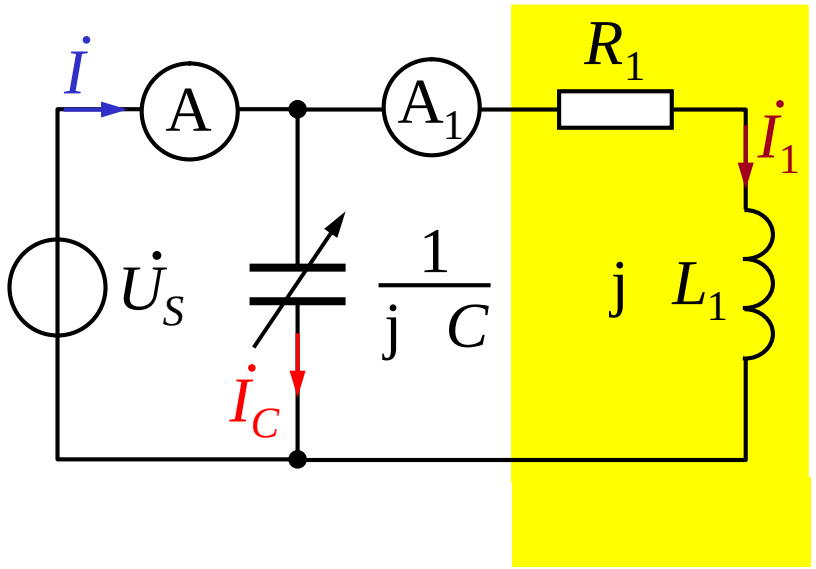
Y j C $\frac{R_1}{|Z_1|^2}$ j $\frac{L_1}{|Z_1|^2}$



4 U_S 380V f 50Hz C

C 80.95 F A 2.59A

A_1



( )

$\dot{I}_1$ $10\angle 70^{\circ}$ A

Z_1 $\dfrac{\dot{U}_s}{\dot{I}_1}$ $38\angle 70^{\circ}$ 13 j 35.71

R_1 13 L_1 $\dfrac{35.71}{}$ 113.7mH

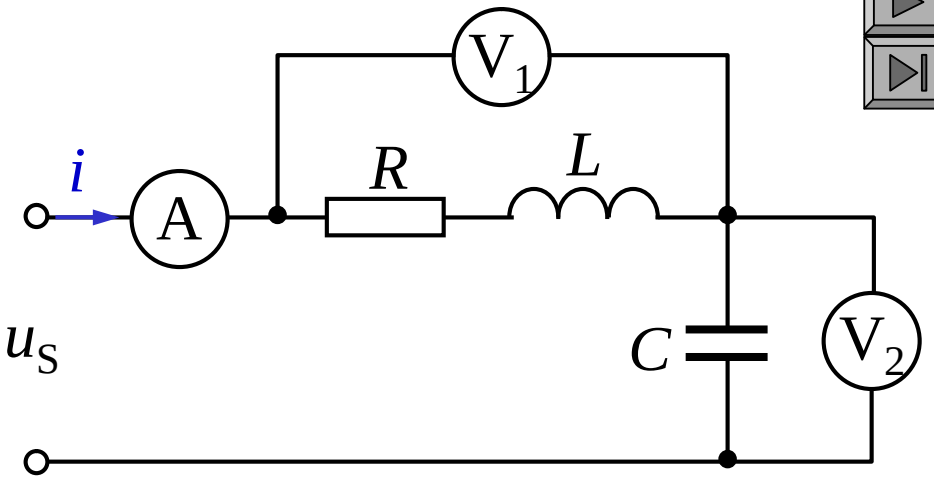
5 P228 9 5

u_S $200\sqrt{2}\cos(314t$) V

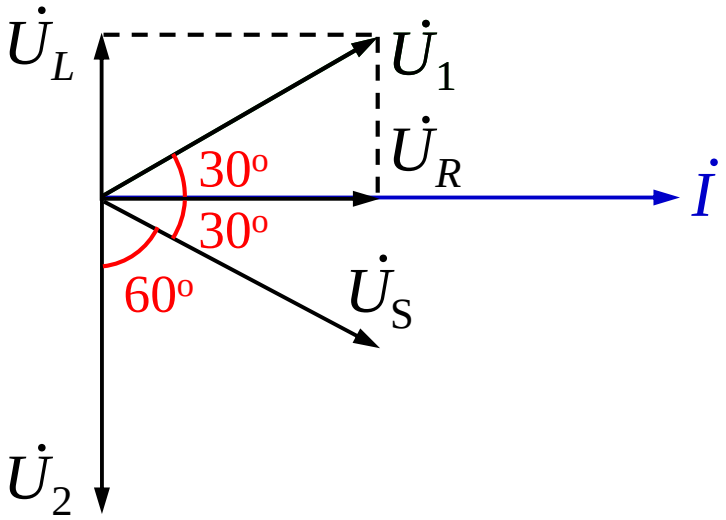
A 2A

V_1 V_2

200V R L C



$\dot{I}$ $\underline{/0^o}$ A



$\dot{U}_2$ j 200 V

$\dot{U}_1$ $200\underline{/30^o}$ V $\dot{U}_S$ $200\underline{/\ 30^o}$ V

$\dot{I}$ $\angle 0^{o}$ A $\dot{U}_2$ j 200 V

$\dot{U}_1$ $200\angle 30^{o}$ V

$\dot{U}_S$ $200\angle\ 30^{o}$ V

Z_1 R j L $\dfrac{\dot{U}_1}{\dot{I}}$ $\dfrac{200\angle 30^{o}}{2\angle 0^{o}}$

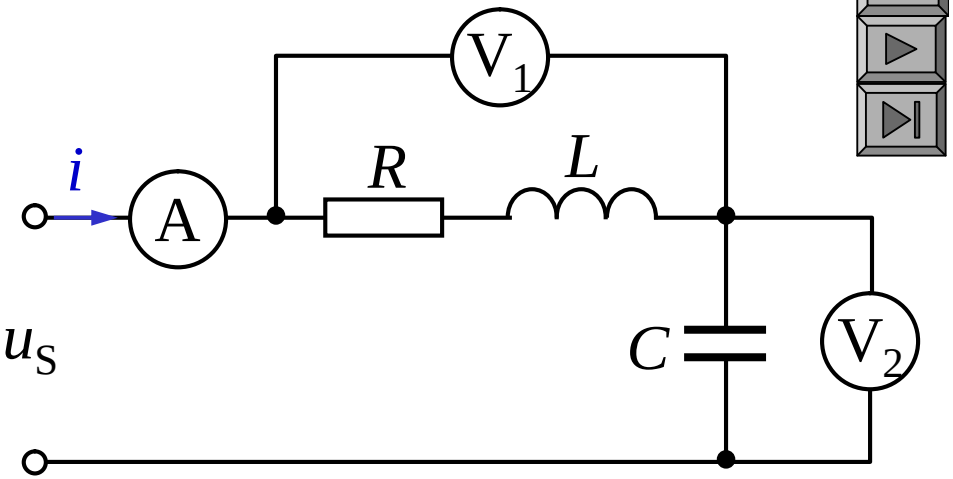
$\angle 30^{o}$ 86.6 j50

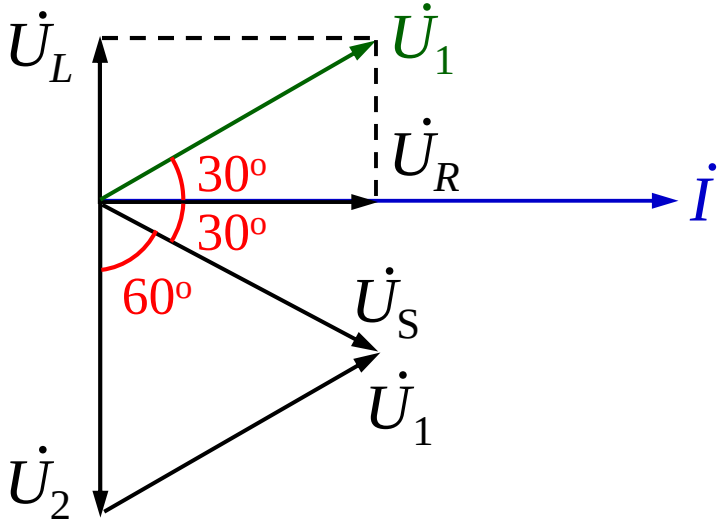
R 86.6 L 50

L $\dfrac{50}{314}$ 0.159H

Z_C $\dfrac{\dot{U}_2}{\dot{I}}$ $\dfrac{\text{j}200}{2}$ j100

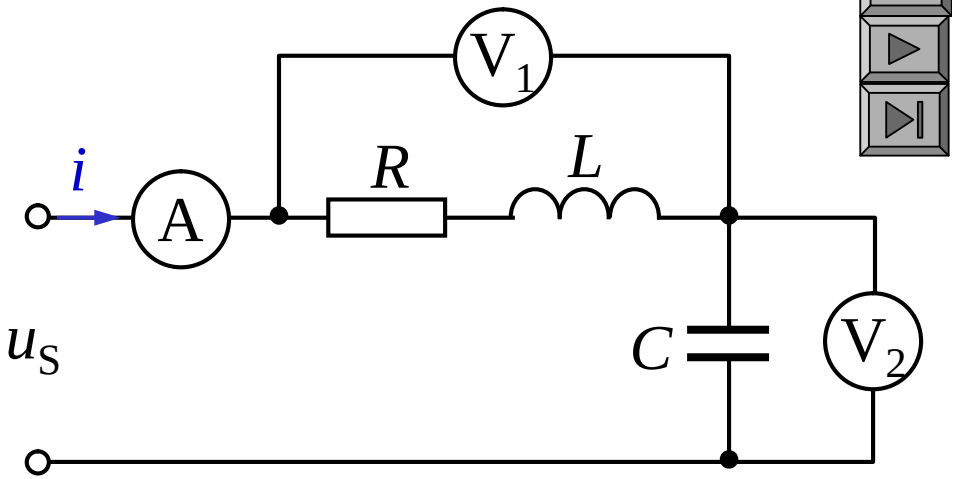
$\text{j}\dfrac{1}{C}$ C $\dfrac{1}{100}$ 31.85 F

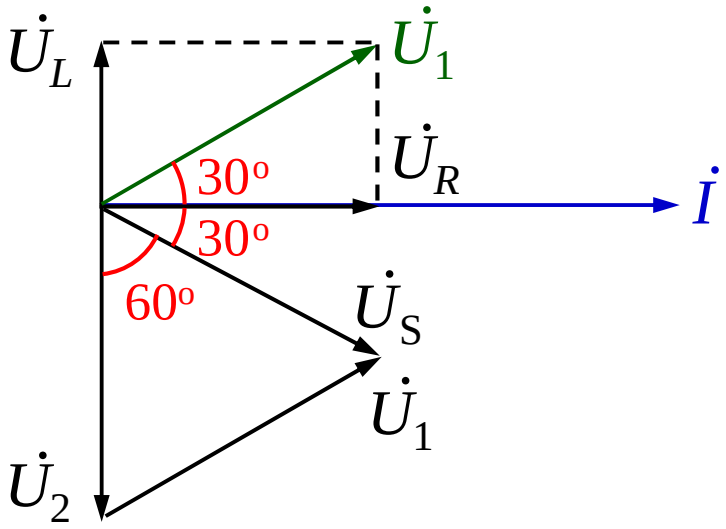




u_S $200\sqrt{2}\cos(314t$) V

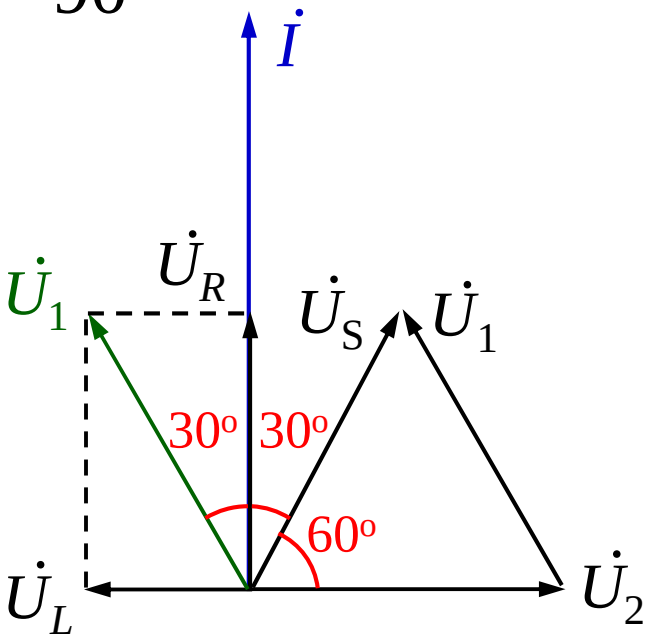
u_S





u_2 $200\sqrt{2}\cos 314t$ V

90o

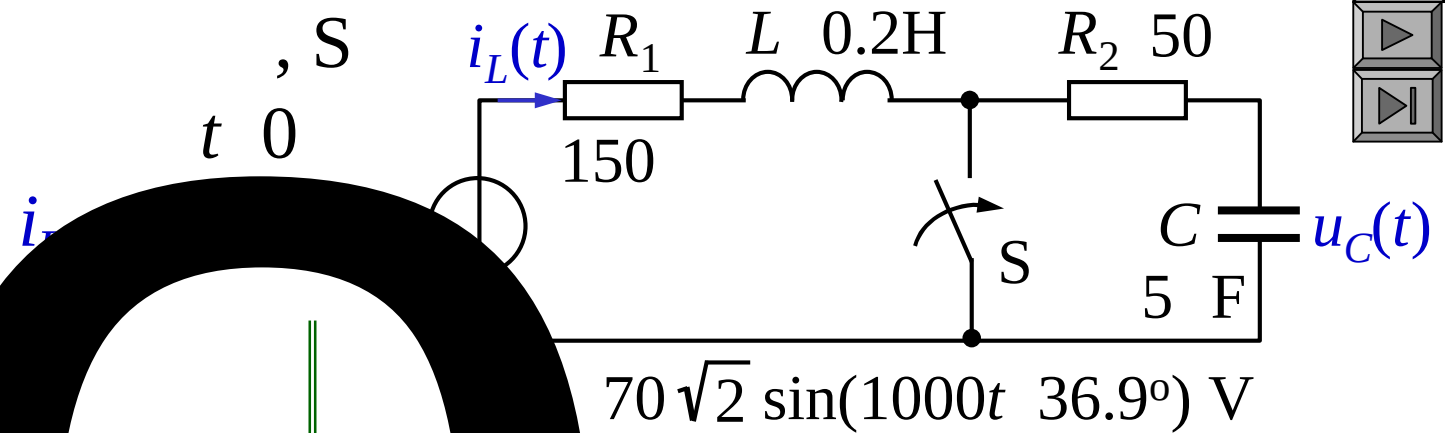


6 , S

t 0

S

S



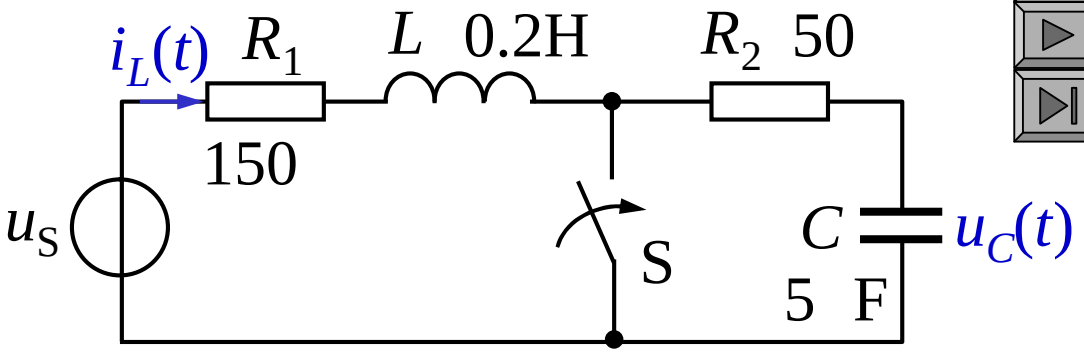
$$\dot{I} = \frac{\dot{U}_S}{R_1 \quad R_2 \quad \mathrm{j}\left(L \quad \frac{1}{C} \right)}$$

150 50 j 588.85452.27 224.5

$\dot{I}_L$ $\angle 36.9^\circ$ A

$\dot{U}_C$ $j200\,\dot{I}_L$

$70.7\angle 53.1^\circ$ V



u_S $70\sqrt{2}\sin(1000t\ 36.9^\circ)$ V

i_L $\sqrt{2}\sin(\ t\ 36.9^\circ)$ A $(t\ 0)$

$i_L(0\ )$ $\sqrt{2}\sin 36.9^\circ$ 0.3A

$u_C(0\ )$ $\sqrt{2}\sin(\ 53.1^\circ)$ 80V

$t\ 0$ RC

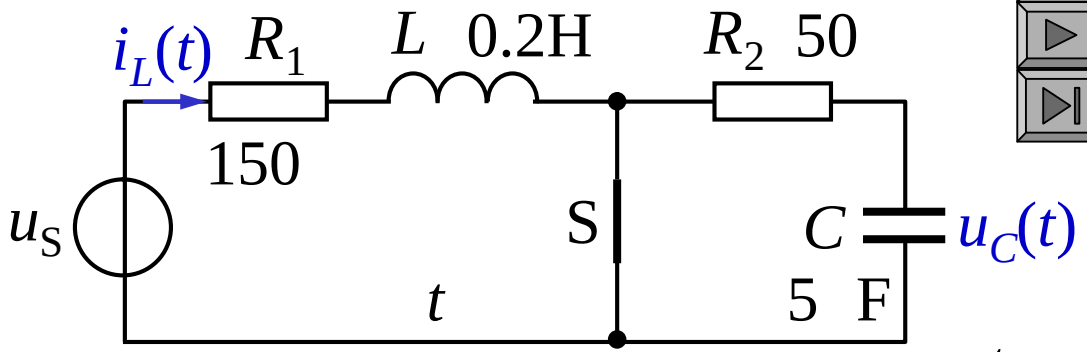
$_C$ R_2C $10^{\ 4}$s $u_C(\ \ )$ 0

$u_C(t)$ $80e^{\ 4000t}$ V $(t\ 0)$

$i_L(0\ )$

L R_1 s

t 0 RL



$$f(t) \quad f'(t) \quad [\,f(0\ ) \quad f'(0\ )\,]\,e^{-\frac{t}{\quad}}$$

$$\dot{I}_L' \quad \frac{\dot{U}_S}{R_1 \quad j \quad L} \quad \frac{70.7\angle 36.9^o}{150 \quad j200}$$

$$\angle\ 16.23^o\ \text{A}$$

$i_L'(t)$ $\sqrt{2}\sin(\ t\ 16.23^o)$

$\sin(\ t\ 16.23^o)$ A

$i_L'(0\ )$ $\sin(\ 16.23^o)$

.112A

$i_L(0\ )$ $i_L(0\ )$

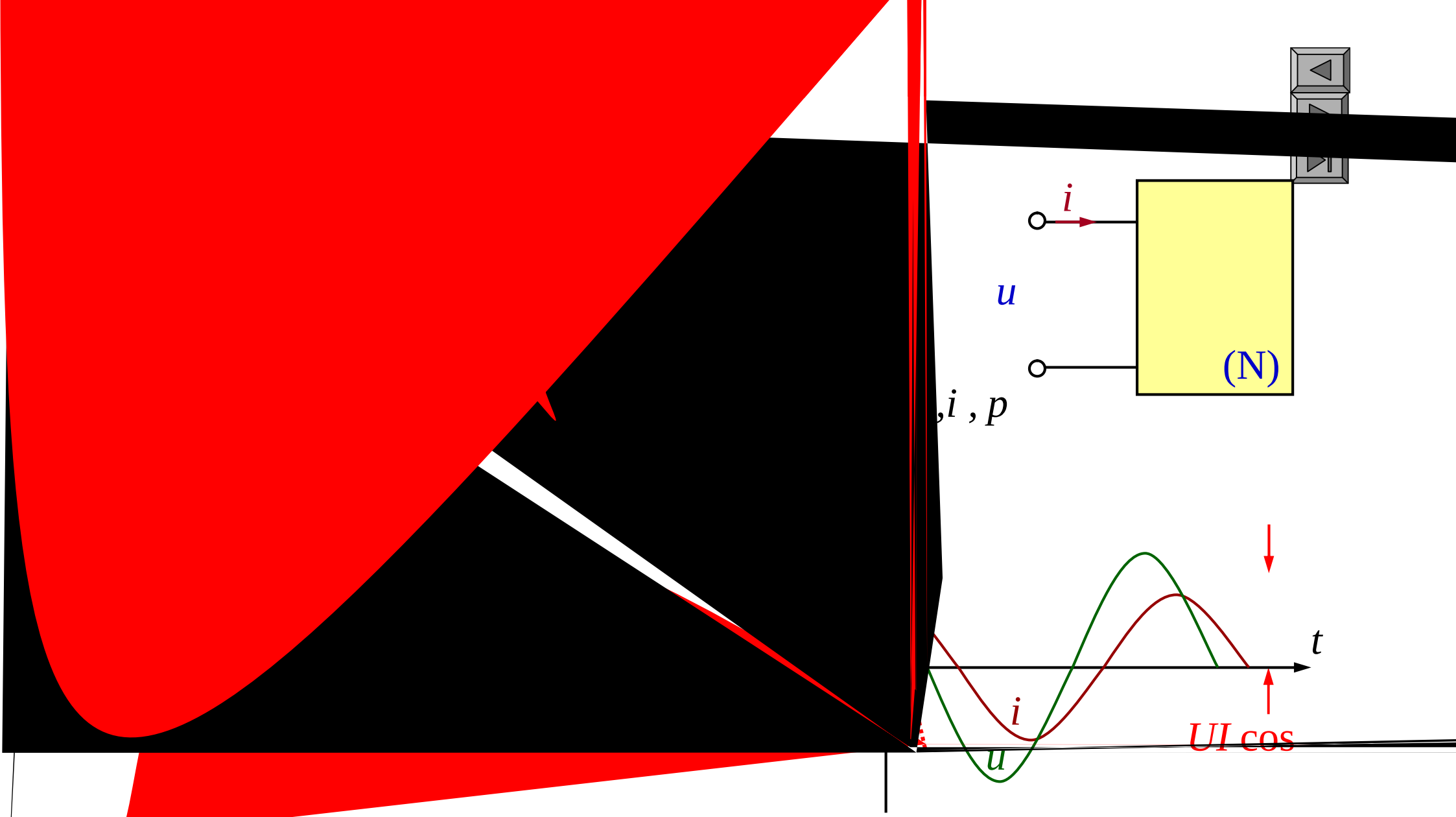
$i_L(t)$ [$\sin(\ t\ 16.23^o)$

$0.4\ 12e^{-750t}]$A $(t \quad 0)$

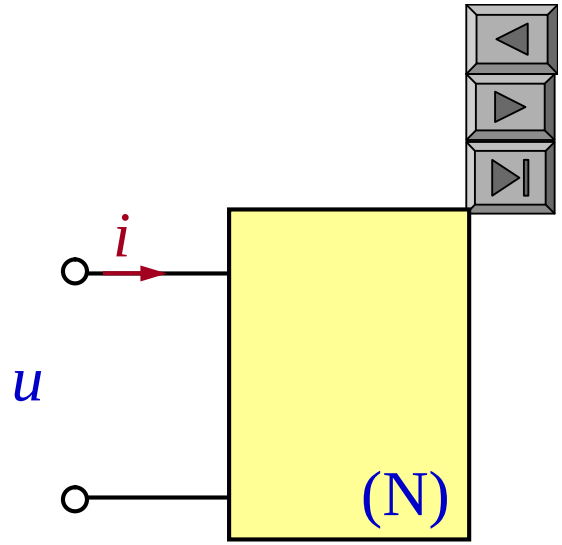
9 4

i 0

u i u


i
u
(N)
,i , p
t
i
u
UI cos

$p \quad UI\cos \qquad \cos 2 \quad t \qquad UI\sin \quad \sin 2 \quad t$



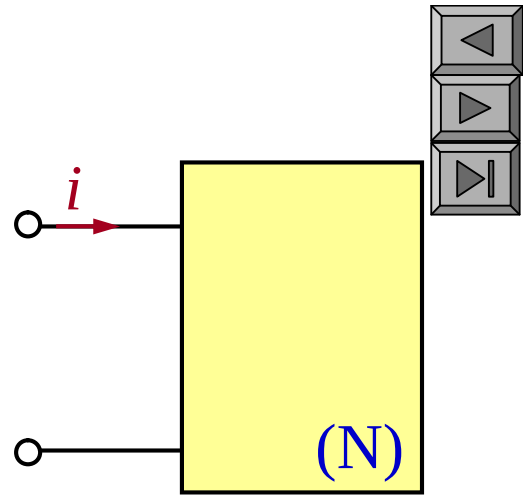
$p \quad 0$

$p \quad 0$

2. P cos (

P

P



$$P \quad \frac{1}{T} \int_0^T p \, \mathrm{d}t$$

P UIcos

P

cos

0 |cos | 1 cos

P UI cos

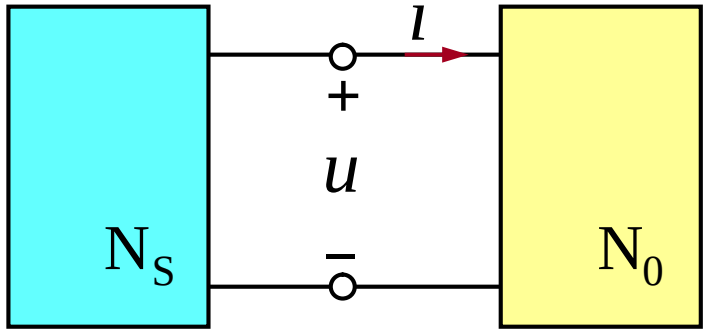
$P = 0$

P

3. Q S

$$Q \overset{\text{def}}{=\!=} U\,I\,\sin$$

Q



$$S \overset{\text{def}}{=\!=} U\,I$$

Q

( )

Q

Var( )

S S

VA( )

4. S P Q

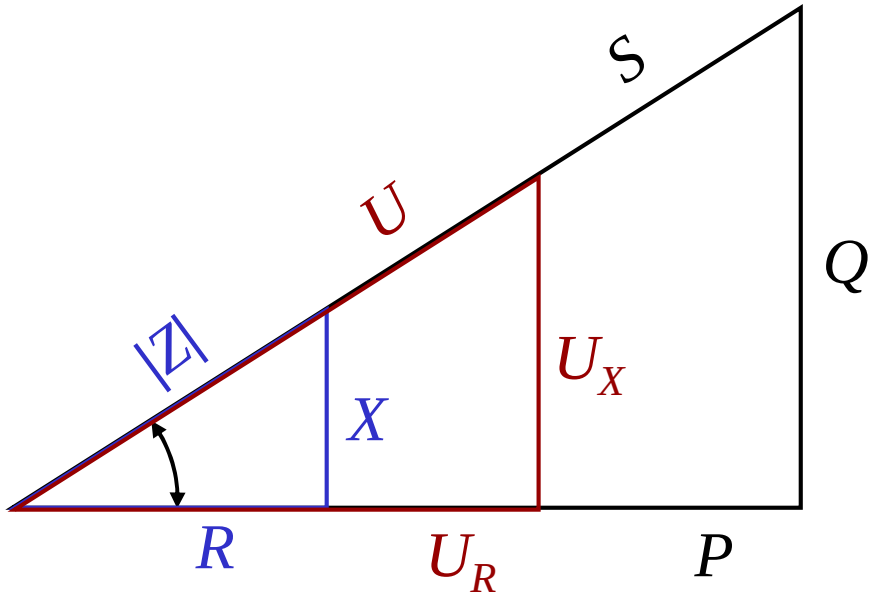
S UI

P $UI\cos$ $S\cos$

Q $UI\sin$ $S\sin$

S $\sqrt{P^2 + Q^2}$

$\arctg \frac{Q}{P}$



5. R L C

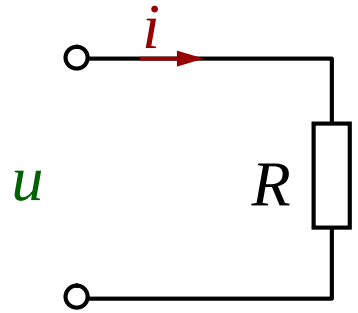
(1) R u i

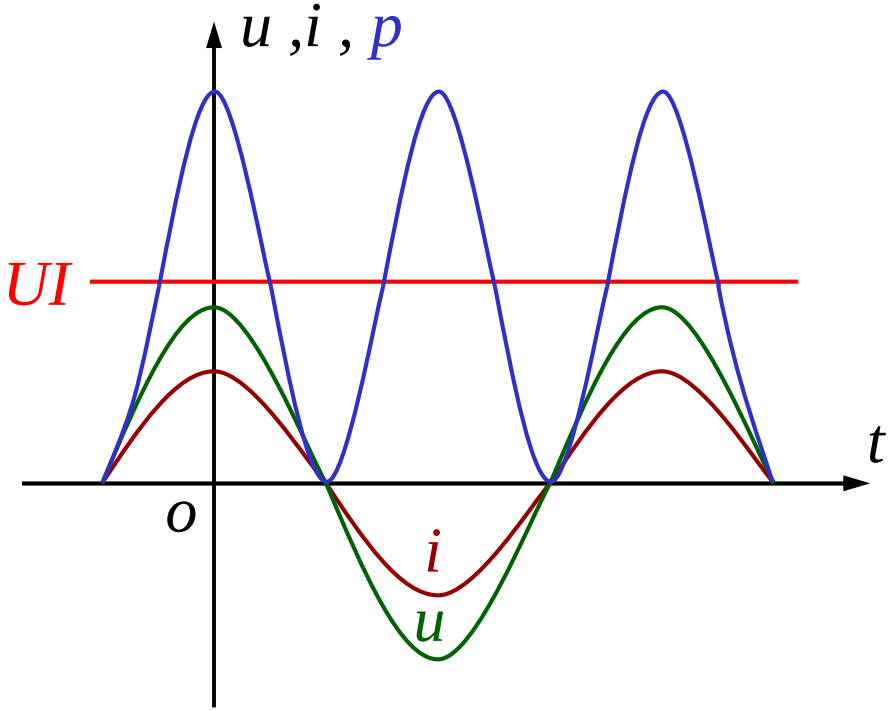
i $\sqrt{2}\,I\cos$ t

u $\sqrt{2}\,I\cos$ t

p ui $UI(1$ $\cos 2$ $t)$ 0

p 0 R





P_R $UI\cos$ UI I^2R U^2G

Q_R $UI\sin$ 0

(2) L u i 90^o ,

i $\sqrt{2}\,I\cos$ t

u $\sqrt{2}\,I\cos($ t

p ui $UI\sin 2$ t

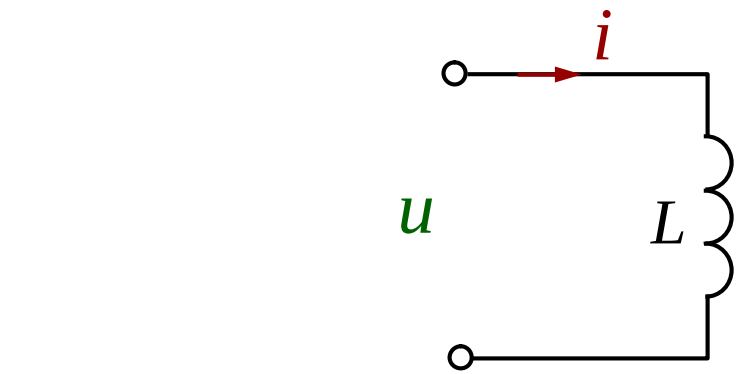
P $UI\cos$ 0

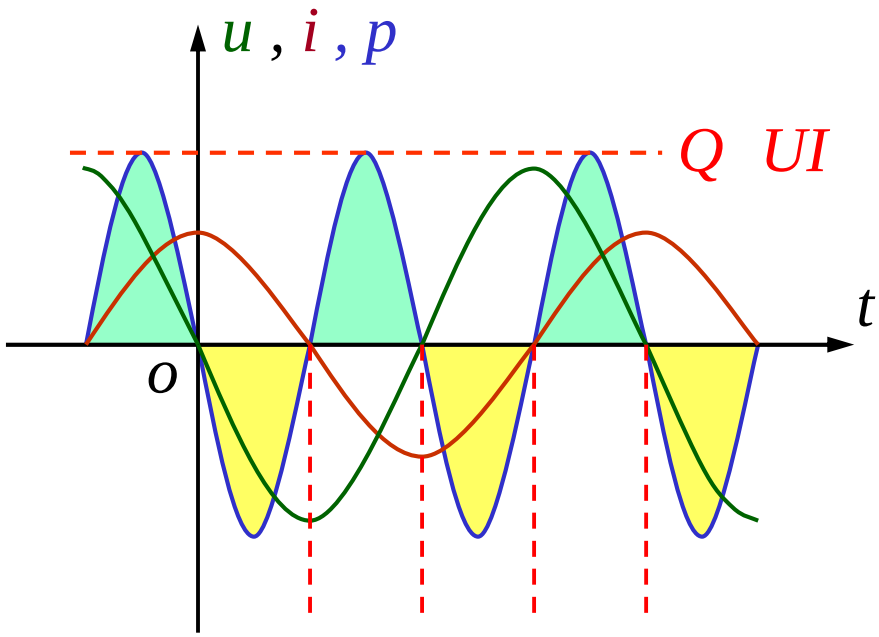
p L

Q_L $UI\sin 90^o$ UI $LI\ I$

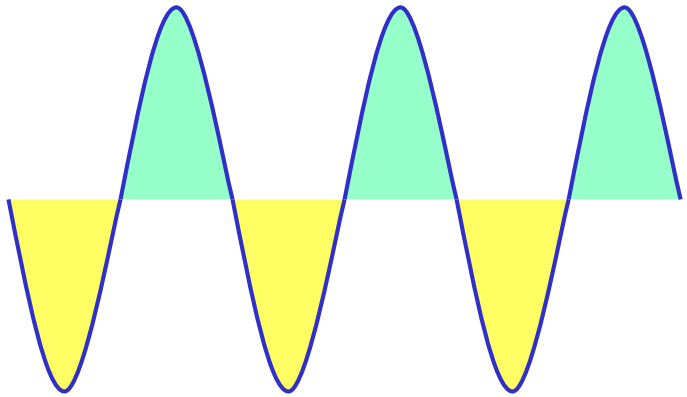
I^2 L $\dfrac{U^2}{L}$ I^2X_L

L





(3)



R L

R L

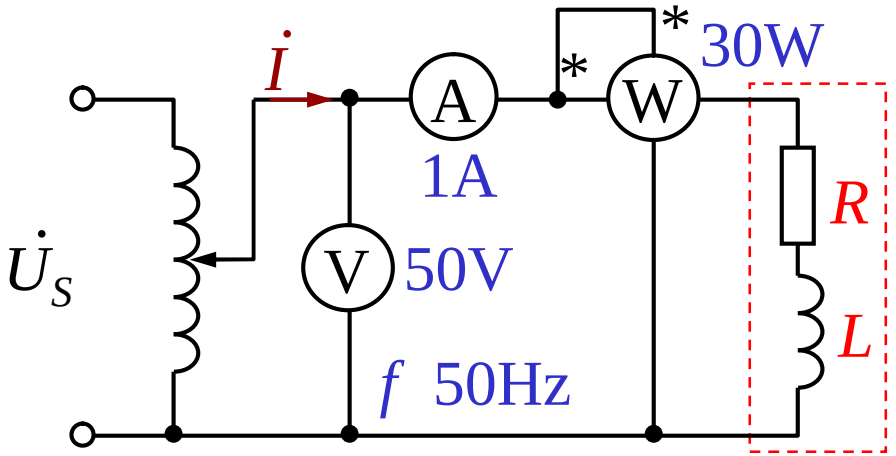
R

P I^2R 30 W

R 30

( )

$|Z|$ $\dfrac{U}{I}$ 50



L $\sqrt{50^2 \quad 30^2}$ 40

L $\dfrac{40}{\quad}$ $\dfrac{40}{314}$ 127mH

P $UI\cos$ 30 W

$\cos$ $\dfrac{P}{UI}$ →

Z 50 ∠ 30 j40

R 30 L 40

9 5

“ ”

1.

$\dot{U}$ $U\angle_{u}$ $\dot{I}$ $I\angle_{i}$

$\overline{S} \overset{\text{del}}{=\!=} \dot{U}\dot{I}^{*}$ $UI\angle_{u\ \ i}$ $S\angle$

$UI\cos + \mathrm{j}UI\sin$ P jQ

$\overline{S}$ P Q S

2.

$P \quad jQ$

$\overline{S} \quad \dot{U}\,\dot{I}^{*} \quad Z\,\dot{I})\,\dot{I}^{*} \quad ZI^{2} \quad R \quad jX \quad I^{2} \quad RI^{2} \quad jXI^{2}$

$\overline{S} \quad \dot{U}\,\dot{I}^{*}$

$\overline{S}$

‘ *d* *xG•* *à*

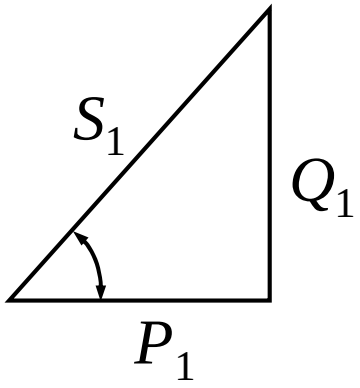
P239 9−10 U 380V

f 50Hz cos $_1$ 0.6 P_1 20kW

cos 0.9 C

1 C

cos $_1$ 0.6 $_1$ 53.13°



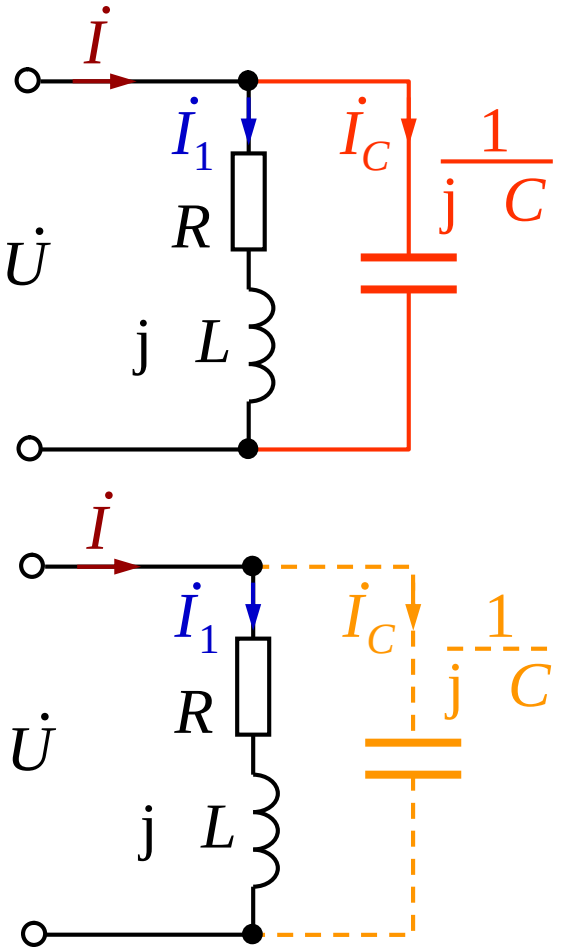
Q_1 P_1tg tg53.13°

26.67 kvar

RL

$\overline{S_1}$ P_1 jQ_1 C S_1

20 j26.67 kVA P_1

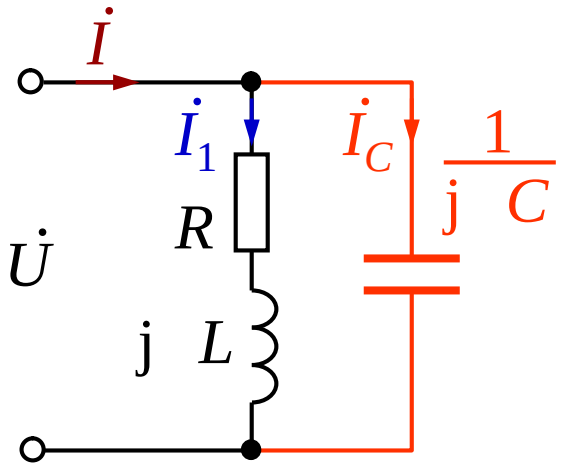


C $\overline{S}_C$ 0 jQ_C

$\overline{S}$ $\overline{S}_1$ $\overline{S}_C$ P_1 j(Q_1 Q_C)

cos 0.9

25.84º



Q_C 16.98 36.36 kvar

Q Q_1 Q_C P_1tg

( )

9.69 kvar

Q_C CU^2

C

C $\dfrac{Q_C}{U^2}$ $\dfrac{19.68 \quad 10^3}{314 \quad 380^2}$

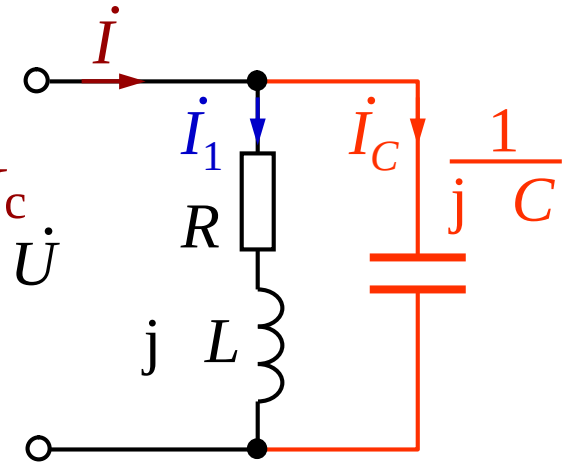
Q_C 9.69 Q_1

F

9.69 26.67 kvar

2

C I_1 $I_1 \sin$ $_{z1}$ I_c

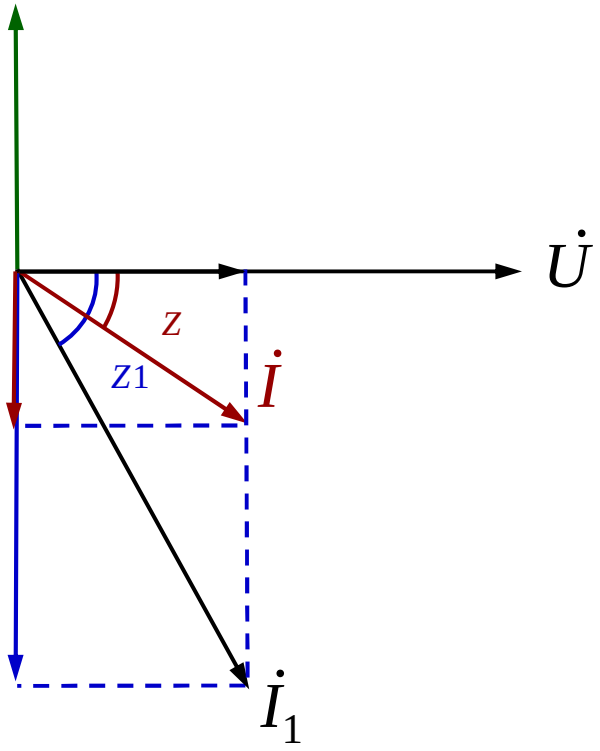


I_C

I_1 P_1 $U\cos$ $_{z1}$ I $\dfrac{P_1}{U\cos\ _{z}}$

I_C CU

C $\dfrac{P_1}{U^2}$ (tg $_{z1}$ tg $_{z}$



C 375 F

3

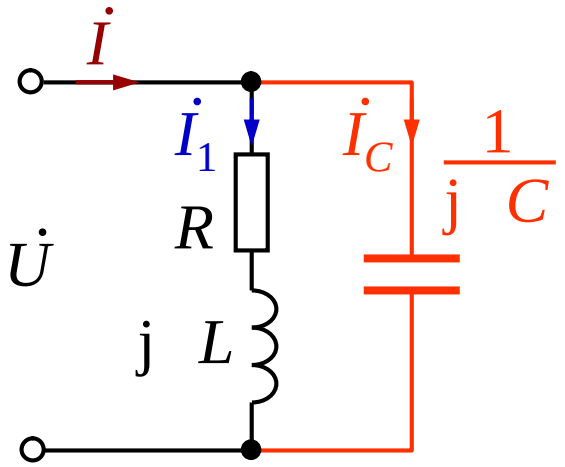
C Y Y_1 Y_C

Y $Y\cos$ $_Y$ j $Y\sin$ $_Y$

Y_1 $Y_1\cos$ $_{Y1}$ j $Y_1\sin$ $_{Y1}$

$Y\cos$ $_Y$ j $Y\sin$ $_Y$ $Y_1\cos$ $_{Y1}$ j $Y_1\sin$ $_{Y1}$ j C

$Y\sin$ $_Y$ $Y_1\sin$ $_{Y1}$ C



P_1 $U(U$ $Y_1)\cos$ $_{Y1}$ Y_1 $\dfrac{P_1}{U^2\cos\ _{Y1}}$ $_Y(\ _{Y1})$

P $U(U$ $Y)\cos$ $_Y$ Y $\dfrac{P_1}{U^2\cos\ _Y}$ $_Z(\ _{Z1})$

$$C \quad \frac{P_1}{U^2}(\mathrm{tg}\ _Y \quad \mathrm{tg}\ _{Y1})$$

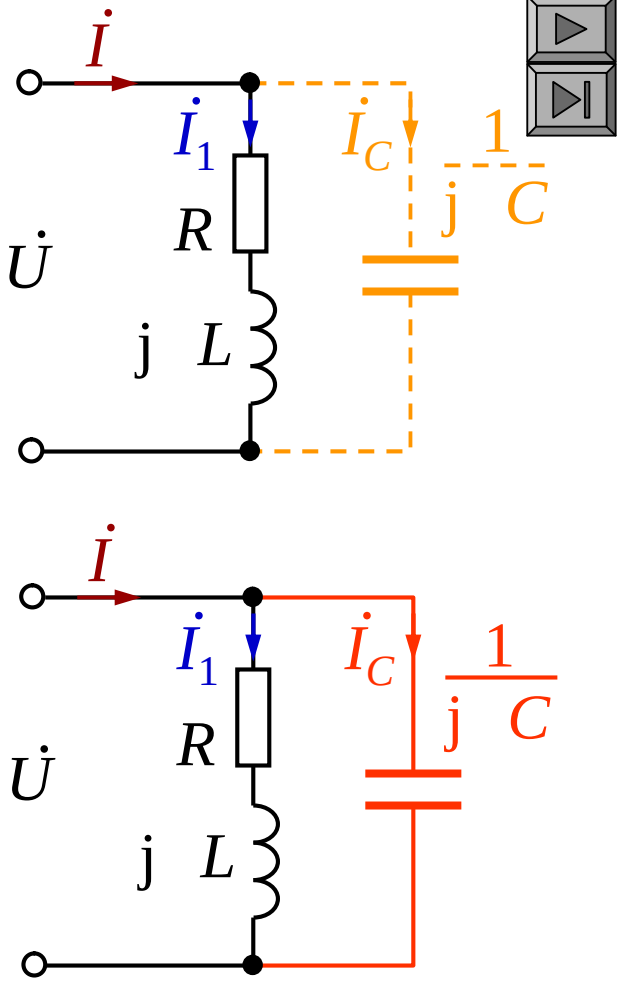
C I I_1

$$I_1 \quad \frac{P_1}{U\cos_{\ 1}} \quad \frac{20 \quad 10^3}{380 \quad 0.6}$$

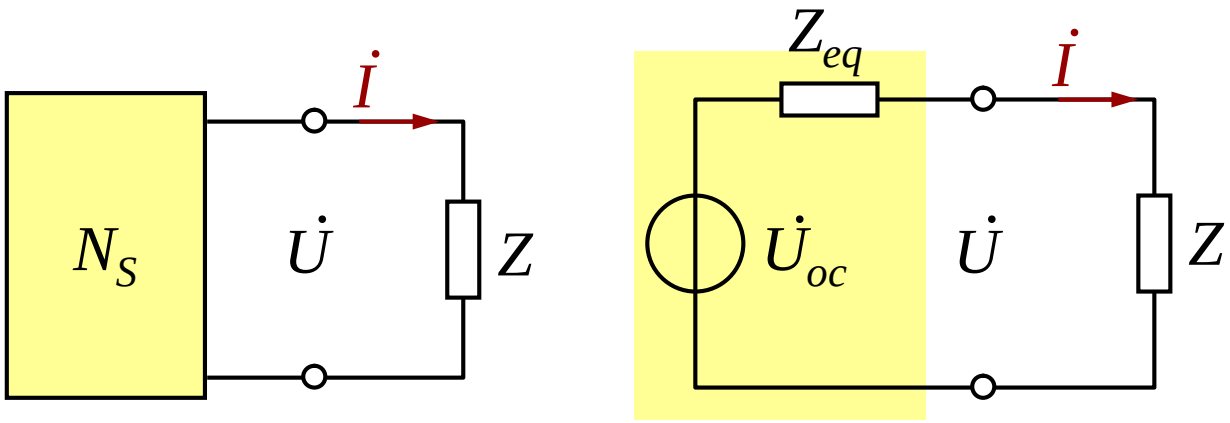
C P_1 I_1

I

$$I \quad \frac{P_1}{U\cos} \quad \frac{20 \quad 10^3}{380 \quad 0.9}$$



9 6



Y Y_{eq}*

Z $P_{\max}$ Z

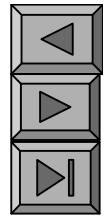
Z R jX Z_{eq} R_{eq} jX_{eq}

X X_{eq} 0

$\dfrac{\mathrm{d}P}{\mathrm{d}R}$ 0

$$P \quad I^2R \quad \frac{U_{oc}^2}{|Z \quad Z_{eq}|^2} \quad R$$

$$\frac{R \; U_{oc}^2}{(R \quad R_{eq})^2 \quad (X \quad X_{eq})^2}$$

Z R_{eq} jX_{eq} Z^*_{eq}

$$P_{\max} \quad \frac{U_{oc}^2}{4R_{eq}}$$