

**O‘ZBEKISTON RESPUBLIKASI OLIY VA O‘RTA
MAXSUS TA‘LIM VAZIRLIGI**

**ISLOM KARIMOV NOMIDAGI TOSHKENT DAVLAT
TEXNIKA UNIVERSITETI**

NAZARIY ELEKTR TEXNIKA

fanining “To‘rtqutbliklarni tadqiq qilish”

bo‘limi bo‘yicha hisob-grafik ishlarini bajarish yuzasidan

uslubiy ko‘rsatma

Toshkent 2017

Tuzuvchilar: Q.G'.Abidov, R.Jo'rayev, A.I.Raxmatullayev, I.V.Ernst. "Nazariy elektr texnika" fanidan "To'rtqutbliklarni tadqiq qilish" bo'limi bo'yicha hisob-grafik ishlarini bajarish yuzasidan uslubiy ko'rsatma. Toshkent: ToshDTU, 2016.

Tavsiya etilayotgan ko'rsatmada "Elektrotexnikaning nazariy asoslari" fanining "To'rtqutbliklarni tadqiq qilish" bo'limi bo'yicha hisob-grafik ishlarini bajarish namunalari ko'rsatilgan.

Uslubiy ko'rsatma bakalavriat yo'nalishida ta'lim oluvchi va "Elektrotexnikaning nazariy asoslari" fanini o'rganuvchi talabalarga mo'ljallangan.

Islom Karimov nomidagi Toshkent davlat texnika universiteti ilmiy-uslubiy kengashi qarori bilan nashr etildi.

Taqrizchilar:

M.Sapayev –

TATU, "Energiya ta'minlash tizimlari" kafedrası, t.f.n.dotsent

A.T.Imomnazarov –

ToshDTU

"Elektr texnika, elektr mexanika va elektr texnologiyalari"

kafedrası, professor

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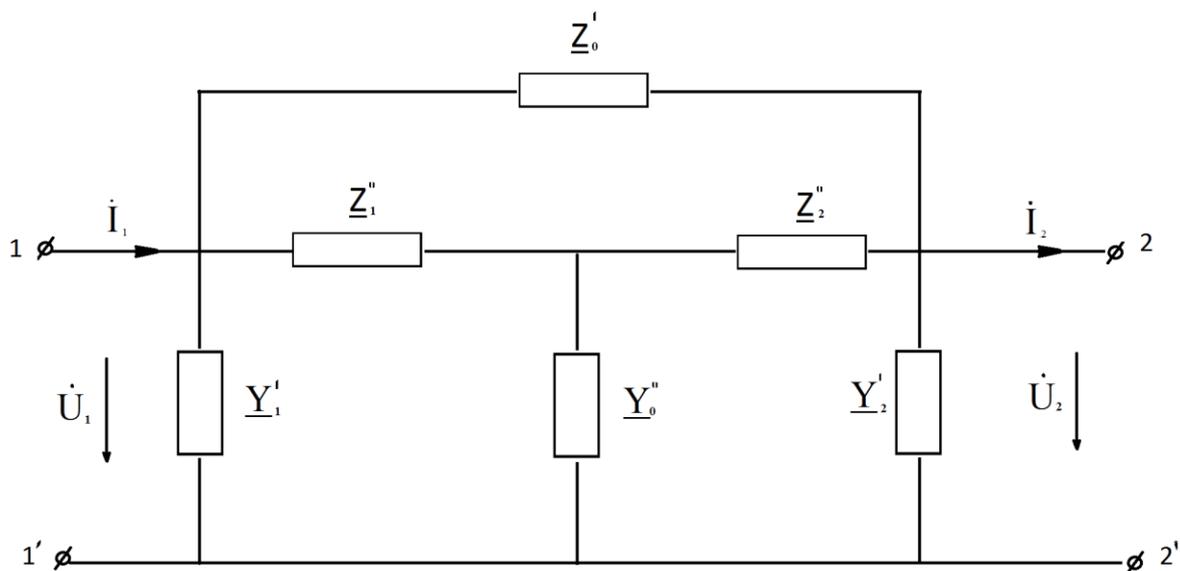
KIRISH

Tavsiya etilayotgan ko‘rsatmada “Nazariy elektr texnika” fanining elementar to‘rtqutblikni parallel va kaskad ulanishlari va uning “A” va “Y” parametrlarini hisoblash ko‘rsatilgan. Yana to‘rtqutblikda o‘tish jarayonini operator formasida hisoblash ko‘rsatilgan.

“To‘rtqutblikni hisoblash” bo‘limi bo‘yicha hisob-grafik ishlarini bajarish uchun mo‘ljallangan mazkur uslubiy ko‘rsatma “Elektr energetikasi”, “Elektr texnika, elektr mexanika va elektr texnologiyalar”, “Biomuhandislik”, “Elektronika va asbobsozlik”, “Radioelektron qurilmalar va tizimlar”, “Kasbiy ta’lim(radioelektron qurilmalar va tizimlar)” bakalavriat ta’lim yo‘nalishlarida tahsil oluvchi talabalarga mo‘ljallangan.

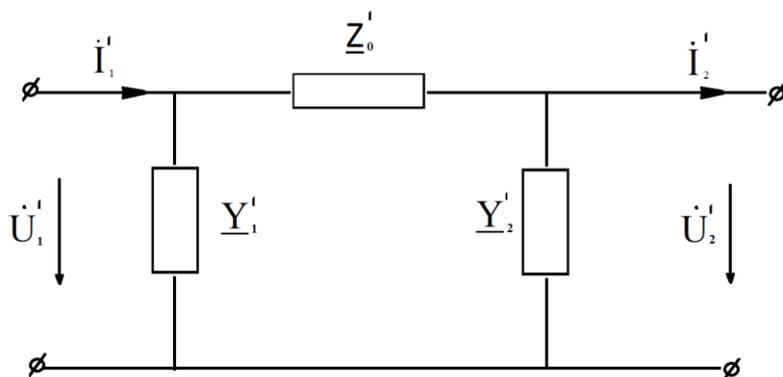
I. Passiv to‘rtqutblikni tadqiq qilish

1. Sxemani kaskadli yoki parallel ulangan elementar to‘rtqutblik ko‘rinishda ifodalang. (keltiring)
2. Elementar to‘rtqutblikning parametrlarini “A” ko‘rinishda ifodalang va $AD-BC=1$ ifodani tekshiring.
3. Agar elementar to‘rtqutblik parallel ulangan bo‘lsa uning parametrlarini “Y” – formada ifodalang.
4. Parallel ulangan elementar to‘rtqutbliklar uchun uning parametrlarini “Y” formadagimatritsa ko‘rinishida tuzib chiqing.
5. Kaskadli ulangan elementar to‘rtqutbliklar uchun uning parametrlarini “A” – formadaagi matritsa ko‘rinishida tuzib chiqing.
6. Salt ulangan rejimda kuchlanish bo‘yicha uzatish koeffitsiyentini kompleks va operator ko‘rinishida aniqlang. U_2/U_1
7. $\frac{U_2}{U_1}(\omega) = K(\omega)$ va $\alpha(\omega) = \Psi_{U_2} - \Psi_{U_1}$ ifodaning chastotaviy grafiklarini quring.
8. To‘rtqutblikning kirishiga o‘zgarmas (sinusoidal) $U_1=100$ V kuchlanish berib ekvivalent to‘rtqutblikning chiqishidagi o‘tish jarayonini operator formada hisoblang.
9. Istalgan elementar to‘rtqutblik uchun chastotasi ω ($\omega=10 \div 50$ kHz) bo‘lganda Z_{1C} va Z_{2C} xarakteristik qarshilikni hisoblang.

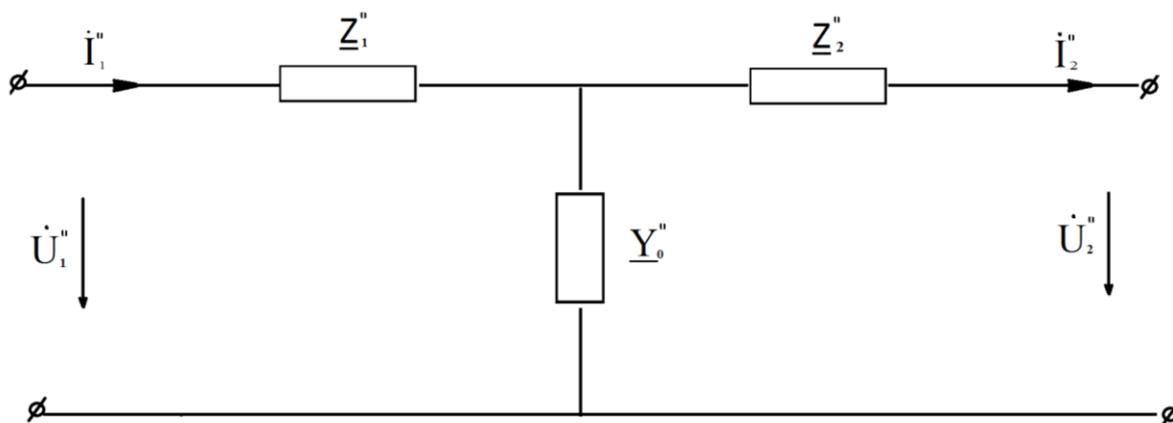


1-rasm.

Keltirilgan 1-rasm quyidagi ikkita elementar parallel ulangan to'rtqutbliklardan tashkil topgan:

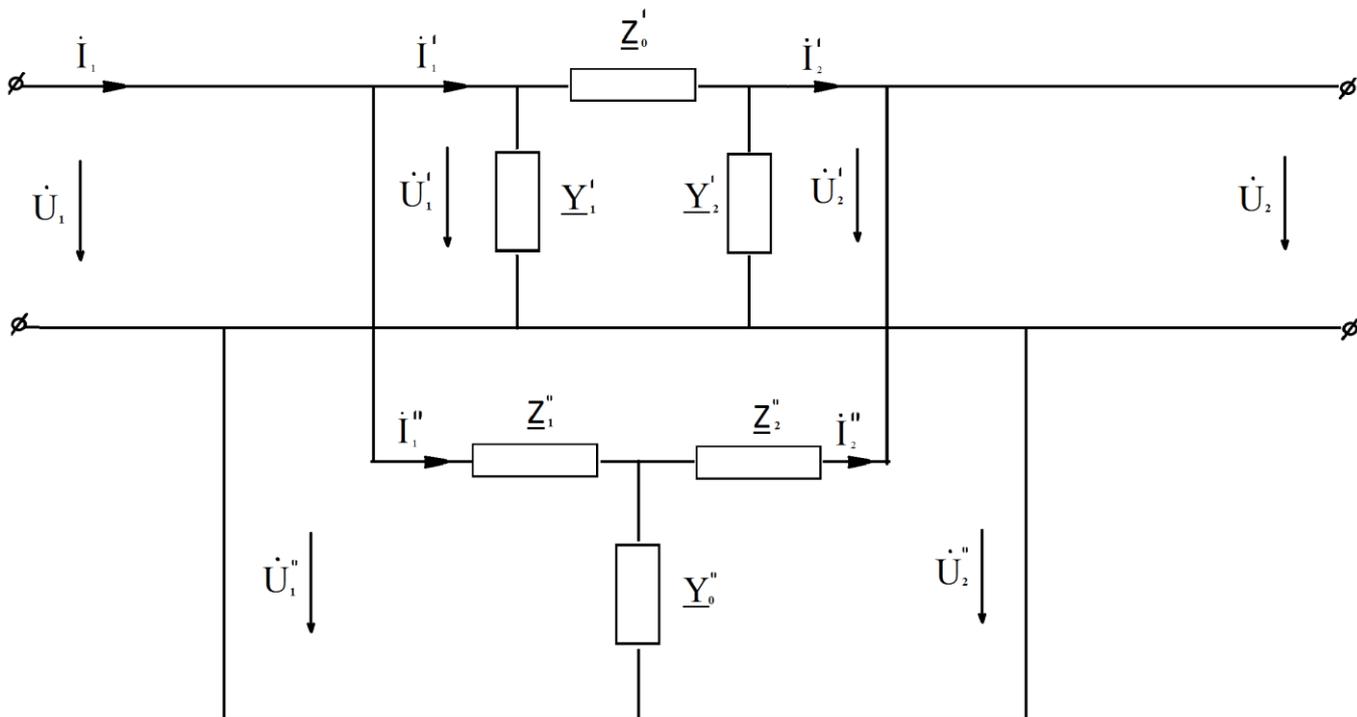


2-rasm.

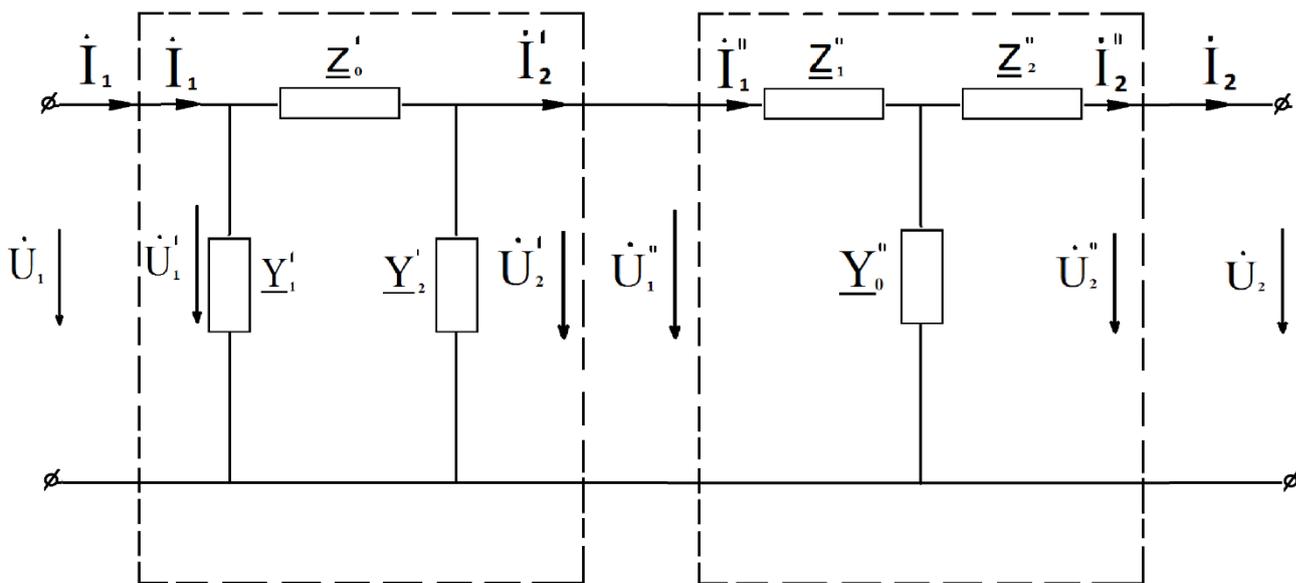


3-rasm.

1-rasmdagi parallel ulangan elementar (2,3-rasm) to'rtqutbliklarni parallel ulangan 4-rasm va kaskad ulangan 5-rasm ko'rinishida keltiramiz.



4-rasm.

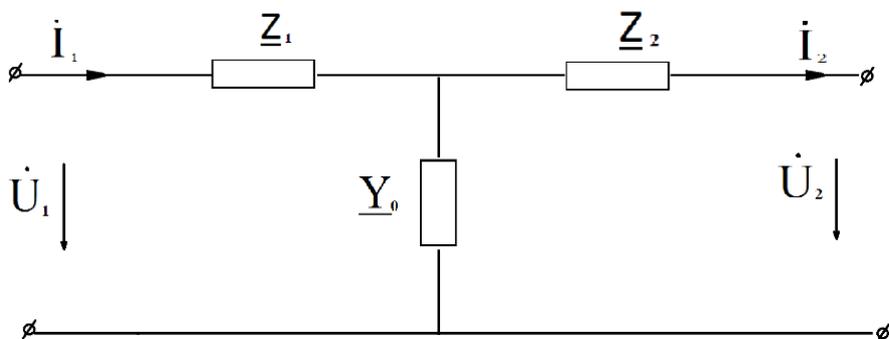


5-rasm.

(Elementar to'rtqutbliklarning sxemalaridagi toklar va kuchlanishlarning ko'rsatilgan yo'nalishlari uchun:

1. T-ko'rinishidagi to'rtqutblikning "A"-formadagi koeffitsiyentlari quyidagicha

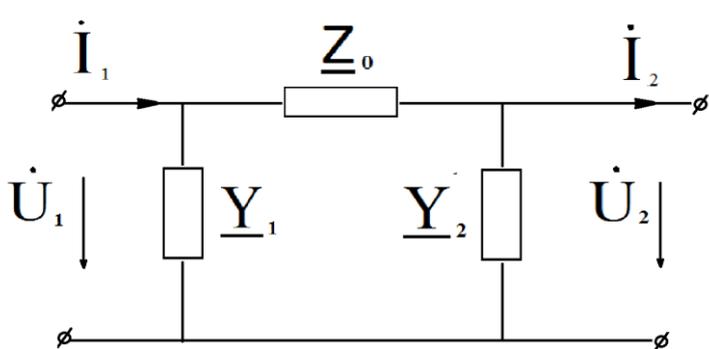
yoziladi.



$$\begin{aligned} \underline{A} &= 1 + \underline{Z}_1 \underline{Y}_0 \\ \underline{B} &= \underline{Z}_1 + \underline{Z}_2 + \underline{Z}_1 \underline{Z}_2 \underline{Y}_0 \\ \underline{C} &= \underline{Y}_0 \\ \underline{D} &= 1 + \underline{Z}_2 \underline{Y}_0 \end{aligned}$$

6-rasm.

2. Π-ko'rinishidagi to'rtqutblikning "A" formasi koeffitsiyenti quyidagicha yoziladi:



$$\begin{aligned} \underline{A} &= 1 + \underline{Y}_2 \underline{Z}_0 \\ \underline{B} &= \underline{Z}_0 \\ \underline{C} &= \underline{Y}_1 + \underline{Y}_2 + \underline{Y}_2 \underline{Y}_1 \underline{Z}_0 \\ \underline{D} &= 1 + \underline{Y}_1 \underline{Z}_0 \end{aligned}$$

7-rasm.

6,7-rasmlar uchun to'rtqutblikning tenglamasi "A" formada

$$U_1 = \underline{A} U_2 + \underline{B} I_2$$

$$I_1 = \underline{C} U_2 + \underline{D} I_2$$

3. "T" va Π-ko'rinishdagi to'rtqutbliklar uchun $AD - BC = 1$ ifodani tekshiring.

A-Formadan y-formaga o'tish uchun quyidagi formulalarni qo'llang.

$$\underline{Y}_{11} = \frac{\underline{D}}{\underline{B}} ; \quad \underline{Y}_{12} = \frac{-1}{\underline{B}} ; \quad \underline{Y}_{21} = \frac{+1}{\underline{B}} ; \quad \underline{Y}_{22} = \frac{-\underline{A}}{\underline{B}}$$

6,7-rasmlar uchun to'rtqutblikning "Y" formadagi tenglamasi

$$I_1 = \underline{Y}_{11}U_1 + \underline{Y}_{12}U_2$$

$$I_2 = \underline{Y}_{21}U_1 + \underline{Y}_{22}U_2$$

4. Ekvivalent to'rtqutblikning "Y"-formadagi parametrlari matritsasi:

$$[\underline{Y}] = \begin{bmatrix} \underline{Y}'_{11} & \underline{Y}'_{12} \\ \underline{Y}'_{21} & \underline{Y}'_{22} \end{bmatrix} + \begin{bmatrix} \underline{Y}''_{11} & \underline{Y}''_{12} \\ \underline{Y}''_{21} & \underline{Y}''_{22} \end{bmatrix} = \begin{bmatrix} \underline{Y}'_{11} + \underline{Y}''_{11} & \underline{Y}'_{12} + \underline{Y}''_{12} \\ \underline{Y}'_{21} + \underline{Y}''_{21} & \underline{Y}'_{22} + \underline{Y}''_{22} \end{bmatrix}$$

5. Ekvivalent to'rtqutblikning "A" formadagi parametrlari matritsasi:

$$[\underline{A}] = [\underline{A}'] + [\underline{A}''] = \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} + \begin{bmatrix} A'' & B'' \\ C'' & D'' \end{bmatrix} = \begin{bmatrix} A'A'' + B'C'' & A'B'' + B'D'' \\ C'A'' + D'C'' & C'B'' + D'D'' \end{bmatrix}$$

6. To'rtqutblikning A va Y-formadagi tenglamalari.

$$U_1 = \underline{A}U_2 + \underline{B}I_2$$

$$I_1 = \underline{C}U_2 + \underline{D}I_2 \quad (1)$$

$$I_1 = \underline{Y}_{11}U_1 + \underline{Y}_{12}U_2$$

$$I_2 = \underline{Y}_{21}U_1 + \underline{Y}_{22}U_2 \quad (2)$$

Salt yurish holatida ($I_2=0$):

$$U_1 = \underline{A}U_2$$

$$I_1 = \underline{C}U_2 \quad (3)$$

$$I_1 = \underline{Y}_{11}U_1 + \underline{Y}_{12}U_2$$

$$0 = \underline{Y}_{21}U_1 + \underline{Y}_{22}U_2 \quad (4)$$

(3),(4) tenglamalardan chastotaviy bog'liqlik.

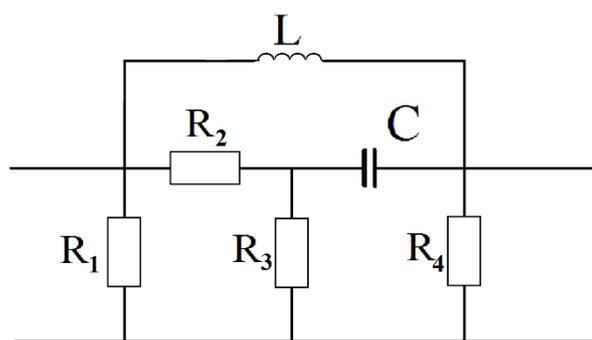
$$K(j\omega) = \frac{U_2(j\omega)}{U_1(j\omega)} = \frac{1}{A}$$

$$K(j\omega) = \frac{U_2(j\omega)}{U_1(j\omega)} = \frac{-Y_{21}}{Y_{22}} = \frac{Y_{12}}{Y_{22}}$$

7. Chastotaviy bog‘lanish grafigini qurish uchun chastotasi $\omega_1=0$ dan (o‘qituvchi ko‘rsatgan) ω chastotagacha oraliqni tanlash kerak.
8. Ekvivalent to‘rtqutblikning chiqish kuchlanishining o‘tish jarayonini hisoblash misolda keltirilgan, shuningdek shu misolda 4-7 bandlar ham o‘z ifodasini topgan.
9. Variantda berilgan chastota uchun xarakteristik qarshilik quyidagi ifoda bo‘yicha hisoblanadi:

$$Z_{1C} = \sqrt{\frac{A B}{C D}} \quad Z_{2C} = \sqrt{\frac{D B}{C A}}$$

Misol:



$$\begin{aligned} R_1 &= 1 \text{ kOm} \\ R_2 &= 2 \text{ kOm} \\ R_3 &= 3 \text{ kOm} \\ R_4 &= 4 \text{ kOm} \\ C &= 2000 \text{ nF} = 2 \cdot 10^{-9} \text{ F} \\ L &= 40 \text{ mGn} = 0.04 \text{ Gn} \end{aligned}$$

8-rasm.

8-rasm.Π – ko‘rinishdagi (R_1, L, R_4) va T – ko‘rinishdagi (R_2, C, R_3) to‘rtqutbliklar parallel ulangan.

Π – ko‘rinishdagi sxema uchun ($j\omega$ ni P ga almashtirish bilan) to‘rtqutblikning koeffitsiyentlari A va Y formada:

$$\underline{A}' = 1 + \underline{Y}_2' \underline{Z}_0' = 1 + \frac{j\omega L}{R_4} = \frac{R_4 + PL}{R_4}$$

$$\underline{B}' = \underline{Z}'_0 = j\omega L = pL$$

$$\underline{C}' = \underline{Y}'_1 + \underline{Y}'_2 + \underline{Y}'_1 \underline{Y}'_2 \underline{Z}'_0 = \frac{1}{R_4} + \frac{1}{R_1} + \frac{1}{R_1 R_4} j\omega L = \frac{R_1 + R_4 + pL}{R_1 R_4}$$

$$\underline{D}' = 1 + \underline{Y}'_1 \underline{Z}'_0 = 1 + \frac{R_1 + pL}{R_1}$$

$$\underline{Y}'_{11} = \frac{D'}{B'} = \boxed{\frac{R_1 + pL}{pLR_1}}$$

$$\underline{Y}'_{12} = -\frac{1}{B'} = \boxed{-\frac{1}{pL}}$$

$$\underline{Y}'_{21} = \frac{1}{B'} = \boxed{\frac{1}{pL}}$$

$$\underline{Y}'_{22} = -\frac{A'}{B'} = \boxed{\frac{R_4 + pL}{pLR_4}}$$

AD-BC=1 munosabat isbotlandi.

T – ko‘rinishidagi sxema uchun to‘rtqutblikning koeffitsiyentlari A va Y formalarda:

$$\underline{A}'' = 1 + \underline{Z}''_1 \underline{Y}''_0 = 1 + R_2 \frac{1}{R_3} = \boxed{\frac{R_3 + R_2}{R_3}}$$

$$\underline{B}'' = \underline{Z}''_1 + \underline{Z}''_2 + \underline{Z}''_1 \underline{Z}''_2 \underline{Y}''_0 = R_2 + \frac{1}{j\omega C} + R_2 \frac{1}{j\omega C} \frac{1}{R_3} = \boxed{\frac{R_2 R_3 pC + R_3 + R_2}{pCR_3}}$$

$$\underline{C}'' = \underline{Y}''_0 = \boxed{\frac{1}{R_3}}$$

$$\underline{D}'' = 1 + \underline{Z}''_2 \underline{Y}''_0 = 1 + \frac{1}{j\omega C} \frac{1}{R_3} = \boxed{\frac{1 + pCR_3}{pCR_3}}$$

$$\underline{Y}''_{11} = \frac{D''}{B''} = \frac{(1 + pCR_3)}{pCR_3} \frac{pCR_3}{(pCR_2 R_3 + R_3 + R_2)} = \boxed{\frac{1 + pCR_3}{pCR_2 R_3 + R_3 + R_2}}$$

$$\underline{Y}''_{12} = -\frac{1}{B''} = \boxed{-\frac{pCR_3}{pCR_2 R_3 + R_3 + R_2}}$$

$$\underline{Y''}_{21} = \frac{1}{B''} = \frac{pCR_3}{pCR_2R_3 + R_3 + R_2}$$

$$\underline{Y''}_{22} = -\frac{A''}{B''} = -\frac{(R_3 + R_2)pCR_3}{R_3(pCR_2R_3 + R_3 + R_2)} = \frac{(R_3 + R_2)pC}{pCR_2R_3 + R_3 + R_2}$$

Ekvivalent to'rtqutblik uchun matritsani Y – formada yozamiz.

$$[\underline{Y}] = [\underline{Y}'] + [\underline{Y}''] = \begin{bmatrix} \underline{Y}'_{11} & \underline{Y}'_{12} \\ \underline{Y}'_{21} & \underline{Y}'_{22} \end{bmatrix} + \begin{bmatrix} \underline{Y}''_{11} & \underline{Y}''_{12} \\ \underline{Y}''_{21} & \underline{Y}''_{22} \end{bmatrix} = \begin{bmatrix} \underline{Y}'_{11} + \underline{Y}''_{11} & \underline{Y}'_{12} + \underline{Y}''_{12} \\ \underline{Y}'_{21} + \underline{Y}''_{21} & \underline{Y}'_{22} + \underline{Y}''_{22} \end{bmatrix} = \begin{bmatrix} \underline{Y}_{11} & \underline{Y}_{12} \\ \underline{Y}_{21} & \underline{Y}_{22} \end{bmatrix}$$

Bu yerda

$$\underline{Y}_{11} = \underline{Y}'_{11} + \underline{Y}''_{11} = \frac{R_1 + pL}{pLR_1} + \frac{1 + pCR_3}{pCR_2R_3 + R_3 + R_2} = \frac{p^2LCR_2R_3 + p[CR_1R_2R_3 + L(R_2 + R_3)] + R_1(R_2 + R_3)}{p[pLCR_1R_2R_3 + LR_1(R_2 + R_3)]};$$

$$\underline{Y}_{12} = -\underline{Y}_{21} = \underline{Y}'_{12} + \underline{Y}''_{12} = -\frac{1}{pL} - \frac{pCR_3}{pCR_2R_3 + R_3 + R_2} = \frac{p^2LCR_3 + pCR_2R_3 + R_3 + R_2}{pL(pCR_2R_3 + R_3 + R_2)};$$

$$\begin{aligned} \underline{Y}_{22} &= \underline{Y}'_{22} + \underline{Y}''_{22} = -\frac{R_4 + pL}{pLR_4} - \frac{(R_3 + R_2)pC}{pCR_2R_3 + R_3 + R_2} \\ &= -\frac{p^2[LCR_2R_3 + LCR_4(R_3 + R_2)] + p[CR_2R_3R_4 + L(R_3 + R_2)] + R_4(R_3 + R_2)}{pLR_4(pCR_2R_3 + R_3 + R_2)} \end{aligned}$$

Kuchlanish bo'yicha operator uzatish koeffitsiyenti salt holatda.

$$\begin{aligned} K(p) &= \frac{U_2(p)}{U_1(p)} = \frac{Y_{12}(p)}{Y_{22}(p)} = \\ &= \frac{p^2LCR_3R_4 + pCR_2R_3R_4 + R_4(R_3 + R_2)}{p^2[LCR_2R_3 + LCR_4(R_3 + R_2)] + p[CR_2R_3R_4 + L(R_3 + R_2)] + R_4(R_3 + R_2)} \end{aligned}$$

Salt yurish holi uchun kuchlanish bo'yicha kompleks uzatish koeffitsiyentini operator uzatish koeffitsiyentidan P ni $j\omega$ ga almashtirib hosil qilish mumkin ($j^2 = -1$ ni nazarda tutib):

$$K(j\omega) = \frac{U_2(j\omega)}{U_1(j\omega)} = \frac{Y_{12}(j\omega)}{Y_{22}(j\omega)}$$

$$= \frac{[R_4(R_3 + R_2) - \omega^2 LCR_3R_4] + j\omega CR_2R_3R_4}{\{R_4(R_3 + R_2) - \omega^2[LCR_2R_3 + LCR_2R_3 + LCR_4(R_3 + R_4)]\} + j\omega[CR_2R_3R_4 + L(R_3 + R_2)]}$$

Demak,

$$K(j\omega) = \frac{(4 \cdot 10^3 \cdot 5 \cdot 10^3 - 4 \cdot 10^{-2} \cdot 2 \cdot 10^{-9} \cdot 12 \cdot 10^6 \cdot \omega^2) + j2 \cdot 10^{-9} \cdot 4 \cdot 10^3 \cdot 5 \cdot 10^3}{4 \cdot 10^3 \cdot 5 \cdot 10^3 - (4 \cdot 10^{-2} \cdot 2 \cdot 10^{-9} \cdot 6 \cdot 10^6 + 4 \cdot 10^{-2} \cdot 2 \cdot 10^{-9} \cdot 4 \cdot 10^3 \cdot 5 \cdot 10^3)\omega^2 + j(2 \cdot 10^{-9} \cdot 4 \cdot 10^3 \cdot 5 \cdot 10^3)\omega}$$

$$K(j\omega) = \frac{(2 \cdot 10^7 - 96 \cdot 10^{-5}\omega^2) + j48\omega}{(2 \cdot 10^7 - 208 \cdot 10^{-5}\omega^2) + j248\omega}$$

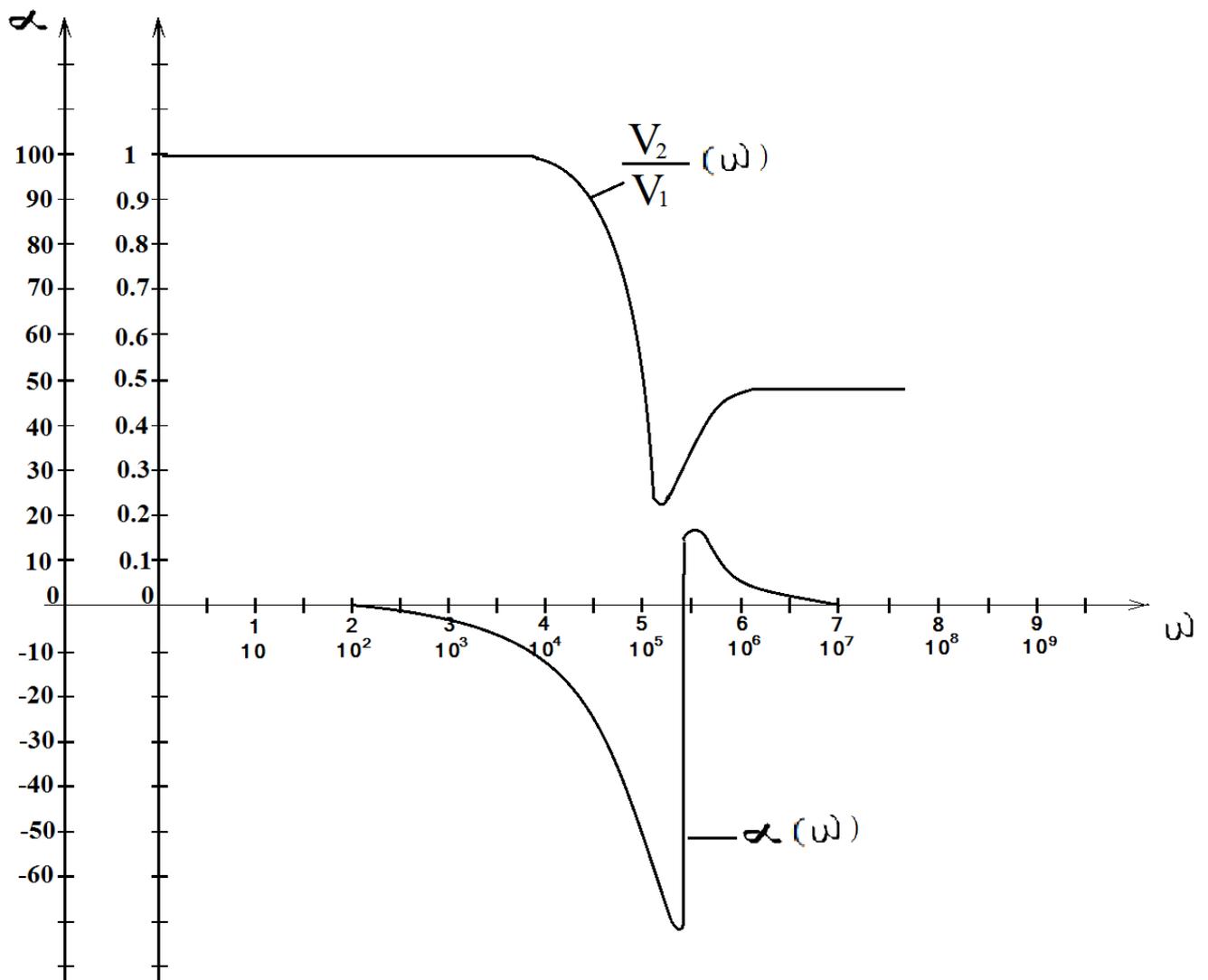
Quyidagi belgilanish kiritamiz:

$$\begin{aligned} a &= 2 \cdot 10^7 - 96 \cdot 10^{-5}\omega^2 & b &= 48\omega \\ c &= 2 \cdot 10^7 - 208 \cdot 10^{-5}\omega^2 & d &= 248\omega \end{aligned}$$

$$K(j\omega) = \frac{U_2(j\omega)}{U_1(j\omega)} = K(\omega)e^{j\alpha(\omega)}$$

Ifodaning hisobini jadval ko‘rinishida keltirish maqsadga muvofiq bo‘ladi.

ω	a	b	c	d	$K(\omega) = \frac{U_2}{U_1}(\omega)$	$\alpha(\omega) = \psi_{U_2} - \psi_{U_1}$
0	$2 \cdot 10^7$	0	$2 \cdot 10^7$		1	0
10	$2 \cdot 10^7$	480	$2 \cdot 10^7$	2480	1	$-5.729578 \cdot 10^{-3}$
100	19999990	4800	19999979	24800	0.99999979	$-5.729578 \cdot 10^{-2}$
1000	19999040	48000	19997920	248000	0.99998199	- 0.572988887
10000	19904000	480000	19792000	2480000	0.99814586	-0.57606245
$5 \cdot 10^4$	17600000	$240 \cdot 10^4$	14800000	$124 \cdot 10^5$	0.91997386	-32.192389
10^5	10400000	$48 \cdot 10^5$	-800000	$248 \cdot 10^5$	0.46162506	-67.072469
$1.5 \cdot 10^5$	-1600000	7200000	- 26800000	$372 \cdot 10^5$	0.160879991	-23.24131
$2 \cdot 10^5$	- 18400000	9600000	- 63200000	49600000	0.2583268	10.57237
$5 \cdot 10^5$	$-2.2 \cdot 10^8$	24000000	$-5 \cdot 10^8$	$1.24 \cdot 10^8$	0.4295658	7.70251
10^6	$-9.4 \cdot 10^8$	$48 \cdot 10^6$	- $2.06 \cdot 10^9$	$2.48 \cdot 10^8$	0.45362973	3.94151
10^7	- $9.598 \cdot 10^{10}$	$48 \cdot 10^7$	- $2.0798 \cdot 10^4$	$2.48 \cdot 10^9$	0.46145965	0.39664



9 – rasm

$K(\omega) = \frac{U_2}{U_1}(\omega)$ va $\alpha(\omega)$ ning grafigi 9-rasmda keltirilgan. $U_2(p)$ ning operator ko‘rinishdagi ifodasini (p) kuchlanishning operator ko‘rinishdagi ifodasi va uzatish koeffitsiyentining operatori orqali aniqlash mumkin (salt yurish holatda):

$$U_2(p) = U_1(p) \cdot K(p)$$

8-rasmning kirishiga o‘zgarmas kuchlanish ta‘sir etsin (1-1 qisqichlar)

$$U_1(t) = U_1 = 100 \text{ V}$$

$U_1(p)$ ning operator tasviri $U_1(p) = \frac{100}{p}$

$$(U_1(p) = \int_0^{\infty} U_1 e^{-pt} dt \quad \text{tasviri})$$

$U_2(p)$ ning operator tasviri

$$\begin{aligned} U_2(p) &= \frac{100}{p} \cdot \frac{(96 \cdot 10^{-5} p^2 + 48p + 2 \cdot 10^7)}{(208 \cdot 10^5 p^2 + 248p + 2 \cdot 10^7)} = \frac{46.153846 p^2 + 2.3076923 \cdot 10^6 \cdot p + 9.6153846 \cdot 10^{11}}{p(p^2 + 119230.76p + 9.6153846 \cdot 10^9)} = \\ &= \frac{46.153846 p^2 + 2.3076923 \cdot 10^6 p + 9.6153846 \cdot 10^{11}}{(p - p_1)(p - p_2)(p - p_3)} \end{aligned}$$

Bu yerda,

$$P_1=0, \quad P_2=-59615.38+77854.936$$

$$P_3= -59615.38-77854.936$$

Qiymatlar quyidagi ifodadan topilgan.

$$P(P^2 + 119230.76p + 9.6153846 \cdot 10^9) = 0$$

$U_2(t)$ originali bu, 2-2 qisqichlarda salt yurish rejimida 1-1 qisqichlarga $U_1(t)$ kuchlanish to'satdan ta'sir etganda o'tkinchi jarayon kuchlanishini bildiradi. P_1 va P_2 ildizlar qo'sh bo'lgani uchun, faqat birgina qo'sh ildizni (albatta P_1 ni) tasvirini haqiqiy qismini ikkilantirib (yoyish teoremasi yoki qoldiqni hisoblash teoremasiga asosan) olish mumkin. Keyinchalik P_1 va P_2 ildizlar ishlatiladi.

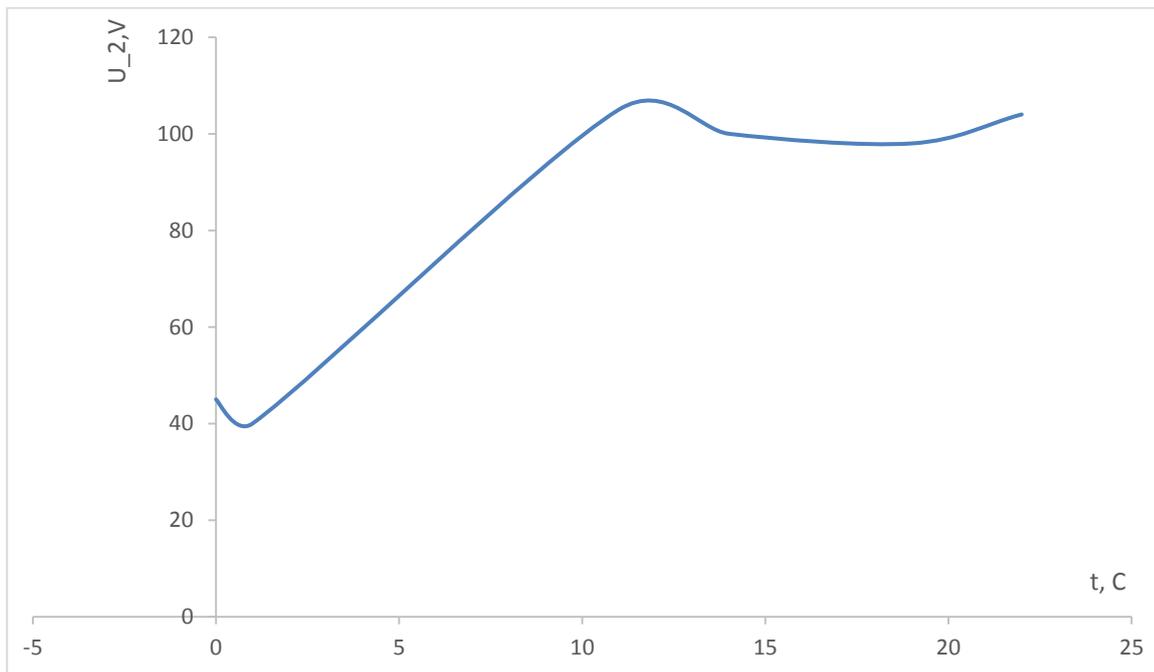
$$\begin{aligned} U_2(t) &= \left[\frac{46.153846 p_1^2 + 2.3076923 \cdot 10^6 \cdot p_1 + 9.61533846 \cdot 10^{11}}{1 \cdot (p_1 - p_2)(p_1 - p_3)} \right] e^{p_1 t} + \\ &+ 2Re \left[\frac{46.153846 p_2^2 + 2.3076923 \cdot 10^6 \cdot p_2 + 9.61533846 \cdot 10^{11}}{(p_2 - p_1) \cdot 1(p_2 - p_3)} e^{p_2 t} \right] = \\ &= \frac{9.6153846 \cdot 10^{11}}{[0 + 59615.38 - j77854.936] \cdot [0 + 59615.38 + j77854.936]} e^{0t} + \\ &+ 2Re \left[\frac{46.153846 \cdot (-59615.38 + j77854.936)^2 + 2.3076923 \cdot 10^6 (-59615.38 + j77854.936) + 9.6153846 \cdot 10^{11}}{(-59615.38 + j77854.936 - 0) \cdot (-59615.38 + j77854.936 + 59615.38 + j77854.936)} \right] e^{(-59615.38 + j77854.936)t} = \\ &= \frac{9.6153846 \cdot 10^{11}}{(59615.38)^2 + (77854.936)^2} \cdot 1 \\ &\quad + 2Re \left[(-26.923077 + j41.136278) e^{-59615.38t} \cdot e^{j77854.936t} \right] = \\ &= \frac{9.6153846 \cdot 10^{11}}{9.6153846 \cdot 10^9} + 2Re \left[49.163456 e^{j123.20415^\circ} \cdot e^{-59615.38t} \cdot e^{j77854.936t} \right] = \end{aligned}$$

$$\begin{aligned}
&= 100 + 2\operatorname{Re}[49.163456e^{-5961.38t} \cdot e^{j(77854.936t+123.20415^\circ)}] = \\
&= 100 + 98.326912e^{-5961.38t}\cos(77854.936t + 123.20415^\circ)
\end{aligned}$$

Demak, $U_2(t)$ ni quyidagicha yozish mumkin

$$U_2(t) = 100 - 98.326912e^{-5961.38t}\sin(77854.936t + 33.204^\circ)$$

$U_2(t)$ 10- rasmda keltirilgan



10-rasm.

8-rasm kuchlanish $U_1(t) = U_{m1}\sin\omega t$ bolsa, bu yerda $U_{m1} = 100\text{ V}$
 $\omega = 10^5\text{ s}^{-1}$

$U_1(p)$ ni operator tasviri

$$U_1(p) = U_{m1} = \frac{\omega}{p^2 + \omega^2} = 100 \cdot \frac{10^5}{p^2 + (10^5)^2} = \frac{10^7}{(p - j10^5)(p + j10^5)}$$

$U_2(p)$ ifodaning operatori tasviri

$$U_2(p) = \frac{10^7}{(p - j10^5)(p + j10^5)} \cdot \frac{66 \cdot 10^5 p^2 + 48p + 2 \cdot 10^7}{(208 \cdot 10^{-5} p^2 + 248p + 2 \cdot 10^7)} =$$

$$= \frac{4615384.6p^2 + 2.3076923 \cdot 10^{11}p + 9.6153846 \cdot 10^{16}}{(p - j10^5)(p + j10^5)(p^2 + 119230.75p + 9.6153846 \cdot 10^9)}$$

$$p^2 + 119230.76p + 9.6153846 \cdot 10^9 = 0$$

Ifodaning ildizlarini aniqlaymiz.

$$p_{1,2} = -\frac{119230.76}{2} \pm \sqrt{\left(\frac{119230.76}{2}\right)^2 - 9.6153846 \cdot 10^9}$$

$$= -59615 \pm j77854.936$$

$U_2(p)$ ni quyidagi ko'rinishda faraz qilaylik.

$$U_2(p) = \frac{4615384.6p^2 + 2.3076923 \cdot 10^{11}p + 9.6153846 \cdot 10^{16}}{(p - p_1)(p - p_2)(p - p_3)(p - p_4)}$$

Bu yerda

$$p_1 = j10^5; \quad p_2 = -j10^5; \quad p_5 = -59615.38 + j77854.936$$

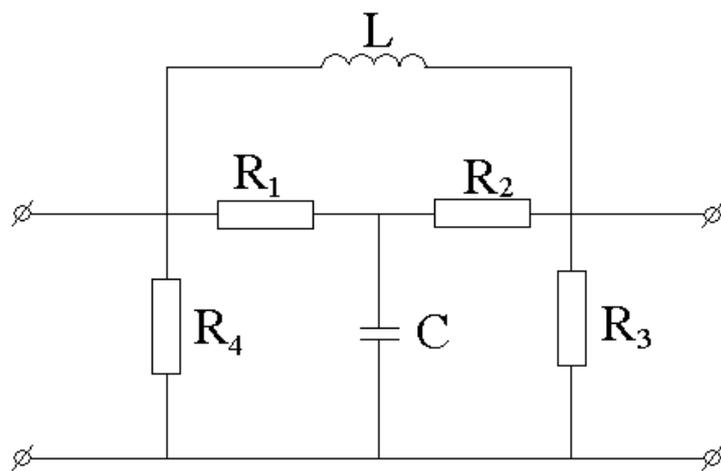
$$p_4 = -59615.38 - j77854.936$$

$U_2(t)$ originali bu 2-2 qisqichlarda salt yurish rejimida 1-1 qisqichlarga $U_1(t)$ kuchlanish to'satdan ta'sir etganda o'tkinchi jarayon kuchlanishni bildiradi. P_1 va P_2 , P_3 , P_4 ildizlar qo'sh bo'lgani uchun, faqat birgina qo'sh ildizni tasvirini haqiqiy qismini ikkilantirib (yoyish teoremasi yoki qoldiqni hisoblash originalini olish mumkin).

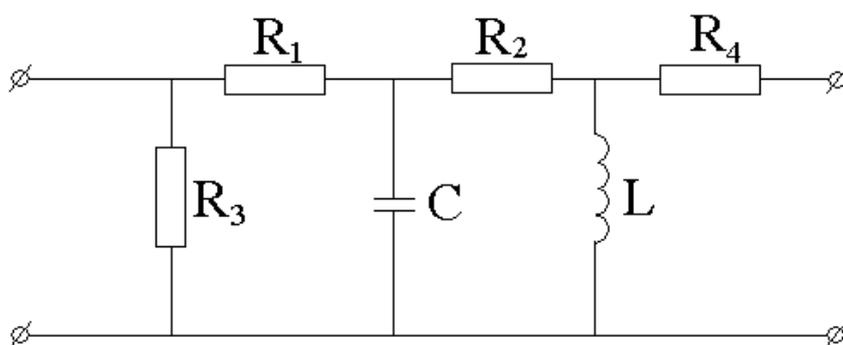
Keyinchalik P_1 va P_3 ildizlar ishlatiladi.

Berilganlar jadvali.

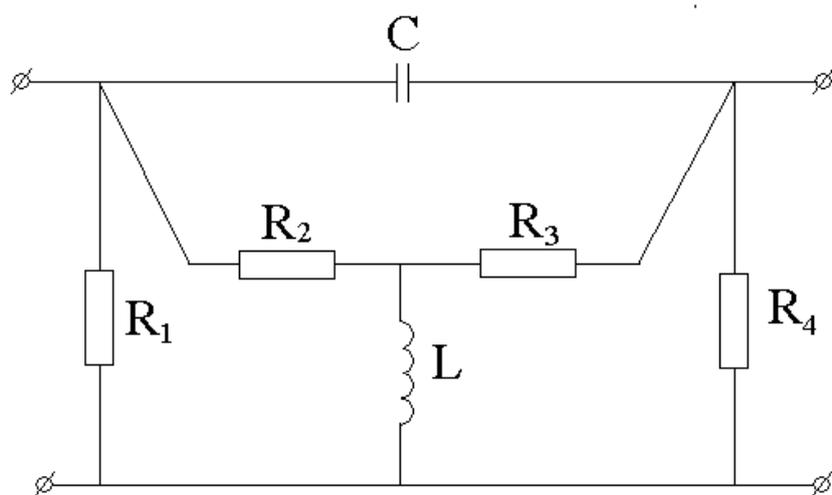
Variant №	R₁	R₂	R₃	R₄	C	L
	k Om				p F	m Gn
1	3	4	2	1	1000	20
2	1	2	1	3	2000	30
3	2	1	3	2	1500	40
4	4	2	1	3	3000	20
5	3	2	3	2	2000	40
6	5	3	4	2	4000	30
7	4	5	3	4	3500	25
8	3	4	2	2	2500	35
9	5	4	2	3	1500	20
10	4	5	4	4	2000	35
11	5	3	5	3	1000	20
12	4	3	2	1	1500	40
13	1	2	3	4	2000	30
14	3	4	2	1	1500	30
15	4	5	2	2	2000	20
16	3	4	5	6	3000	40
17	1	2	3	4	2000	25
18	2	3	2	3	2000	30



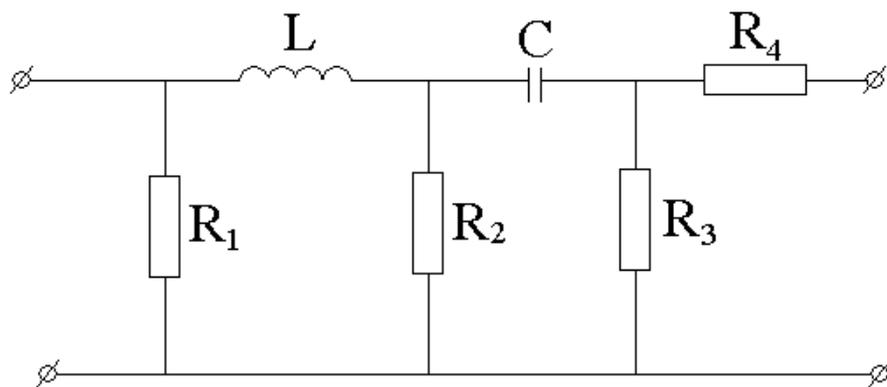
№ 1



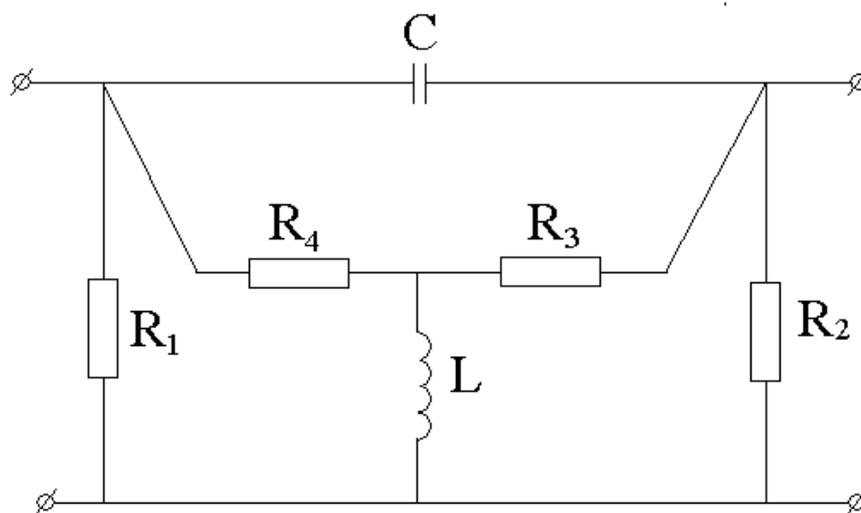
№ 2



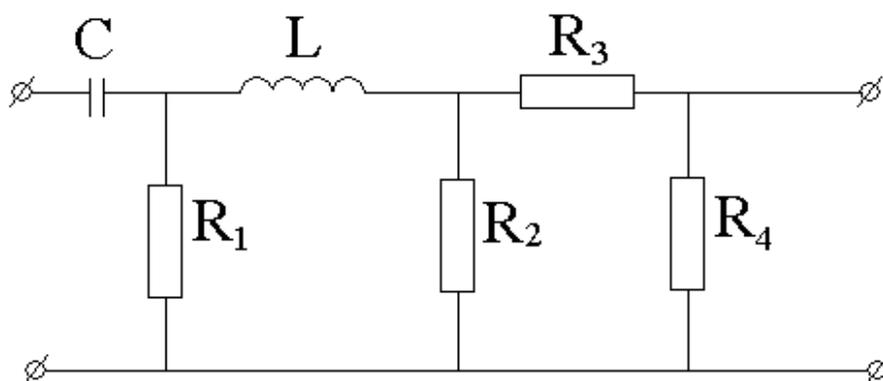
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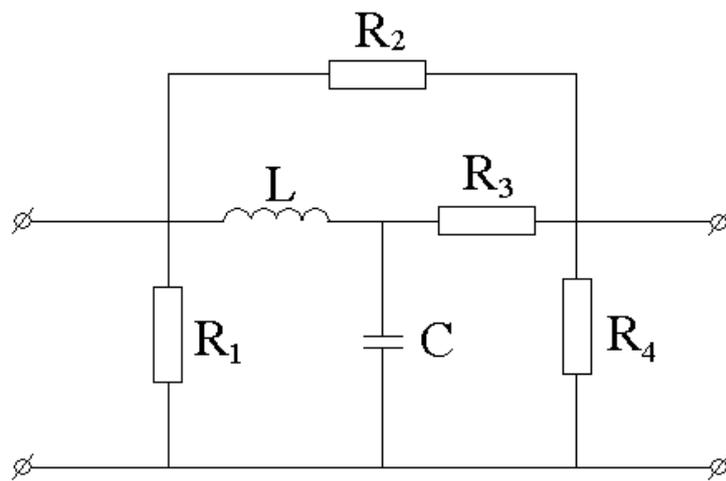
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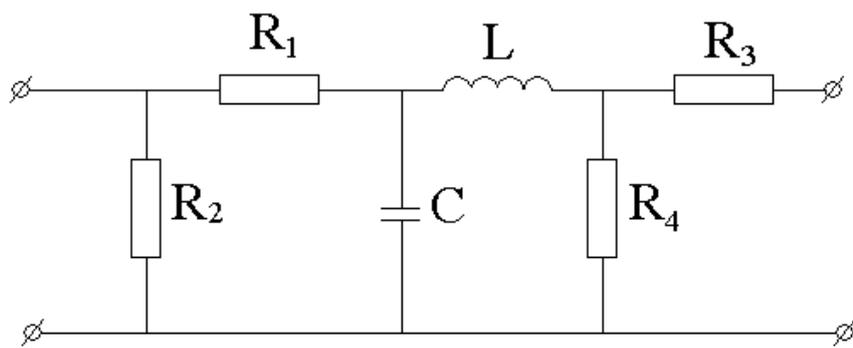
№ 5



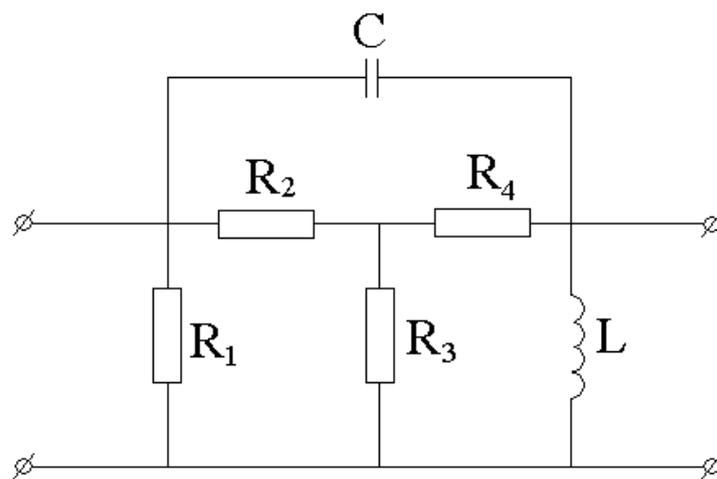
№ 6



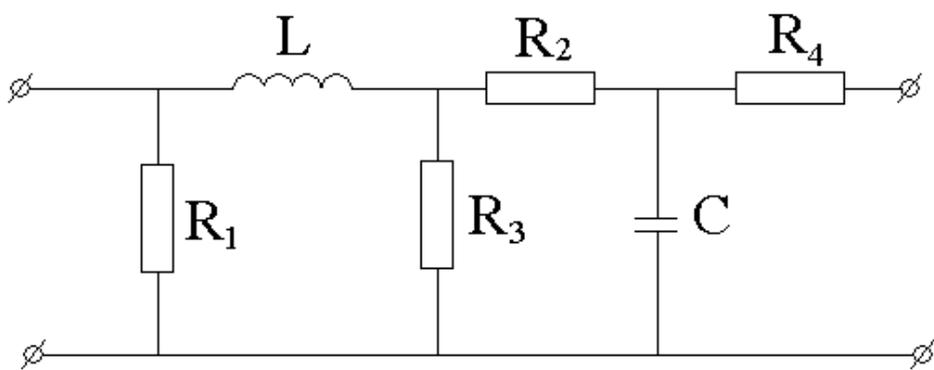
№ 7



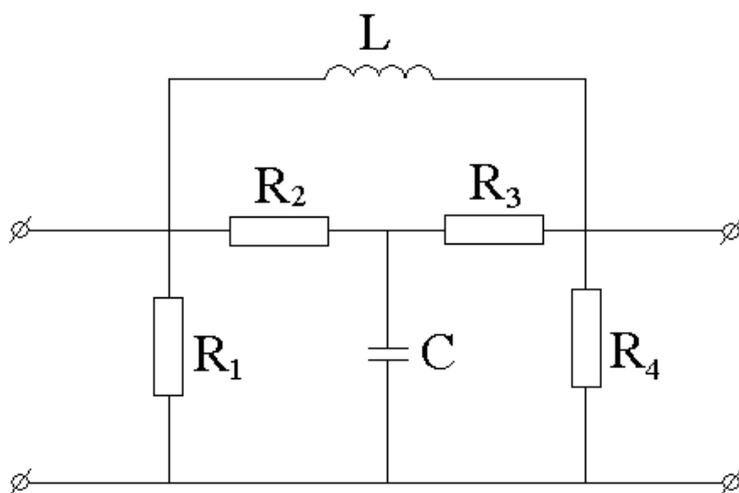
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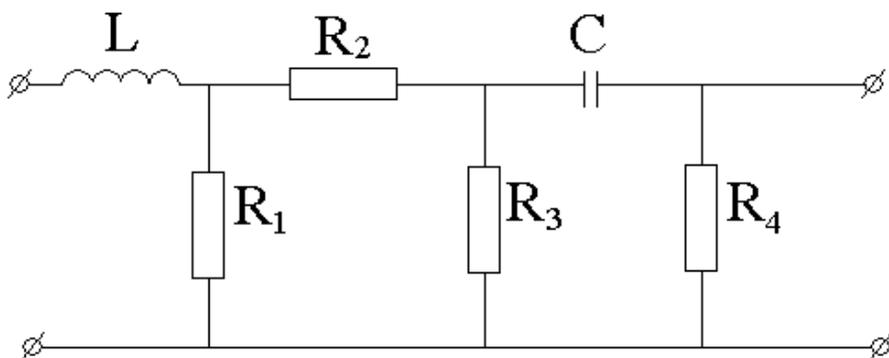
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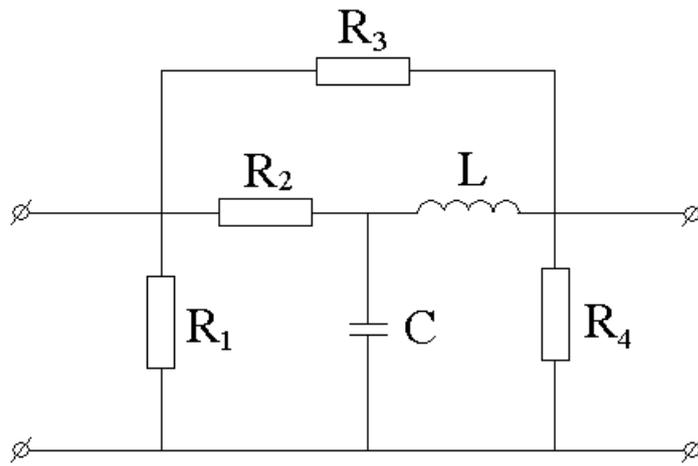
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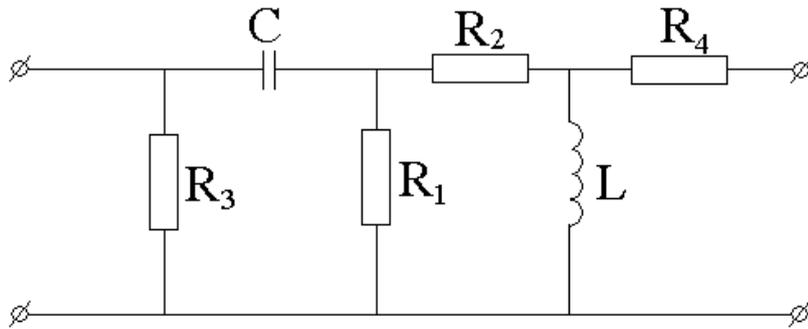
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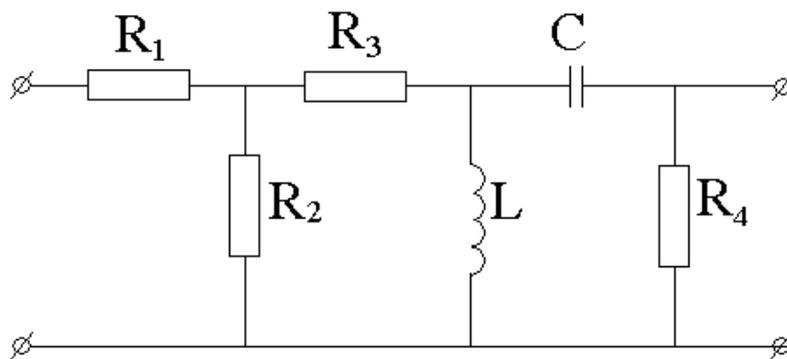
№ 12



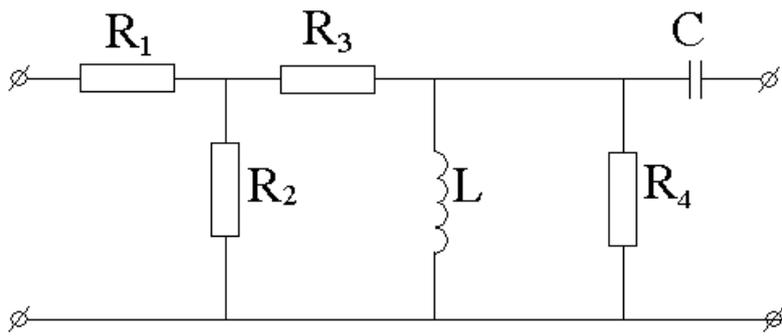
№ 13



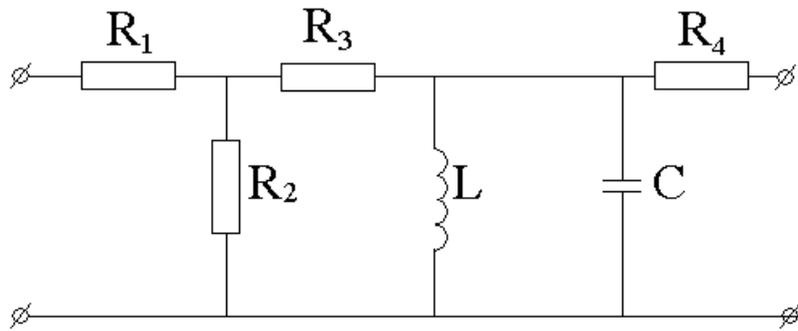
№ 14



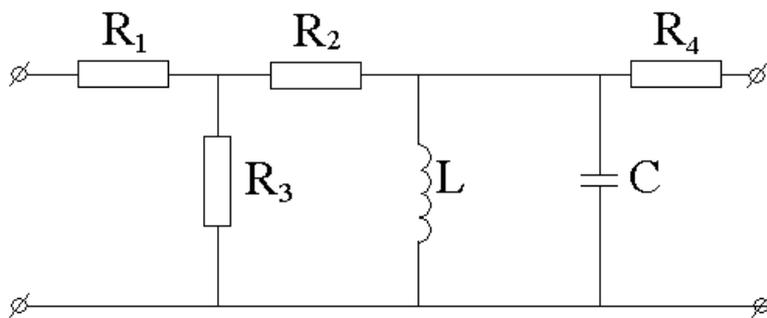
№ 15



№ 16

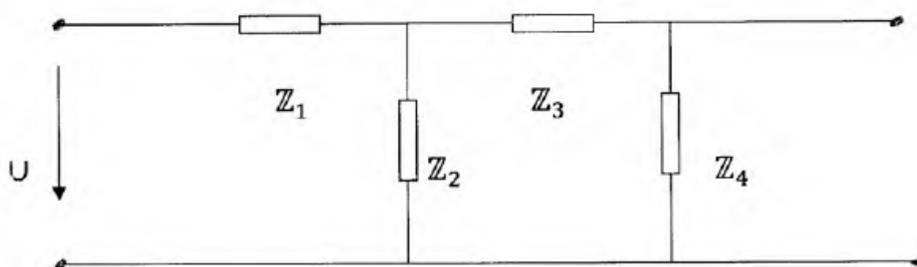


№ 17



№ 18

II. Passiv to‘rtqutblikni simvolik usulda hisoblash na‘munasi



11-rasm.

$$Z_1 = 3 - j5 \quad [\Omega]$$

$$U_1 = 90 \quad [V]$$

$$Z_2 = 2 + j3 \quad [\Omega]$$

$$\varphi_1 = 20^\circ$$

$$Z_3 = 1 + j2 \quad [\Omega]$$

$$Z_4 = 4 + j2 \quad [\Omega]$$

Variant

Berilgan elektr zanjir (to‘rtqutblik) uchun ko‘rsatilgan boshlang‘ich ma‘lumotlarga asoslanib, quyidagi topshiriq bajarilsin.

1: [A] matritsani aniqlang, $AD - BC = 1$ shartini tekshiring.

2: Passiv 4 qutblikning “T” va “II” ekvivalent sxemalarining parametrlarini aniqlang.

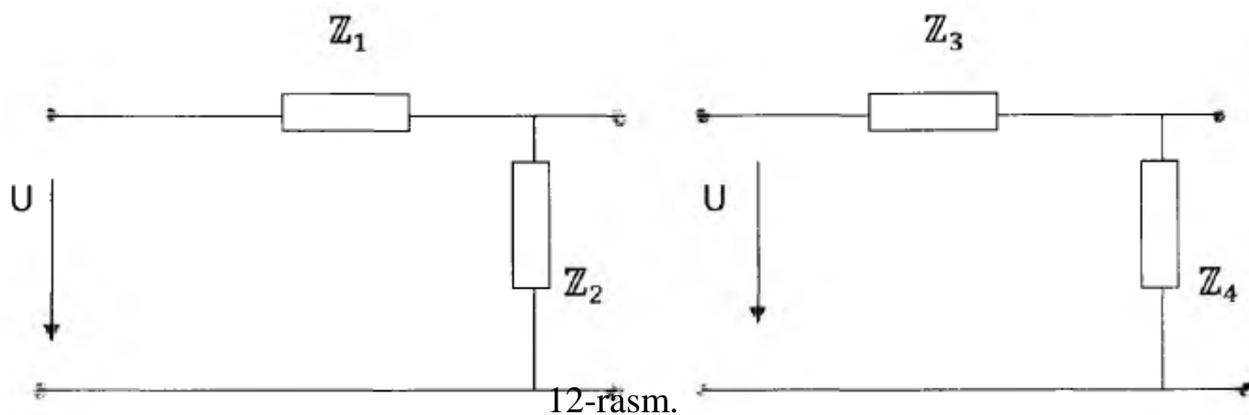
3: Passiv 4 qutblikning xarakteristik parametrlarini aniqlang.

4: $Z_H = Z_{c2}$ deb olib, kirishdagi va chiqishdagi tok kuchlari va kuchlanishlarini aniqlang. Tok kuchi bo‘yicha va kuchlanish bo‘yicha kuchaytirish koeffitsiyentini hisoblang.

5: Tok va kuchlanishlarning kompleks ko‘rinishidagi vektor diagrammasini quring

1-Topshiriq

Berilgan sxemani 2 ta ‘T’ ko‘rinishdagi sxemalarga bo‘lib olamiz



bu yerda [A[†]]

$$A_1 = 1 + \frac{Z_1}{Z_2} = 1 + \frac{3-j5}{2+j3} = 1 + \frac{5.83 * e^{-j59.03}}{3.6 * e^{j56.03}} = 1 + 1.62 * e^{-j115.33} = 1 + 1.62 * \cos(115.33) - j * 1.62 \sin(115.33) = 1 - 0.69 - j * 1.46 = 1.49 * e^{-j78.11}$$

$$B_1 = Z_1 = 3 - j * 5 = 5.83 * e^{-j59.03}$$

$$C_1 = \frac{1}{Z_2} = \frac{1}{2 + j3} = \frac{1}{3.6 * e^{j56.3}} = 0.278 * e^{-j56.3}$$

$$D_1 = 1$$

[A^{††}] uchun

$$A_2 = 1 + \frac{Z_3}{Z_4} = 1 + \frac{1+j2}{4+j2} = 1 + \frac{\sqrt{5}e^{j63.43}}{\sqrt{20}e^{j26.56}} = 1 + 0.5e^{j37.27} = 1.39999 + j0.3 = 1.43e^{j12.09}$$

$$B_2 = Z_3 = 1 + j2 = \sqrt{5}e^{j\arctan 2} = 2.24e^{j63.43}$$

$$C_2 = \frac{1}{Z_4} = \frac{1}{4+j2} = \frac{1}{\sqrt{20}e^{j\arctan(0.5)}} = \frac{1}{4.47e^{j26.56}} = 0.2237e^{-j26.56}$$

$$D_2 = 1$$

Tenglikni tekshirib ko'ramiz

$$A_1 D_1 - B_1 C_1 = 1$$

$$1(0.31 - j1.46) - 5.83e^{-j59.04} * 0.278e^{-j56.3} = 0.31 - j1.46 - 1.62074e^{-j115.34} =$$

$$= 0.31 - j1.46 + 0.69366 + 1.4604 = 1.004 + j0.0004$$

$$A_2 D_2 - B_2 C_2 = 1$$

$$1(1.3999 + j0.3) - 2.24e^{j63.43} * 0.2237e^{-j26.56} = 1.3999 + j0.3 - 0.501e^{j36.87} =$$

$$= 1.3999 + j0.3 - 0.501\cos(36.87) - j0.501\sin(36.87) = 1.3999 + j0.3 - 0.39979 -$$

$$j0.3004007 = 1.0002 - j0.0004$$

[A] matritsa quyidagi ifodaga teng bo'ladi

$$[A] = A^1 * A^{11} = \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} * \begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} A_1 * A_2 + B_1 * C_2 & A_1 * B_2 + D_2 * B_1 \\ A_2 * C_1 + D_1 * C_2 & B_2 * C_1 + D_1 * D_2 \end{bmatrix}$$

$$A_{\text{ЭKB}} = A_1 * A_2 + B_1 * C_2$$

$$B_{\text{ЭKB}} = A_1 * B_2 + D_2 * B_1$$

$$C_{\text{ЭKB}} = A_2 * C_1 + D_1 * C_2$$

$$D_{\text{ЭKB}} = A_2 * C_1 + D_1 * C_2$$

$$A = \begin{vmatrix} 1.49 * e^{-j78.11} & 5.83 * e^{-j59.03} \\ 0.278 * e^{-j56.3} & 1 \end{vmatrix} * \begin{vmatrix} 1.43 * e^{j12.09} & 2.24 * e^{j63.43} \\ 0.2237 * e^{-j26.56} & 1 \end{vmatrix} =$$

$$= \begin{vmatrix} 2.1307 * e^{-j66.02} + 1.3 * e^{-j85.59} & 3.34 * e^{-j14.68} + 5.83 * e^{-j59.03} \\ 0.397 * e^{-j44.21} + 0.2237 * e^{-j26.56} & 0.623 * e^{j7.13} + 1 \end{vmatrix} =$$

$$= \begin{vmatrix} 0.8659 - j1.9468 + 0.0998 - j1.296 & 3.23 - j0.846 + 3 - j4.9988 \\ 0.28456 - j0.2768 + 0.2 - j0.1 & 0.618 + j0.077 + 1 \end{vmatrix} =$$

$$= \begin{vmatrix} 0.9658 - j3.2428 & 6.23 - j5.8448 \\ 0.48456 - j0.3768 & 1.618 + j0.077 \end{vmatrix}$$

$$A_{\text{ЭKB}} = 0.9658 - j3.2428 = 3.395e^{-j73.413}$$

$$B_{\text{ЭKB}} = 6.23 - j5.8448 = 8.54e^{-j43.17}$$

$$C_{\text{ЭKB}} = 0.48456 - j0.3768 = 0.614e^{-j38.27}$$

$$D_{\text{ЭKB}} = 1.618 + j0.077 = 1.62e^{j3.13}$$

$$A_{\text{ЭKB}} * D_{\text{ЭKB}} - B_{\text{ЭKB}} * C_{\text{ЭKB}} = 1$$

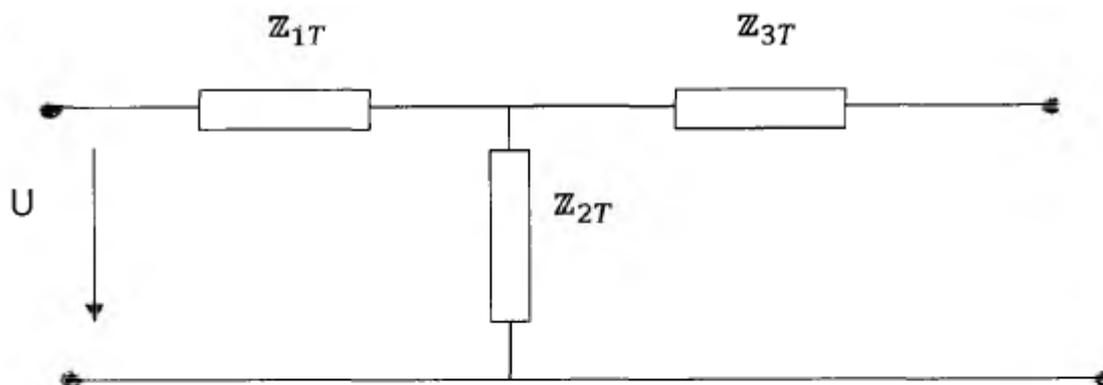
$$(0.9658 - j3.2428)(1.61 + j0.077) - (6.23 - j5.8448)(0.48456 - j0.3768) = 1$$

$$1.5549 + j0.0544 - j5.2209 + 0.2497 -$$

$$3.0068 + j2.3475 + j2.8321 + 2.2023 = 1.0001 + j0.00031 \approx 1$$

2- topshiriq

“T” sxemaning ekvivalent parametrlarini aniqlaymiz



13-rasm.

$$A_{\text{ЭKB}} = 0.9658 - j3.2428 = 3.4e^{-j73.413}$$

$$B_{\text{ЭKB}} = 6.23 - j5.8448 = 8.54e^{-j43.17}$$

$$C_{\text{ЭKB}} = 0.48456 - j0.3768 = 0.614e^{-j38.27}$$

$$D_{\text{ЭKB}} = 1.618 + j0.077 = 1.62e^{j3.13}$$

"T" ko'rinishdagi sxemaning kirish qarshiligi

$$Z_{1T} = \frac{A_{\text{ЭKB}} - 1}{C_{\text{ЭKB}}} = \frac{0.9658 - j3.2428 - 1}{0.6138e^{-j37.867}} = \frac{-0.0342 - j3.2428}{0.6138e^{-j37.867}} = -\frac{3.25e^{j89.458}}{0.6138e^{-j37.867}} = -5.295e^{j127.325}$$

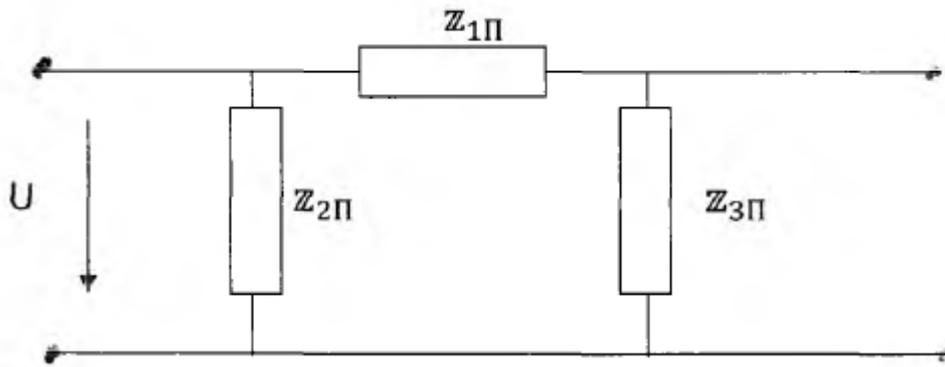
To'la qarshiligi

$$Z_{2T} = \frac{D_{\text{ЭKB}} - 1}{C_{\text{ЭKB}}} = \frac{1.618 + j0.077 - 1}{0.6138e^{-j37.867}} = \frac{0.618 + j0.077}{0.6138e^{-j37.867}} = \frac{0.62e^{j7.125}}{0.6138e^{-j37.867}} = 1.01e^{j45.3}$$

Chiqish qarshiligi

$$Z_{3T} = \frac{1}{C_{\text{ЭKB}}} = \frac{1}{0.6138e^{-j37.867}} = 1.63e^{j38.26}$$

“Π” sxemaning ekvivalent parametrlarini topamiz



14-rasm.

"Π" ko'rinisdagi sxemaning kirish qarshiligi

$$Z_{1\Pi} = B_{\text{ЭКВ}} = 8.54e^{-j43,17}$$

To'la qarshiligi

$$Z_{2\Pi} = \frac{B_{\text{ЭКВ}}}{D_{\text{ЭКВ}-1}} = \frac{8,54e^{-j43,17}}{1,618+j0,077-1} = \frac{8,54e^{-j43,17}}{0,618+j0,077} = \frac{8,54e^{-j43,17}}{0,62e^{j7,125}} = 13,77e^{-j50,3}$$

Chiqish qarshiligi

$$Z_{3\Pi} = \frac{C_{\text{ЭКВ}}}{D_{\text{ЭКВ}-1}} = \frac{0,6138e^{-j37,867}}{1,618+j0,077-1} = \frac{0,6138e^{-j37,867}}{0,618+j0,077} = \frac{0,6138e^{-j37,867}}{0,62e^{j7,125}} = 0,99e^{-j45,12}$$

3-topshiriq

Passiv 4 qutblikning xarakteristik parametrlarini aniqlaymiz.

Z_{c1} va Z_{c2} lar kirish va chiqishdagi xarakteristik qarshiliklari,

γ -4 qutblikning uzatish koeffitsiyenti

bu yerda Z_{c1} salt ulash rejimining kirish qarshiligi

$$Z_{C1} = \sqrt{\frac{A_{\text{ЭКВ}} * B_{\text{ЭКВ}}}{C_{\text{ЭКВ}} * D_{\text{ЭКВ}}}} = \sqrt{\frac{3,4e^{-j73,31} * 8,54e^{-j43,17}}{0,614e^{-j38,27} * 1,62e^{j3,13}}} = \sqrt{\frac{29,036e^{-j116,48}}{0,994e^{-j35,1424}}} = 5,4e^{-j41,16}$$

Z_{C2} salt ulash rejimining chiqish qarshiligi

$$Z_{C2} = \sqrt{\frac{D_{\text{ЭКВ}} * B_{\text{ЭКВ}}}{C_{\text{ЭКВ}} * A_{\text{ЭКВ}}}} = \sqrt{\frac{1,62e^{j3,13} * 8,54e^{-j43,17}}{0,614e^{-j38,27} * 3,4e^{-j73,413}}} = \sqrt{\frac{13,83e^{-j40,04}}{2,087e^{-j111,177}}} = 2,57e^{j35,3658}$$

$$\gamma = \ln[\sqrt{A_{\text{ЭКВ}} * D_{\text{ЭКВ}}} + \sqrt{B_{\text{ЭКВ}} * C_{\text{ЭКВ}}}] \quad \gamma = A + Bj$$

$$e^{\gamma} = \sqrt{A_{\text{ЭКВ}} * D_{\text{ЭКВ}}} + \sqrt{B_{\text{ЭКВ}} * C_{\text{ЭКВ}}}$$

$$e^A * e^{Bj} = \sqrt{3,4e^{-j73,31} * 1,62e^{j3,13}} + \sqrt{8,54e^{-j43,17} * 0,614e^{-j38,27}} =$$

$$= 2,348e^{-j35,3} + 2,289e^{-j40,5} = 1,916 - j1,3566 + 1,74 - j1,4866 = 3,656 - j2,8432 =$$

$$= 4,63e^{-j38,27}$$

$$e^A = 4,63$$

$$e^{Bj} = e^{-j38,27}$$

$$B = -38,27 = \frac{\pi}{180} * 38,27 = -0,6676$$

$$A = \ln(4,63) = 1,53256$$

$$\gamma = A + Bj = 1,53256 - 0,6676j$$

4 -topshiriq

$$U_1 = \left(A_{\text{ЭКВ}} + B_{\text{ЭКВ}} \cdot \frac{1}{Z_{C2}} \right) U_2 \Rightarrow U_2 = \frac{U_1 * Z_{C2}}{A_{\text{ЭКВ}} * Z_{C2} + B_{\text{ЭКВ}}}$$

$$U_1 = 90e^{j20}$$

$$Z_{C2} = 2,57e^{j35,3658}$$

$$A_{\text{ЭКВ}} = 3,4e^{-j73,31}$$

$$B_{\text{ЭКВ}} = 8,54e^{-j43,17}$$

$$U_2 = \frac{U_1 * Z_{C_2}}{A_{\text{ЭKB}} Z_{C_2} + B_{\text{ЭKB}}} = \frac{90e^{j20} * 2,57e^{j35,3658}}{3,4e^{-j73,31} * 2,57e^{j35,3658} + 8,54e^{-j43,17}} = \frac{231,3e^{j55,365}}{8,738e^{-j38,34} + 8,54e^{-j43,17}}$$

$$= \frac{231,3e^{j55,365}}{6,89 - j5,37 + 6,228 - j5,843} = \frac{231,3e^{j55,365}}{13,118 - j11,213} = \frac{231,3e^{j55,365}}{17,26e^{j40,5}} = 13,4e^{j96,26}$$

$$I_2 = \frac{U_1}{A_{\text{ЭKB}} Z_{C_2} + B_{\text{ЭKB}}} = \frac{90e^{j20}}{3,4e^{-j73,31} * 2,57e^{j35,3658} + 8,54e^{-j43,17}} = \frac{90e^{j20}}{8,738e^{-j38,34} + 8,54e^{-j43,17}}$$

$$= \frac{90e^{j20}}{6,89 - j5,37 + 6,228 - j5,843} = \frac{90e^{j20}}{17,26e^{j40,5}} = 5,214e^{j60,5}$$

$$I_1 = (C_{\text{ЭKB}} * Z_{C_2} + D_{\text{ЭKB}}) I_2 = (0,614e^{-j38,27} * 2,57e^{j35,3658} + 1,62e^{j3,13}) 5,214e^{j60,5}$$

$$= (1,577e^{-j2,5} + 1,6198e^{3,1246}) 5,214e^{j60,5} = 1,575 - j0,0688 + 1,61797 + j0,076998 =$$

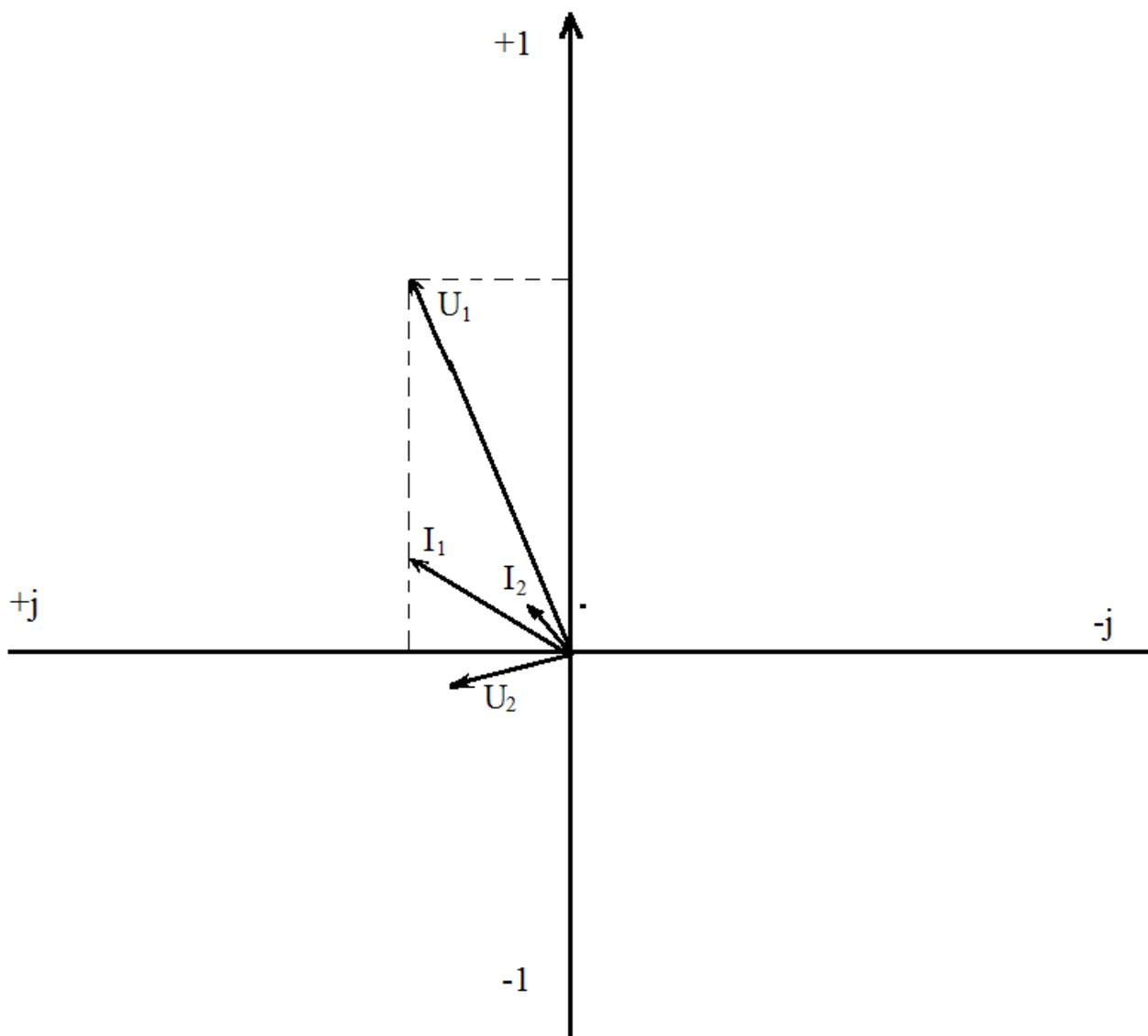
$$= 3,193 + j0,0082 = 3,19e^{j0,15} * 5,214e^{j60,5} = 16,633e^{j61,15}$$

Endi tok kuchi va kuchlanish bo'yicha kuchaytirish koefitsiyentlarini topamiz

$$K_u = \frac{U_2}{U_1} = \frac{13,4e^{j96,26}}{90e^{j20}} = 0,15e^{j76,266}$$

$$K_I = \frac{I_2}{I_1} = \frac{5,214e^{j60,5}}{16,633e^{j61,15}} = 0,3135e^{-j0,15}$$

Quyida tok va kuchlanishlarning kompleks tekislikdagi vektor diagrammasini keltiramiz:



15-rasm

Masshtab

$m_U: 1\text{sm/V}$

$m_I: 1\text{sm/A}$

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Muharrir: Siddikova K.