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

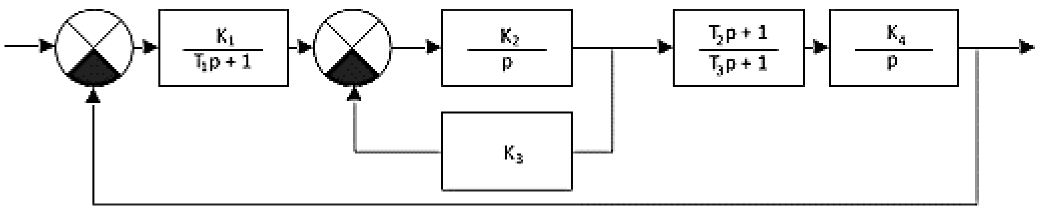
ISLOM KARIMOV NOMIDAGI TOSHKENT DAVLAT TEXNIKA UNIVERSITETI

BOSHQARISH NAZARIYASI

fanidan

amaliy mashg‘ulotlar bajarish uchun

USLUBIY KO‘RSATMALAR



Toshkent – 2018

Tuzuvchilar: Sevinov J.U., Yakubova N.S.

«Boshqarish nazariyasi» fanidan amaliy mashg‘ulotlar bajarish uchun uslubiy ko‘rsatmalar. – Toshkent, ToshDTU: 2018. 56 bet.

Uslubiy ko‘rsatmalarda «Boshqarish nazariyasi» fani bo‘yicha amaliy mashg‘ulotlar bajarishga doir ko‘rsatmalar hamda boshqarish tizimlarini tekshirishga oid misollar keltirilgan.

Ushbu uslubiy ko‘rsatmalar oliy o‘quv yurtlarining 5311000 - «Texnologik jarayonlar va ishlab chiqarishni avtomatlashtirish va boshqarish (kimyo, neft-kimyo va oziq-ovqat sanoati) yo‘nalishi bakalavr talabalari uchun mo‘ljallangan.

Islom Karimov nomidagi ToshDTU ilmiy-uslubiy kengashining qaroriga muvofiq chop etildi.

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KIRISH

Jamiyat taraqqiy etgan sari boshqariladigan obyektlar soni ko‘payib, boshqarish muammolari murakkablashib boradi. Murakkab mashina va dastgohlar, korxona va muassasalar, hatto odamning o‘zi ham, jamiyat ham boshqarish obyekti hisoblanadi. Bunday obyektlarni kibernetikada murakkab dinamik (harakatdagi) tizimlar deb ataladi. Ana shunday tizimlarni boshqarishga oid umumiy qonunlarni o‘rganish, odam qo‘liga boshqarish sirlari kalitini topib berish hozirgi kunda eng dolzarb masalalardan biriga aylandi. Natijada boshqarish fani, ya‘ni kibernetika paydo bo‘ldi.

Kadrlar tayyorlash milliy dasturi “Ta‘lim to‘g‘risida”gi O‘zbekiston Respublikasi qonunining qoidalariga muvofiq holda bo‘lib, milliy tajribaning tahlili va ta‘lim tizimidagi jahon miqyosidagi yutuqlar asosida tayyorlangan. Albatta, kadrlarni zamon talabi darajasida tayyorlashda fanlardan yaratilgan darslik va o‘quv qo‘llanmalar muhim ahamiyat kasb etadi. Bugungi kunda talabalarga har bir fandan nazariy bilimlarni amaliyotga tatbiq etishni mukammal o‘rgata oladigan o‘quv qo‘llanmalarning mavjudligi muhim masalalardan biridir.

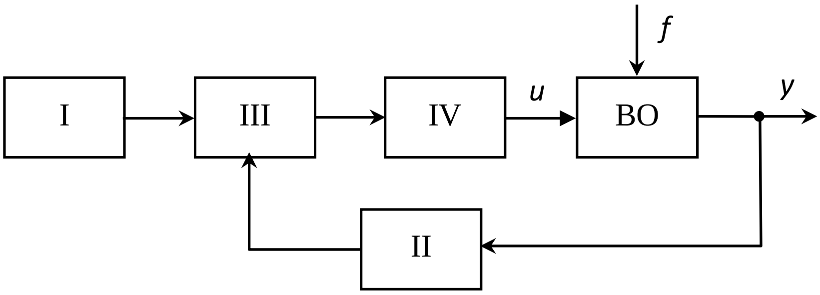
Texnologik jarayonlar va ishlab chiqarishni avtomatlashtirish masalalariga avtomatik boshqarishni qo‘llash texnologik jarayonlarni avtomatik boshqarish tizimlari yordamida amalga oshiriladi. Ularda texnologik jarayon va texnologik obyekt holati zamonaviy EHMlardan foydalanilgan holda tahlil qilinadi. Shulardan ko‘rinadiki, avtomatik boshqarish insonlar tomonidan amalga oshiriladi, boshqaruv tizimining texnik vositalari, shu jumladan, EHMlar boshqaruv yechimlarini ishlab chiqish va qo‘llashning murakkab jarayonida inson imkoniyatlarini ko‘p marta oshiruvchi qudratli vosita sanaladi. EHMlar asosidagi zamonaviy avtomatik boshqaruv tizimi hozirgi davr ishlab chiqarish amaliyotida keng qo‘llanilmoqda.

Shunday ekan, boshqarish nazariyasining predmeti avtomatik tizim modelining xossalari hisoblanadi, bu xossalar differensial tenglamalar hamda ularning turli o‘zgartirishlari va interpretatsiyalari ko‘rinishida ifodalanadi.

1-Amaliy mashg‘ulot
Boshqarish sistemalari, ularning prinsipal va funksional sxemalari. Uzatish funksiyalari.

1.1. Boshqarish sistemalari, ularning prinsipal va funksional sxemalari

Har qanday jarayonni oldiga qo‘yilgan maqsad sari yo‘naltirishga *boshqarish* deyiladi. Har qanday jarayonni boshqarish 4 bosqichdan iborat bo‘ladi. Sxematik tarzda buni quyidagicha ifoda etish mumkin (1.1-rasm).



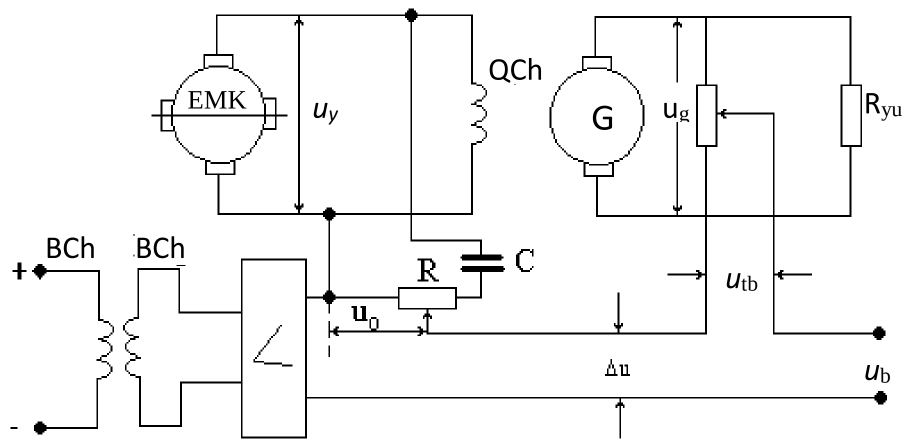
1.1-rasm. Avtomatik boshqarish bosqichlarining strukturaviy sxemasi

I – boshqarish maqsadi;
II – boshqarish to‘g‘risida axborot;
III – taqqoslash, solishtirish va qaror qabul qilish;
IV – qabul qilingan qarorni bajarish.

Funksional sxema sistema tarkibidagi elementlarni yoki bu elementlarning bajaradigan funksiyasini bildiradi. Prinsipial sxema esa funksional sxemaning kengaytirilgan ko‘rinishi hisoblanadi.

1.1- misol

O‘zgarmas tok generatorining kuchlanishini avtomatik boshqarish sistemasining prinsipial sxemasi (1.2-rasm).



1.2 - rasm. O‘zgarmas tok generatori kuchlanishini avtomatik boshqarish sistemasining prinsipial sxemasi

Bu yerda:

- EMK – elektr mashina kuchaytirgich;
- BCH_1; BCH_2 – EMK ning boshqarish cho‘lg‘amlari;
- G – o‘zgarmas tok generatori;
- QCH – generatorning qo‘zg‘atuvchi cho‘lg‘ami;
- R_{yu} – yuklama;
- u_g – boshqariluvchi, rostlanuvchi kattalik;
- u_{tb} – teskari bog‘lanish signali;
- $\Delta u=u_b-u_{tb}$– rostlanuvchi kattalikning berilgan qiymatdan og‘ishi;
- u_b – rostlanuvchi kattalikning berilgan qiymati;
- u_u – rostlovchi, boshqaruvchi signal.

Sistemaning ishlash prinsipi quyidagicha: Sistemaning maqsadi generator kuchlanishini u_g – o‘zgarmas holda tutib turish. Buning uchun u_b kuchlanish olinadi, uning qiymati rostlanuvchi kattalik u_g kuchlanish bilan bir xil qilib olinadi, chunki generator nominal kuchlanish u_{gnom} ishlab chiqarganda $\Delta u=u_b–u_{tb}=>0$ bo‘lishi kerak. Yuklama R_{yu} o‘zgarishi bilan generator kuchlanishi u_g ham o‘zgaradi, buning natijasida teskari bog‘lanish kuchlanishi u_{tb} ham o‘zgarib $\Delta u=u_b–u_{tb}$ kuchlanish hosil bo‘ladi.

Agar $\Delta u=u_b–u_{tb}$ ishorasi musbat (+) bo‘lsa, ya‘ni rostlanuvchi kattalik u_g o‘z nominal qiymati u_{gnom} kichik bo‘lsa, unda Δu signal EMKning ikkinchi boshqarish chulg‘ami BCH_1 da BCH_2 dagi magnit oqimiga mos yo‘nalgan magnit oqimi hosil qiladi. Buning natijasida BCH_1 va BCH_2 chulg‘amlardagi magnit oqimlari qo‘shilib EMKning boshqaruvchi kattaligi u_u ko‘tarilishiga olib keladi. EMK esa generatorning qo‘zg‘atuvchi cho‘lg‘amiga QCH qo‘zg‘atuvchi rolini o‘taydi. Va oxir oqibatda generator kuchlanishi u_g nominal qiymat u_{gnom} ga teng bo‘ladi. Agar $\Delta u = u_b - u_{tb}$ manfiy ishoraga ega bo‘lsa, unda EMKning BCH_1 va BCH_2 cho‘lg‘amlaridagi magnit oqimlari qarama-qarshi yo‘nalgan bo‘lib, EMKning ishlab chiqargan kuchlanishi u_u kamayishiga olib keladi.

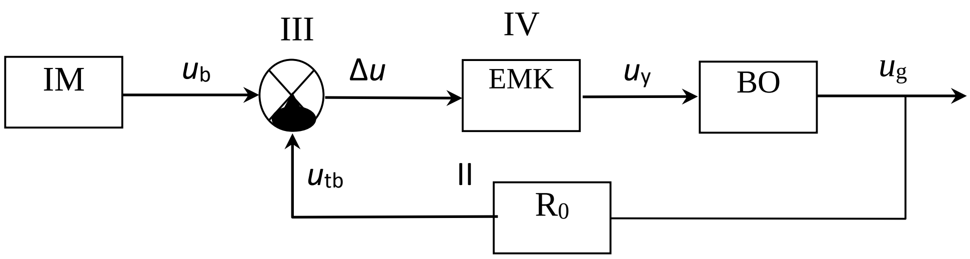
Endi bu sistema boshqarish sistemasi ekanligini isbotlaymiz. Buning uchun boshqarishga muvofiq keluvchi 4 bosqichlarni aniqlaymiz (1.3-rasm).

I – BM. – u_g = const bo‘lishi kerak;

II – BTA – u_{tb} = var o‘zgarishi;

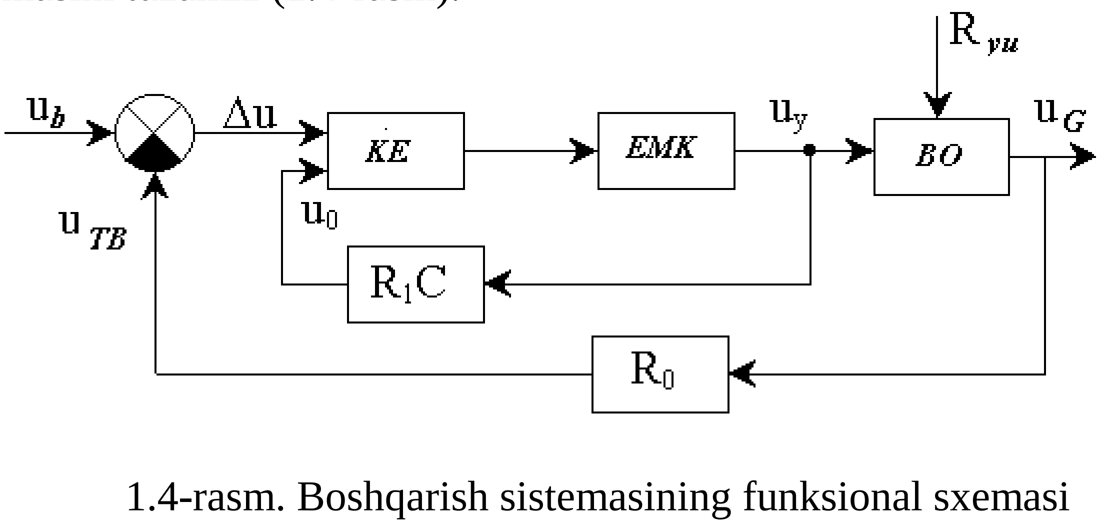
III – T.S. va QQQ - $\Delta u = u_b - u_{tb}$ hosil bo‘lishi;

IV – QQQB – kuchaytirgich va EMK yordamida amalga oshiriladi.



1.3 - rasm. Boshqarish sistemasining strukturali ko‘rinishi

Ko‘rilayotgan sistemaning ishlash prinsipiga ko‘ra, uning funksional sxemasini tuzamiz (1.4-rasm).



1.4-rasm. Boshqarish sistemasining funksional sxemasi

1.2. UZATISH FUNKSIYALARI

Bir o‘lchamli uzluksiz statsionar chiziqli sistemaning differensial tenglamasini umumiy ko‘rinishda quyidagicha ifodalash mumkin:

$$\left[a_0 \frac{d^n y}{dt^n} + a_1 \frac{d^{n-1} y}{dt^{n-1}} + ... + a_n y(t)\right] = \left[b_0 \frac{d^m x}{dt^m} + b_1 \frac{d^{m-1} x}{dt^{m-1}} + ... + b_m x(t)\right] \qquad (1.1)$$

Sistema yoki zvenoning *uzatish funksiyasi* deb – boshlang‘ich shartlari nol bo‘lganida chiqish signalining Laplas tasvirini kirish signalining Laplas tasviri signali nisbatiga aytiladi. (1.1)-tenglamani Laplas tasviri bo‘yicha o‘zgartiramiz, buning uchun differensial tenglamada $\frac{d}{dt}$ operatorni «*p*» kompleks o‘zgaruvchi bilan almashtiramiz

$$(a_0 p^n + a_1 p^{n-1} + ... + a_n) y(p) = (b_0 p^m + b_1 p^{m-1} + ... + b_m) x(p) \qquad (1.2)$$

Uzatish funksiyasining ta‘rifiga muvofiq $W(p)$ni quyidagi ko‘rinishda ifodalash mumkin:

$$W(p) = \frac{y(p)}{x(p)}\Big|_{t=0} = \frac{(b_0 p^m + b_1 p^{m-1} + ... + b_m)}{(a_0 p^n + a_1 p^{n-1} + ... + a_n)}. \qquad (1.3)$$

yoki

$$W(p) = \frac{P(p)}{Q(p)}$$

bunda $P(p) = b_0 p^m + b_1 p^{m-1} + b_2 p^{m-2} + ... + b_m$ - m darajali ko‘phad;

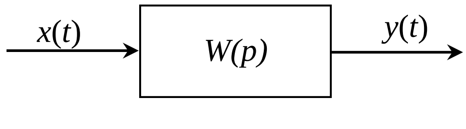
$Q(p) = a_0 p^n + a_1 p^{n-1} + a_2 p^{n-2} + ... + a_n$ - n darajali ko‘phad.

Sistemani amalga oshirish uchun $m < n$ shart bajarilishi kerak. Shundagina sistema ishlashi mumkin.

(2.3) tenglamaga muvofiq zveno yoki sistema chiqish signalining Laplas tasviri

$$y(p) = W(p) \cdot x(p). \qquad (1.4)$$

Endi zveno yoki sistemaning uzatish W(p) funksiyasi bilan o‘tkinchi funksiyasi $h(t)$ hamda impulsli o‘tkinchi funksiyasi $\omega(t)$ orasidagi bog‘lanishni ko‘rib chiqamiz (1.5-rasm).



1.5 - rasm. Sistemaning o‘tkinchi funksiyasi h(t) hamda impulsli o‘tkinchi funksiyasi ω(t) orasidagi bog‘lanish sxemasi

a) Agar kirish signali $x(t)$=1(t) bo‘lsa, unda uning Laplas tasviri $x(t)=\frac{1}{p}$ bo‘ladi. (1.1) formulaga muvofiq Chiqish signalining Laplas tasviri $y(p)=W(p)\cdot\frac{1}{p}$ ga teng bo‘ladi. Bundan original funksiyaga o‘tsak, $y(t)=h(t)=L^{-1}\left\{W(p)\cdot\frac{1}{p}\right\}$ bo‘ladi.

Demak, o‘tkinchi funksiya $h(t)$ bilan uzatish funksiyasi $W(p)$ bir ma‘noli bog‘langan ekan.

b) Agar $x(t)=\delta(t)$ bo‘lsa, unda $x(p)$=1 bo‘ladi. (1.4) formulaga muvofiq Chiqish signalining Laplas tasviri $y(p)=W(p)$ bo‘lib, uning originali impulsli o‘tkinchi funksiya bo‘ladi, ya‘ni $y(t)=\omega(t)=L^{-1}\{W(p)\}$.

Demak, impulsli o‘tkinchi funksiya $\omega(t)$ uzatish funksiyasining originali ekan.

Endi uzatish funksiyasining mohiyatini aniq misolda ko‘rib chiqamiz.

1.2 - Misol.

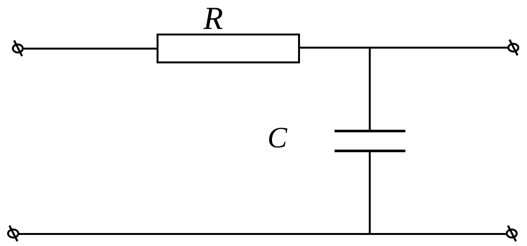
Obyektning modeli quyidagi ko‘rinishga ega: y‘‘+4y‘+7y=8u‘+2u.Obyekt uchun uzatish funksiyasini aniqlang.

Yechish. Obyektning tenglamasini differensiallash operatori ko‘rinishida yozamiz.$(p^2+4p+7)y=(8p+2)u$

Obyektning uzatish funksiyasini aniqlash uchun $W(p)=y/u$ ifodalaymiz:

$$W(p)= (8p+2)/ (p^2+4p+7).$$

1.3-misol. O‘zgarmas tok generatorining uzatish funksiyasining aniqlang.



1.6-rasm. O‘zgarmas tok generatorining elektr zanjir sxemasi

Berilgan:

R_q = 65.5 Om;

L_q = 27,5 gn.

Yechish:

$m_г = \frac{E_г}{I_к} = 108 \quad v/a$ – generator salt ish xarakteristikasining chiziqli qismidagi burchak koeffitsiyenti.

Generatorning uzatish funksiyasini aniqlash uchun qo‘zg‘atuvchi zanjirlarning kuchlanishlar tenglamasidan foydalanamiz.

$$u_к(p) = I_к(p) \cdot p \cdot L_к + R_к I_к(p) \qquad (1.5)$$

$$u_к(p) = I_к(p) \cdot [pL_к + R_к]$$

$$I_к = \frac{E_г(p)}{m_г} \qquad (1.6)$$

$(2) \rightarrow (1)$ qo‘yamiz.

$$u_к(p) = \frac{E_г(p)}{m_г}(pL_к + R_к) \qquad (1.7)$$

bundan uzatish funksiyasi:

$$W(p) = \frac{E_г(p)}{u_к(p)} = \frac{m_г}{pL_к + R_к} = \frac{\frac{m_г}{R_к}}{p\frac{L_к}{R_к} + 1} = \frac{K_г}{pT_к + 1}$$

$K_г = \frac{m_г}{R_к}$ - uzatish koeffitsiyenti; $T_к = \frac{L_к}{R_к}$ - vaqt doimiysi.

Shunday qilib, hosil bo‘lgan uzatish funksiyasi birinchi tartibli inersial zvenoni bildiradi.

$$K_г = \frac{m_г}{R_к} = \frac{108}{65,5} = 1,65; \quad T_к = \frac{L_к}{R_к} = \frac{27,5}{65,5} = 0,42 \ сек; \ W_г(p) = \frac{1,65}{0,42p + 1}.$$

Topshiriqlar

1.1. Obyektning differensial tenglamasi bo‘yicha uzatish funksiyasini $W(p) = y(p)/u(p)$. toping (1.1-jadval).

1.1- Jadval

№	Obyektning differensial tenglamasi
1	$11y''' + y'' - 15y' = 7u' + 6u$
2	$3y'' + 5y' + y = u$
3	$7y''' + 10y'' + 2y' + y = 3u' + u$

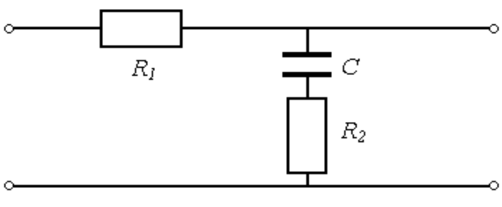
1.1-jadvalning davomi

4	$2y''' + y' + 3y = 2u'' + 3u' + u$
5	$5y''' + 4y'' + 13y = u'' + 4u' + 2u$
6	$4y''' + 4y'' + 2y' + y = 4u' + u$
7	$4y''' + 4y'' + 2y' = 2u''' + u'' + 4u' + u$
8	$y''' + 4y'' + 2y' = u'' + 4u' + u$
9	$y''' + 2y' + 3y = u'' + 2u' + u$
10	$y''' + 2y'' + y' = 2u'' + 3u' + u$
11	$y''' + 12y'' + y' = 5u' + u$
12	$13y'' + 8y' + 2y = 9u$
13	$y''' + 2y'' + 16y = 23u' + 2u$
14	$3y''' + 17y'' - y' = u'' + 5u$
15	$4y'' + 2y' + 10y = 5u$
16	$5y''' + 2y' + 3y = 3u'' + 14u' + u$
17	$23y'' + 18y' + 2y = 9u$
18	$y''' + 22y'' + 3y = 3u' + u$
19	$y''' - 15y' = 2u' + 5u$
20	$y''' + 2y' = 2u'' + u$
21	$3y'' + 28y' + 32y = 19u$
22	$9y''' + 7y'' + y = 4u'' + u' + 2u$
23	$y''' + 8y' - 4y = 2u'' + 15u$
24	$18y'' + 2y' + 12y = 9u$
25	$y''' + 10y'' - 8y' = 2u'' + 9u$
26	$y''' + 7y'' - 5y' = u' + 5u$

1.2. Elektr zanjirning uzatish funksiyasining aniqlang.

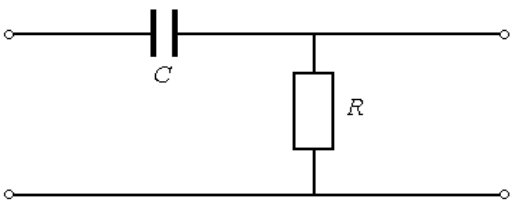
1)

R_1=11кОМ
R_2=5.2кОМ
C=10 мкФ

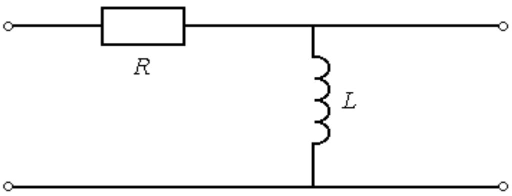


2)

R =2.2кОМ
C=30 мкФ

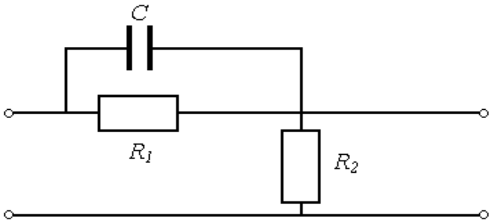


3) *R =10кОМ*
L=5.3Гн

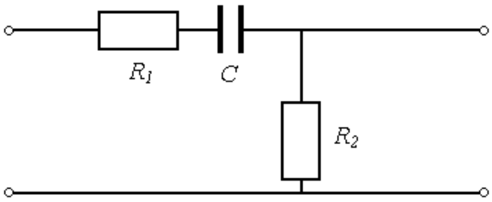


4)

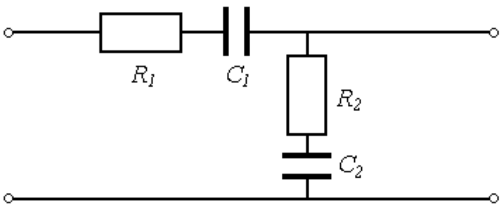
R_1*=8кОМ*
R_2*=10кОМ*
C=50мкФ



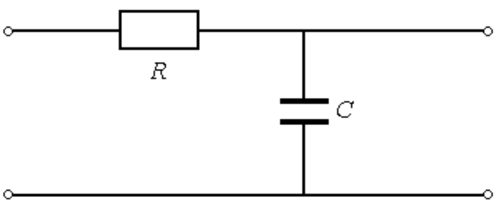
5) R_1*=4кОМ*
R_2*=5кОМ*
C=12 мкФ



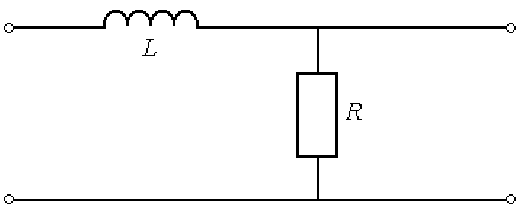
6) R_1*=13кОМ*
R_2*= 5кОМ*
C_1=1.5 мкФ
C_2=10мкФ



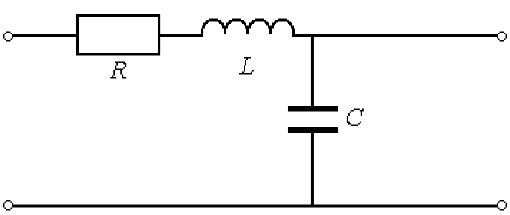
7)
R =10кОМ
L=20Гн



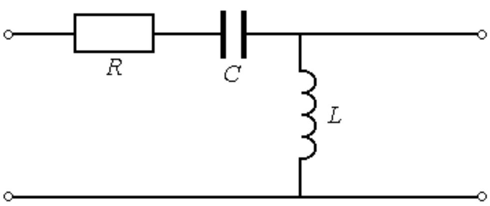
8)
R =5кОМ
C=10 мкФ



9) *R =10кОМ*
L=15Гн
C=25 мкФ



10) *R* =7кОМ
L=35Гн
C=10 мкФ



Nazorat savollari

1. Boshqarish deb nimaga aytiladi?
2. Boshqarish tizimi necha xil sxemalar ko‘rinishida ifodalanadi?
3. Uzatish funksiyasi haqida ma‘lumot bering.
4. Holat tenglamasi haqida ma‘lumot bering.
5. Uzatish funksiyasining nollari qutblari nima?

2-Amaliy mashg‘ulot
Chiziqli sistemalarning chastotaviy xarakteristika (AFCHX va FCHX) larini tadqiq etish

Chiziqli statsionar sistemalarni tasvirlashda chastotali xarakteristikalar juda muhim rol o‘ynaydi. Bir o‘lchamli chiziqli statsionar sistemaning umumiy ko‘rinishdagi operator tenglamasini quyidagicha ifodalash mumkin:

$$(a_0 p^n + a_1 p^{n-1} + a_2 p^{n-2} + ... + a_n) y(p) =$$
$$= (b_0 p^m + b_1 p^{m-1} + b_2 p^{m-2} + ... + b_m) x(p) \qquad (2.1.)$$

Uzatish funksiyasining ta‘rifiga ko‘ra:

$$W(p) = \frac{y(p)}{x(p)} = \frac{b_0 p^m + b_1 p^{m-1} + b_2 p^{m-2} + ... + b_m}{a_0 p^n + a_1 p^{n-1} + a_2 p^{n-2} + ... + a_n} = \frac{P(p)}{Q(p)} \qquad (2.2.)$$

$W(j\omega)$ funksiyaning uzatish funksiyasi $W(p)$ dan $p = j\omega$ bilan almashtirish orqali olinadi va *chastotaviy uzatish funksiyasi* deyiladi:

$$W(j\omega) = \frac{b_0 (j\omega)^m + b_1 (j\omega)^{m-1} + b_2 (j\omega)^{m-2} + ... + b_m}{a_0 (j\omega)^n + a_1 (j\omega)^{n-1} + a_2 (j\omega)^{n-2} + ... + a_n} \qquad (2.3.)$$

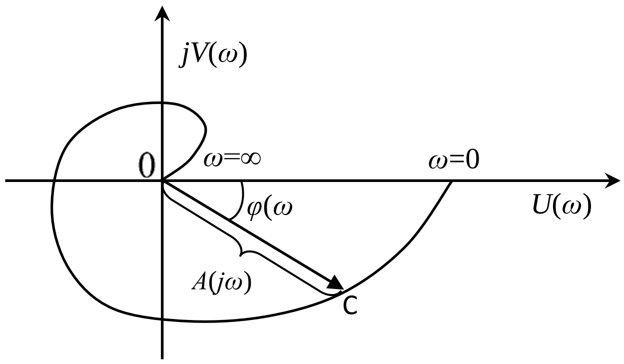
Chastotaviy uzatish funksiya $W(j\omega)$ chatota deb ataluvchi haqiqiy o‘zgaruvchi «ω» ga bog‘liq bo‘lgan kompleks funksiyadir.

$W(j\omega) = U(\omega) + jV(\omega)$ - algebraik ko‘rinishi;

$W(j\omega) = A(\omega) e^{j\varphi(\omega)}$ - darajali ko‘rinishi, bu yerda $U(\omega)$ - haqiqiy qism; $V(\omega)$ - mavhum qism; $A(\omega)$ - amplituda; $\varphi(\omega)$ - faza.

$$A(\omega)=\sqrt{U^2(\omega)+V^2(\omega)}\ ;\ \varphi(\omega)=arctg\frac{V(\omega)}{U(\omega)} \qquad (2.4.)$$

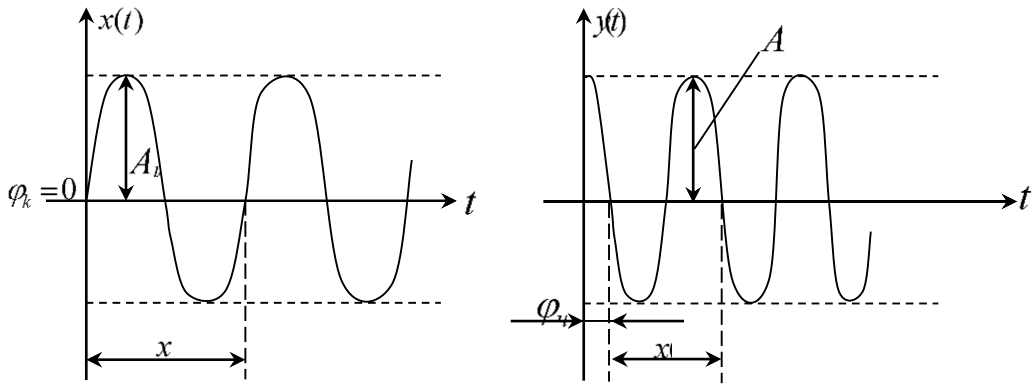
Kompleks tekisligida $W(j\omega)$ funksiyasini $\overrightarrow{OC}$ vektor orqali ifodalash mumkin. Bu vektorning uzunligi chastotali uzatish funksiyasining amplitudasi «*A*»ga vektorning haqiqiy musbat o‘q bilan hosil qilgan burchagi fazasi «φ»ga teng bo‘ladi (2.1-rasm).



2.1 - rasm. Chiziqli sistemaning amplituda-faza chastotaviy xarakteristikasi

Chastota noldan cheksiz (0<ω<∞) oraliqda o‘zgarganda $\overrightarrow{OC}$ vektorning kompleks tekisligida chizgan egri chizig‘iga *amplituda-fazali xarakteristika* (AFX) deyiladi, yoki boshqa qilib aytganda AFX deb kompleks tekisligida chastotaning o‘zgarishiga qarab amplituda va fazaning o‘zgarishiga aytish mumkin.

Chastotali uzatish funksiyasining *amplitudasi* chiqish signalining amplitudasini kirish signalining amplitudasiga nisbatan necha marotaba kattaligini ko‘rsatadi. Chastotali uzatish funksiyasining moduli amplitudasini beradi, ya‘ni $A(\omega)=\mathrm{mod}W(j\omega)=\dfrac{Ach(\omega)}{A_k(\omega)}$; chastotali uzatish funksiyasining argumenti chiqish va kirish signallari orasidagi burchak siljishini ko‘rsatadi, ya‘ni $\varphi(\omega)=\arg W(j\omega)$ (2.2-rasm).



2.2 - rasm. Chastotali uzatish funksiyasi amplituda va faza xarakteristikalarining chatotaga bog‘liqlik grafigi

$$W(j\omega)=\frac{y(j\omega)}{x(j\omega)}=\frac{A_{ч}(\omega)e^{j[\omega t+\varphi_{ч}]}}{A_{к}(\omega)e^{j[\omega t+\varphi_{к}]}}=A(\omega)e^{j\varphi(\omega)} \qquad (2.5.)$$

$A(\omega)$ - kuchaytirishning amplitudasi

$$A(\omega)=\frac{A_{чик}(\omega)}{A_{кир}(\omega)};\ \varphi(\omega)=\varphi_{чик}-\varphi_{кир}\,. \qquad (2.6.)$$

$W(j\omega)$ - amplituda fazaviy xaraketistika (AFX);
$U(\omega)$ - haqiqiy chastotaviy xarakteristika (HCHX);
$V(\omega)$ - mavhum chastotaviy xarakteristika (MCHX);
$A(\omega)$ - amplituda chastotaviy xarakteristika (ACHX);
$\varphi(\omega)$ - faza chastotaviy xarakteristika (FCHX).

2.1-misol. $W(p)=\frac{9{,}8p}{p+1}$ uzatish funksiyasi bilan berilgan obyekt uchun amplituda-fazaviy (AFX), moddiy chastotaviy va fazaviy chastotali xarakteristikalarini (MCHX, FCHX) quring.

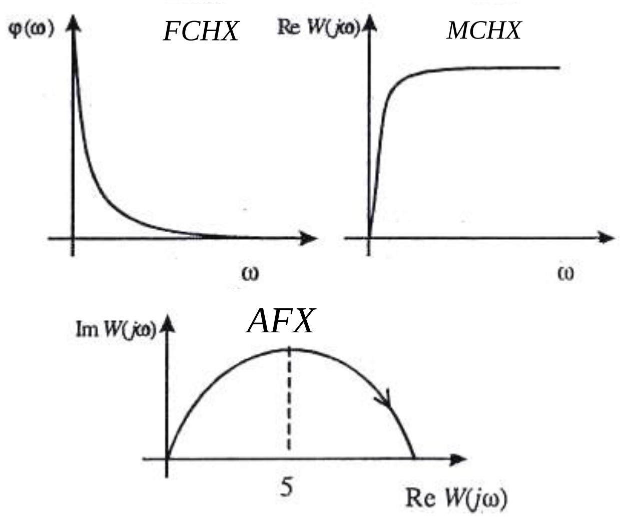
Yechish: Uzatish funksiyasida $p\to j\omega$ almashtirishni amalga oshirib, umumlashgan chastotaviy xarakteristikalar uchun ifodani yozamiz:.

$$W(j\omega)=\frac{9{,}8j\omega}{j\omega+1}=\frac{9{,}8\omega^2}{\omega^2+1}+j\frac{9{,}8\omega}{\omega^2+1}\,.$$

MCHX va FCHX lar uchun ifodalar quyidagi ko‘rinishga ega:

$$R(\omega) = \frac{9{,}8\omega^2}{\omega^2 + 1}, \qquad \varphi(\omega) = arctg\,\frac{I(\omega)}{R(\omega)} = arctg\,\frac{1}{\omega}.$$

Chastota 0 dan ∞ ga o‘zgarganda qurilgan mos chastotaviy xarakteristikalar 2.3-rasmda keltirilgan.



2.3 - rasm. Tizimning mavhum va amplituda chastotaviy xarakteristikalari

Topshiriqlar

Uzatish funksiyasi quyidagi ko‘rinishga ega bo‘lsa, u holda obyektning AFX, ACHX, FCHX larini quring:

2.1-jadval

№	Obyektning uzatish funksiyasi
1	$w_{yu}(p) = \frac{5}{4p+3};$
2	$w_{yu}(p) = \frac{12}{p+8};$
3	$w_{yu}(p) = \frac{15}{p+5};$
4	$w_{yu}(p) = \frac{9}{2p+1};$

2.1-jadvalning davomi

5	$w_{yu}(p) = \frac{2}{8p+6}$
6	$w_{yu}(p) = \frac{3}{5p+3};$
7	$w_{yu}(p) = \frac{10}{p+8};$
8	$w_{yu}(p) = \frac{3}{7p+6};$
9	$w_{yu}(p) = \frac{5}{p+9}$
10	$w_{yu}(p) = \frac{4}{3p+6};$
11	$w_{yu}(p) = \frac{10}{5p+3};$
12	$w_{yu}(p) = \frac{7}{2p+1};$
13	$w_{yu}(p) = \frac{6}{2p+8};$
14	$w_{yu}(p) = \frac{5}{2p+5}$
15	$w_{yu}(p) = \frac{4}{2p+8};$
16	$w_{yu}(p) = \frac{10}{p+4};$
17	$w_{yu}(p) = \frac{3}{p+8}$
18	$w_{yu}(p) = \frac{8}{8p+6};$
19	$w_{yu}(p) = \frac{5}{4p+6}$
20	$w_{yu}(p) = \frac{9}{3p+5}$

Nazorat savollari

1. Chastotaviy xarakteristika deganda nimani tushunasiz?
2. Chastotaviy xarakteristikaning turlari haqida gapiring.
3. Chastotaviy uzatish funksiyasi haqida ma‘lumot bering.
4. Amplituda va faza xarakteristikalarning o‘zaro farqi.

3- Amaliy mashg‘ulot
Elementar zvenolarning vaqt xarakteristikalarini tadqiq qilish

Matematik ifodasi differensial tenglama bilan ifodalanadigan zvenolarga *dinamik zveno* deyiladi.

Tipik dinamik zveno deb tartibi ikkidan yuqori bo‘lmagan differensial tenglama bilan ifodalanadigan zvenolarga aytiladi. Ularga asosan quyidagi zvenolar kiradi:

1. Inersiyasiz (proporsional, kuchaytiruvchi) zveno.
2. Birinchi tartibli inersial (aperiodik) zveno.
3. Ideal integrallovchi zveno.
4. Ideal differensiallovchi zveno.
5. Tebranuvchi zveno.
6. Birinchi tartibli tezlatuvchi zveno.
7. Ikkinchi tartibli tezlatuvchi zveno.

Quyida shu zvenolarning vaqt hamda chastotali xarateristikalarini ko‘rib chiqamiz.

1. Inersiyasiz (proporsional, kuchaytiruvchi) zveno.

Bu zvenoning umumiy tenglamasi quyidagicha ifodalanadi:

$$y(t) = K \cdot x(t), \tag{3.1}$$

bu yerda *K* – uzatish koeffitsiyenti.

Bunday zvenoning chiqishidagi kattalik kirishidagi kattalikka nisbatan proporsional ravishda o‘zgaradi.

Bu zvenoga elektron kuchaytirgich, potensiometr, taxogenerator kabi elementlar misol bo‘la oladi .

(3.1) tenglamaga Laplas almashtirishlarini kiritamiz

$$y(p) = K \cdot x(p), \tag{3.2}$$

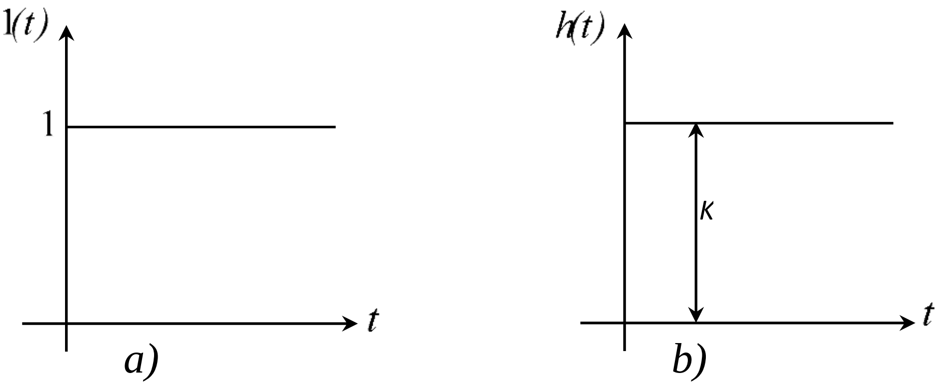
bundan

$$W(p) = \frac{y(p)}{x(p)} = K. \tag{3.3}$$

Shunday qilib, proporsional zvenoning uzatish funksiyasi kuchaytirish koeffitsiyenti «*K*» ga teng bo‘ladi.

Uzatish funksiyasi orqali zveno yoki sistemaning vaqt xarakteristikalarini aniqlash mumkin (3.1-rasm):

$$h(t) = L^{-1}\left\{W(p)\frac{1}{p}\right\} = L^{-1}\left\{K\frac{1}{p}\right\} = K \cdot 1(t). \tag{3.4}$$



3.1-rasm. a) zvenoga berilgan birlik pog‘onali signal; b) zvenoni vaqt xarakteristikasi

2. Birinchi tartibli inersial (aperiodik) zveno.

Bu zvenoning tenglamasi quyidagi ko‘rinishga ega.

$$y(t) + T\frac{dy(t)}{dt} = K \cdot x(t) \qquad (3.5)$$

bu yerda *K* – uzatish koeffitsiyenti; *T* – vaqt doimiyligi.

RC, RL – zanjirlari, o‘zgarmas tok generatori va dvigatellari bu zvenoga misol bo‘la oladi .

(3.5) tenglamaga Laplas o‘zgartirishini kiritib, bu zvenoning uzatish funksiyasini aniqlaymiz:

$$y(p) + Tp \cdot y(p) = Kx(p),$$

bundan

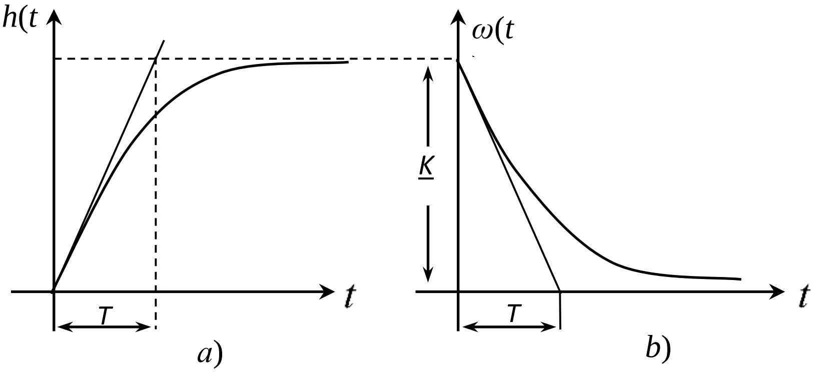
$$W(p) = \frac{y(p)}{x(p)} = \frac{K}{1+Tp}. \qquad (3.6)$$

Inersial zvenoning o‘tkinchi funksiyasi

$$h(t) = L^{-1}\left\{W(p)\frac{1}{p}\right\} = L^{-1}\left\{\frac{K}{1+Tp}\cdot\frac{1}{p}\right\} = K(1-e^{-\frac{t}{T}})1(t) \qquad (3.7)$$

eksponenta qonuni bo‘yicha o‘zgaradi. Impulsli o‘tkinchi funksiyani quyidagicha aniqlash mumkin (3.2-rasm).

$$\omega(t) = h'(t) = L^{-1}\{W(p)\} = L^{-1}\left\{\frac{K}{1+pT}\right\} = \frac{K}{p}e^{-\frac{t}{T}}1(t) \qquad (3.8)$$



3.2-rasm. a) zvenoning vaqt xarakteristikasi;
b) zvenoning impulsli xarakteristikasi

1.3. Ideal integrallovchi zveno. Bu zveno

$$y(t) = K\int_0^t x(t)dt, \qquad (3.9)$$

tenglama bilan ifodalanadi.

Bu yerda K – uzatish koeffitsiyenti. Unga elektr sig‘im, induktivlik, aylanma o‘q va h.k. misol bo‘la oladi.

(3.9) tenglamaning Laplas bo‘yicha tasviri quyidagi ko‘rinishga ega:

$$y(p) = \frac{K}{p}x(p), \qquad (3.10)$$

zvenoning uzatish funksiyasi

$$W(p) = \frac{y(p)}{x(p)} = \frac{K}{p} \qquad (3.11)$$

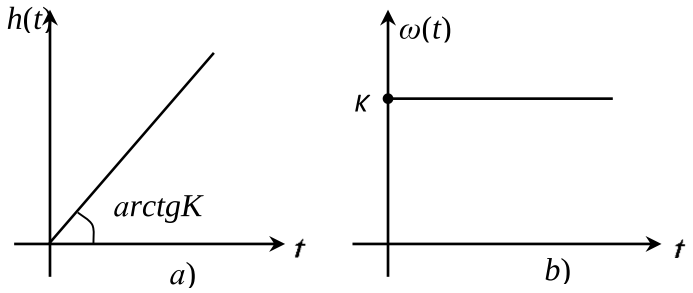
Bu zvenoni yana astatik zveno deb ham yuritiladi.

Integral zvenoning o‘tkinchi funksiyasi

$$h(t) = L^{-1}\left\{W(p)\frac{1}{p}\right\} = L^{-1}\left\{\frac{K}{p}\cdot\frac{1}{p}\right\} = K\cdot t\cdot 1(t) \qquad (3.12)$$

va impulsli o‘tkinchi funksiyasi (vazn funksiyasi) 3.3-rasmda keltirilgan.

$$\omega(t) = h'(t) = K \qquad (3.13)$$



3.3-rasm. a) zvenoning vaqt xarakteristikasi;
b) zvenoning impulsli xarakteristikasi

3.1 - Misol. Dinamik zvenoning uzatish funksiyasi quyidagicha berilgan bo‘lsin:

$$W(p) = \frac{7}{p^2+9p+8} \qquad (3.14)$$

o‘tish xarakteristikasi quyidagicha ifodalanadi:

$$h(t) = L^{-1}\left[\frac{1}{p}\cdot W(p)\right] = L^{-1}\left[\frac{7}{p^2+9p+8}\right] \qquad (3.15)$$

o‘tish xarakteristikasini aniqlashda uzatish funksiyasini uch qismga ajratib olamiz:

$$W(p) = \frac{K1}{p-p1} + \frac{K2}{p-p2} + \frac{K3}{p} \qquad (3.16)$$

Bundan tenglamaning ildizlari va koeffitsiyentlari aniqlanadi K1, K2, K3:

$p\cdot(p^2+5p+4) = 0$; p1=-1; p2=-8; p3=0.

$K1 = \left[(p+1)\cdot\frac{7}{p(p+1)\cdot(p+8)}\right]_{p=-1} = L^{-1}\left[\frac{7}{(-1)(-1+8)}\right]_{p=-1} = -1;$

$$K2 = \left[(p+8)\cdot\frac{7}{p(p+1)\cdot(p+8)}\right]_{p=-8} = L^{-1}\left[\frac{7}{(-8)(-8+1)}\right]_{p=-8} = \frac{1}{8};$$

$$K3 = \left[(p)\cdot\frac{7}{p(p+1)\cdot(p+8)}\right]_{p=0} = L^{-1}\left[\frac{7}{(0+1)(0+8)}\right]_{p=0} = \frac{7}{8};$$

topilgan koeffisiyentlar (3.14) tenglamaga qo‘yiladi:

$$W(p) = -1\cdot\frac{1}{p+1} + \frac{1}{8}\cdot\frac{1}{p+8}\cdot\frac{7}{8}\cdot\frac{1}{p} \qquad (3.17)$$

Laplas almashtirish quyidagicha aniqlanadi:

$$L^{-1}\cdot\left[b\cdot\frac{1}{p+a}\right] = b\cdot e^{-at} \qquad (3.18)$$

a va b - konstantalar.

(3.17) va (3.18) ifodalardan foydalanib o‘tish jarayoni aniqlanadi:

$$h(t) = e^{-t} + \frac{1}{8}\cdot e^{-8t} + \frac{7}{8}$$

Impulsli xarakteristika o‘tish xarakteristikasidan vaqt bo‘yicha olingan hosilaga teng:

$$\omega(t) = -e^{-t} - e^{-8t} \qquad (3.18)$$

Topshiriqlar

Quyida berilgan elementar zvenolarning uzatish funksiyalaridan foydalanib, *h(t)* o‘tish funksiyasi va *w(t)* vazn funksiyalarini aniqlang.

3.1-jadval

№	Obyektning uzatish funksiyasi
1	$W(p) = \frac{3}{p^2 + 10p + 9}$
2	$W(p) = \frac{5}{p^2 + 26p + 25}$

3.1-jadvalning davomi

3	$W(p)=\frac{9}{p^2+82p+81}$
4	$W(p)=\frac{5}{p^2+p+25}$
5	$W(p)=\frac{8}{p^2+65p+64}$
6	$W(p)=\frac{5}{p^2+p+25}$
7	$W(p)=\frac{4}{p^2+17p+16}$
8	$W(p)=\frac{3}{p^2+10p+9}$
9	$W(p)=\frac{6}{p^2+37p+36}$
10	$W(p)=\frac{2}{p^2+8p+4}$
11	$W(p)=\frac{3}{p^2+11p+10}$
12	$W(p)=\frac{5}{p^2+45p+44}$
13	$W(p)=\frac{9}{p^2+33p+32}$
14	$W(p)=\frac{5}{p^2+63p+62}$
15	$W(p)=\frac{8}{p^2+65p+64}$
16	$W(p)=\frac{5}{p^2+26p+25}$
17	$W(p)=\frac{4}{p^2+41p+40}$
18	$W(p)=\frac{3}{p^2+15p+14}$
19	$W(p)=\frac{2}{p^2+37p+36}$
20	$W(p)=\frac{2}{p^2+35p+34}$

Nazorat savollari

1. O‘tkinchi va impulsli o‘tkinchi funksiyalar.
2. Quyidagi zvenolar uchun vaqt xarakteristikalarni keltiring:

- Aperiodik zveno
- Tebranuvchi zveno
- Integrallovchi zveno
- Differensiallovchi zveno

3. Quyidagi zvenolarda vaqt xarakteristikalar manfiy birlik teskari aloqa ta‘sirida qanday o‘zgaradi?

- Aperiodik zveno
- Tebranuvchi zveno
- Integrallovchi zveno
- Differensiallovchi zveno

4-Amaliy mashg‘ulot
Boshqarish tizimlarida struktura sxemalarini o‘zgartirish qoidalari

Dinamik zvenolarning grafik ko‘rinishiga struktur sxema deyiladi. Funksional va struktur sxemalarda bir xillik mavjuddir, chunki ular boshqarish sistemasining berk konturidagi axborotlarni uzatish va o‘zgartirish jarayonlarini aks ettiradilar. Shuning bilan birga ular orasida farq bor, funksional sxema sistema tarkibidagi, elementlarni, ularning bajaradigan funksiyasini ko‘rsatadi.

Bir tomonlama yo‘naltirilgan zvenolardan tashkil topgan struktur sxema sistemaning dinamik xususiyatlarining matematik ifodasini bildiradi. Struktur sxemalarning afzalligi shundan iboratki, u sistemadagi jarayonlarini sistemadan o‘tayotgan signallarning uzatilishini, o‘zgartirilishini yaqqol tasvirlaydi.

Bir tomonlama harakatlanish xususiyatiga ega bo‘lgan ochiq sistemani ko‘rib chiqamiz. Bu bitta zveno yoki ularning turli bog‘lanishi bo‘lishi mumkin.

Uzatish funksiyasining ta‘rifiga ko‘ra

$$W(p) = \frac{y(p)}{x(p)}; \qquad (4.1)$$

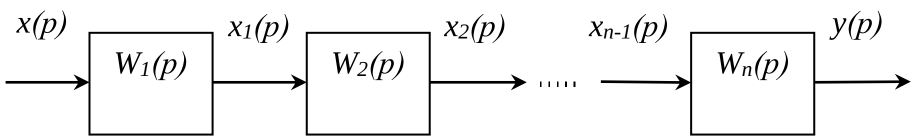
Bundan bir tomonlama yo‘nalgan sistemaning asosiy xususiyati kelib chiqadi.

$$Y(t) = W(p) \cdot x(t) \qquad (4.2)$$

Ya‘ni chiqish signalining tasviri uzatish funksiyasini kirish signalining tasviri ko‘paytmasiga tengdir.

Bir tomonlama yo‘naltirilgan zvenolarning asosiy bog‘lanish hollarini ko‘rib chiqamiz.

a) Ketma-ket bog‘lanish. Bunda oldingi zvenoning chiqish signali keyingi zvenoning kirish signali hisoblanadi (4.1-rasm).



4.1 - rasm. Zvenolarning ketma-ket bog‘lanish sxemasi

(4.2) formulaga ko‘ra

$$\left.\begin{aligned} &y(p) = W_n(p)\; x_{n-1}(p) \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &x_2(p) = W_2(p)\; x_1(p) \\ &x_1(p) = W_1(p)\; x(p) \end{aligned}\right\} \qquad (4.3)$$

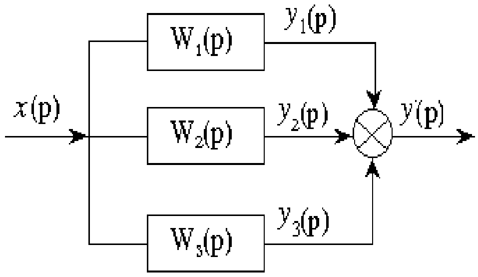
(4.3) tenglamada oraliqdagi kattaliklarni yo‘qotib, quyidagi ifodani $y(p) = W_1(p) \cdot W_2(p) \ldots W_n(p) \cdot x(p)$ hosil qilish mumkin.

Bundan uzatish funksiyasi $W(p) = \dfrac{y(p)}{x(p)} = \prod_{i=1}^{n} W_i(p)$ kelib chiqadi.

Demak, zvenolar ketma-ket ulanganda ularning uzatish funksiyalari ko‘paytiriladi.

b) Parallel bog‘lanish. Bunda hamma zvenolar kirishiga bir xil signal beriladi, chiqish signallari esa qo‘shiladi (4.2-rasm).

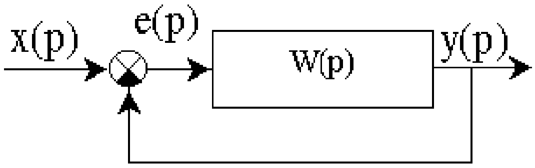
$$y(p) = y_1(p) + y_2(p) + y_3(p)$$
$$y_1(p) = W_1(p) \cdot x(p)$$
$$y_2(p) = W_2(p) \cdot x(p)$$
$$y_3(p) = W_3(p) \cdot x(p)$$
$$y(p) = [W_1(p) + W_2(p) + W_3(p)]x(p)$$
$$W(p) = \frac{y(p)}{x(p)} = \sum_{i=1}^{n} W_i(p)$$



4.2 -rasm. Zvenolarning parallel bog‘lanish sxemasi

Shunday qilib, zvenolar parallel ulanganda ularning uzatish funksiyalari qo‘shiladi.

d) Qarshi parallel bog‘lanish (teskari bog‘lanish). Teskari bog‘lanish deb, chiqish signalining kirishga ulanishiga aytiladi. Agar teskari bog‘lanish signali kirish signalidan ayrilsa manfiy, qo‘shilsa musbat teskari bog‘lanish bo‘ladi (4.3-rasm).



4.3 - rasm. Zvenolarning teskari bog‘lanish sxemasi

$y(p) = W_T(p) \cdot e(p)$

$e(p) = x(p) \pm y_{TБ}(p)$ (+) musbat TB, (-) manfiy TB.

$y_{TБ}(p) = W_{TБ}(p) \cdot y(p)$

$y(p) = W_T(p)[x(p) \pm W_{TБ}(p) \cdot y(p)]$

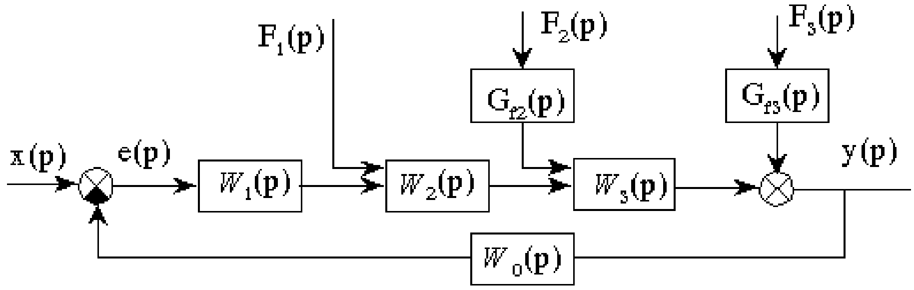
$y(p) = [1 \pm W_T(p)W_{TБ}(p)] = W_T(p)x(p)$ (-) musbat TB, (+) manfiy TB

$$W(p) = \frac{y(p)}{x(p)} = \frac{W_T(p)}{1 \pm W_T(p)W_{TБ}(p)} = \frac{W_T(p)}{1 \pm W(p)} \qquad (4.4)$$

$W(p) = W_T(p) \cdot W_{TБ}(p)$ – ochiq sistema uzatish funksiyasi.

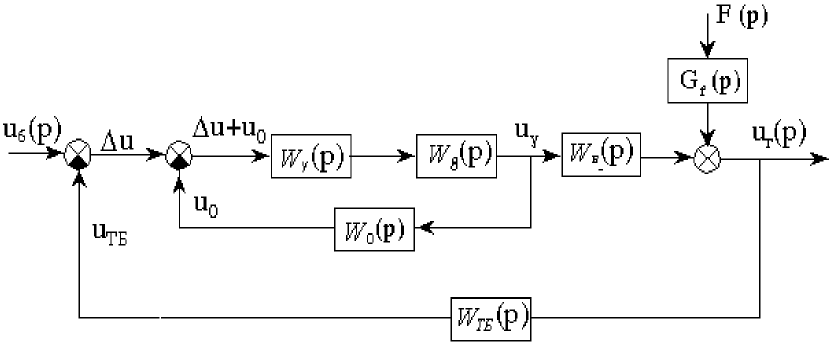
Endi ochiq sistemani manfiy birlik TB bilan bog‘laymiz. Yuqoridagi (4.4) ifodaga ko‘ra berk sistema uzatish funksiyasi $\Phi(p) = \frac{y(p)}{x(p)} = \frac{W(p)}{1+W(p)}$ teng. *F(r)* – berk sistemaning kirish signali bo‘yicha uzatish funksiyasi.

Real sharoitda sistema boshqaruvchi (kirish) signalidan tashqari yana ko‘p qo‘zg‘atuvchi ta‘sirlarga (yuklamaning o‘zgarishi, halaqitlar, element xarakteristikalarining nostabilligi va boshqa) duch kelishi mumkin. Bunday qo‘zg‘atuvchi ta‘sirlarning ta‘sirini bilish uchun struktur sxema bo‘yicha boshqariluvchi kattalik bilan qo‘zg‘atuvchi ta‘sirlar orasidagi bog‘lanishni aniqlashni o‘rganish kerak, quyidagi struktur sxemani ko‘rib chiqamiz (4.4-rasm):



4.4 – rasm. Sistemaga ta‘sir ko‘rsatuvchi tashqi ta‘sirlar sxemasi

Sistemaning to‘g‘ri zanjiri $W_1(p)$; $W_2(p)$; $W_3(p)$ uzatish funksiyasiga ega bo‘lgan bir tomonlama yo‘naltirilgan zvenolardan tashkil topgan. Keyingi ikki zveno kirishga qo‘zg‘atuvchi ta‘sirlar $F_1(r)$; $F_2(r)$ kelib tushib, oldingi zvenoning chiqish kattaligi bilan qo‘shilmoqda. Bundan tashqari $F_3(r)$ qo‘zg‘atuvchi ta‘sir bevosita chiqish kattaligiga ta‘sir ko‘rsatmoqda. $F_3(r)$ signalning qo‘yilgan joyi TB bilan qamrab olingan bo‘lib, bu juda katta ahamiyatga ega, chunki $F_3(r)$ signalning ta‘siri $W_0(p)$ zvenoga ham kelib tushadi, aksincha bo‘lgan holda $F_3(r)$ signalning rostlash jarayoniga ta‘siri bo‘lmay, bu katta xatoliklarga olib kelgan bo‘lar edi.



4.5 - rasm. Sistemaning superpozitsiyali prinsipi bo‘yicha ko‘rinishi

Ko‘rilayotgan sistema chiziqli bo‘lganligi uchun unga superpozitsiya (ustlash) prinsipini qo‘llash mumkin, ya‘ni sistemaning umumiy reaksiyasini, har bir ayrim ta‘sirlardan hosil bo‘lgan reaksiyalar summasi ko‘rinishida aniqlash mumkin.

$x(r)=0$; $F_2(r)=0$; $F_3(r)=0$ deb faraz qilamiz va sistemani $F_1(r)$ signaldan olgan reaksiyasi $u(r)$ ni aniqlaymiz. $W_2(p)$ zveno kirishiga $[F_1(p)+W_1(p)\cdot e(p)]$ signal ta‘sir etadi.

$e(p)=x(p)-W_0(p)y(p)$ e‘tiborga olsak, unda bu signal $W_2(p)$, $W_3(p)$ zvenolardan o‘tib quyidagi reaksiyani hosil qiladi.

$$y(p)=W_2(p)\cdot W_3(p)\left[F_1(p)-W_1(p)\cdot W_0(p)\cdot y(p)\right]$$

$$y(p)\left[1+W_1(p)W_2(p)W_3(p)\cdot W_0(p)\right]=W_2(p)W_3(p)F_1(p)$$

$$y(p)=\frac{W_2(p)W_3(p)}{1+W_1(p)W_2(p)\cdot W_3(p)W_0(p)}\cdot F_1(p)$$

$W(p)=W_1(p)W_2(p)W_3(p)W_0(p)$ – ochiq sistemaning uzatish funksiyasi.

Shunday qilib, sistemaning $F_1(r)$ signaldan olgan reaksiyasi

$$y(p)=\frac{W_2(p)W_3(p)}{1+W(p)}\cdot F_1(p).$$

Xuddi shunday tarzda qolgan ta‘sirlardan hosil bo‘lgan reaksiyalarni aniqlash mumkin.

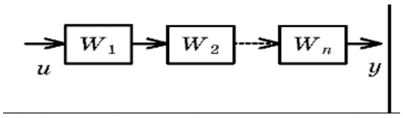
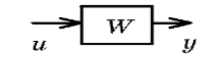
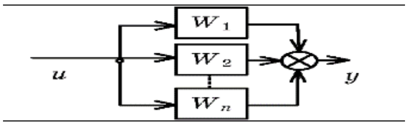
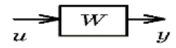
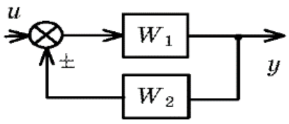
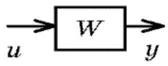
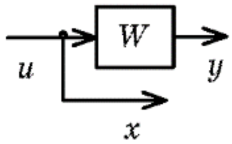
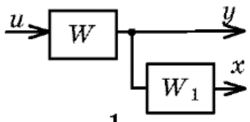
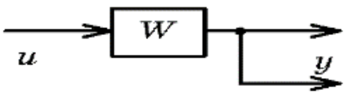
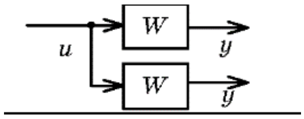
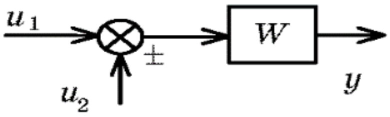
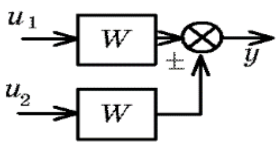
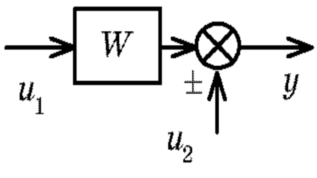
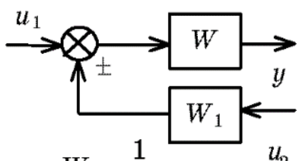
$$y(p)=\frac{W_1(p)\cdot W_2(p)\cdot W_3(p)}{1+W(p)}x(p)$$

$$y(p)=\frac{G_{f2}(p)W_3(p)}{1+W(p)}F_2(p) \quad \Rightarrow \quad y(p)=\frac{G_{f2}(p)}{1+W(p)}F_2(p)$$

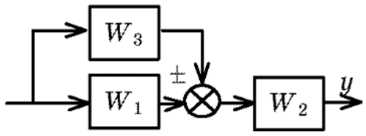
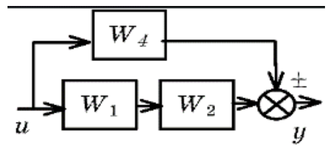
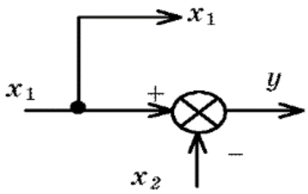
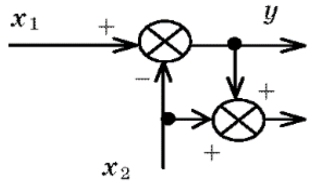
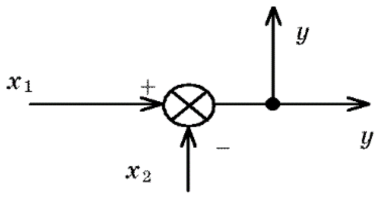
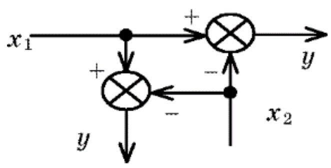
Hamma qo‘zg‘atuvchi ta‘sirlarning bir vaqtda ta‘siridan hosil bo‘lgan reaksiyani quyidagicha ifodalash mumkin.

$$y(p)=\frac{W_1W_2W_3x(p)+W_2W_3F_1(p)+G_{f2}W_3F_2(p)+G_{f3}F_3(p)}{1+W(p)};$$

4.1-jadval

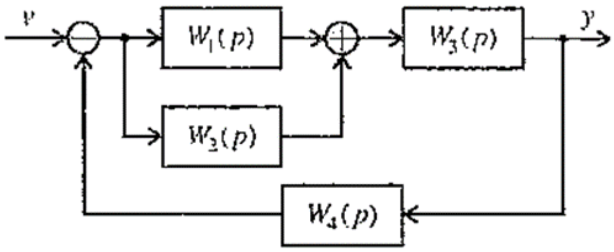
Struktura sxemalarini o‘zgartirish qoidalari		
O‘zgartirish	Struktura sxemasi	
	Berilgani	Ekvivalenti
Ketma-ket bog‘lanishni yoyish		 $W=W_1W_2...W_n$
Parallel bog‘lanishni yoyish		 $W=W_1+W_2+...+W_n$
Teskari bog‘lanishni yoyish		 $W=\frac{W_1}{1\pm W_1W_2}$
Uzelni zvenodan keyinga o‘tkazish		 $W_1=\frac{1}{W}$
Uzelni zvenodan oldinga o‘tkazish		
Yig‘ish elementini zvenodan keyinga o‘tkazish		
Yig‘ish elementini zvenodan oldinga o‘tkazish		 $W_1=\frac{1}{W}$

4.1-jadvalnning davomi

To‘g‘ri bog‘lanishni zveno orqali o‘tkazish		
Bog‘lanish uzelini yig‘ish elementi orqali keyinga o‘tkazish		
Bog‘lanish uzelini yig‘ish elementi orqali oldinga o‘tkazish		

4.1 - masala

Dastlab tipik ulangan zvenolarning uzatish funksiyalarini aniqlaymiz (4.6-rasm):



4.6-rasm. Sistemaning strukturali sxemasi

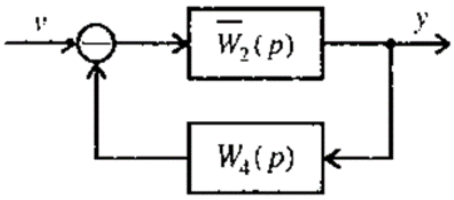
Parallel ulangan zvenolarning uzatish funksiyasi:

$$\overline{W}_1(p) = W_1(p) + W_2(p),$$

ketma-ket ulangan zvenolarning uzatish funksiyasi

$$\overline{W}_2(p) = \overline{W}_1(p) W_3(p)\,.$$

Kiritilgan belgilashlarni hisobga olib sistemaning tuzilishini 4.7-rasmda ko‘rsatilgan ko‘rinishga keltirish mumkin:



4.7- rasm. Ekvivalent sistemaning strukturali sxemasi

Strukturali o‘zgartirishlarida foydalanib, sistemaning umumiy uzatish funksiyasini yozamiz:

$$W(p) = \frac{\overline{W}_2(p)}{1+\overline{W}_2(p)\,W_4(p)}.$$

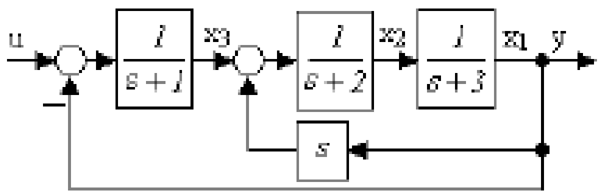
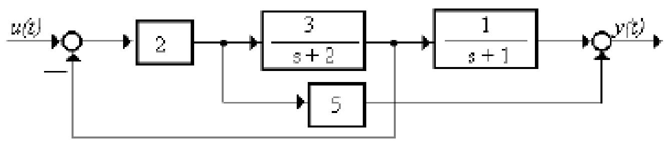
$\overline{W}_1(p)$ va $\overline{W}_2(p)$ larning o‘rniga qiymatlarini qo‘yib, quyidagiga ega bo‘lamiz:

$$W(p) = \frac{\left[W_1(p)+W_2(p)\right]W_3(p)}{1+\left[W_1(p)+W_2(p)\right]W_3(p)W_4(p)}.$$

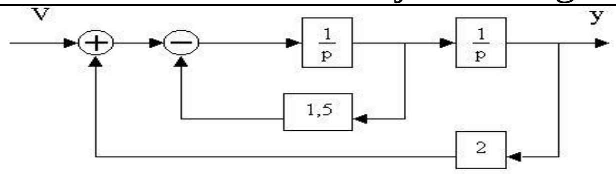
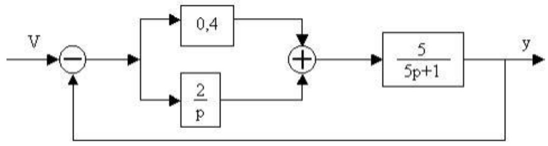
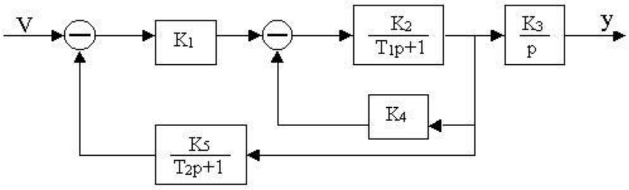
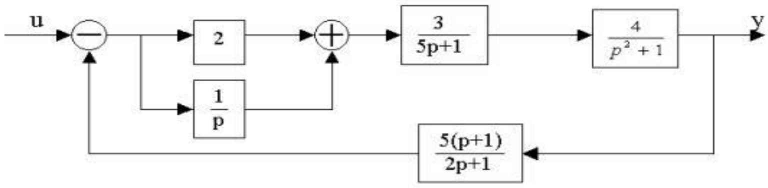
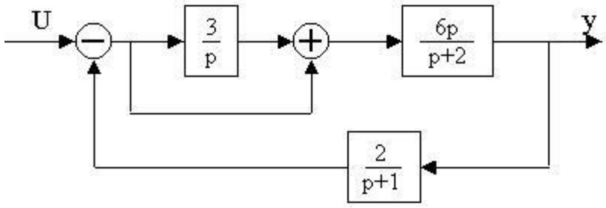
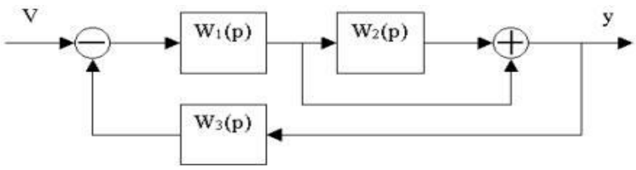
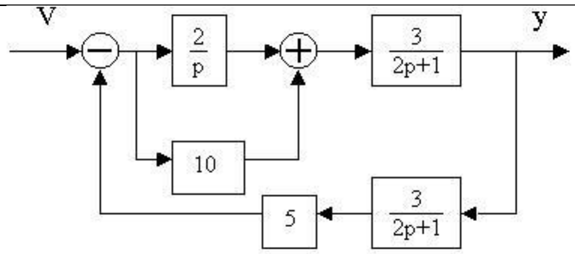
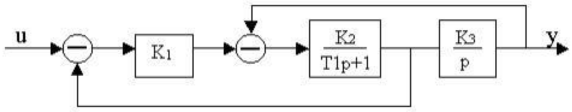
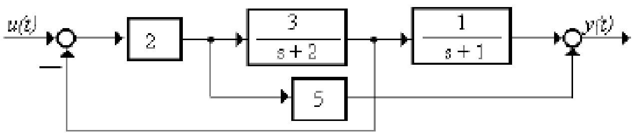
Topshiriqlar

1.1. Quyida tizimning strukturaviy sxemasi keltirilgan. Strukturaviy sxemadan foydalanib tizimning uzatish funksiyasini aniqlang.

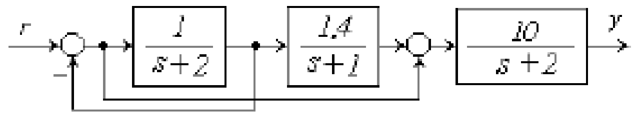
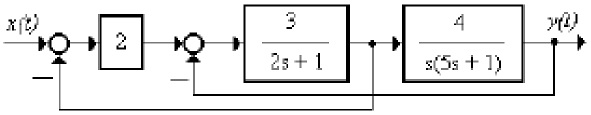
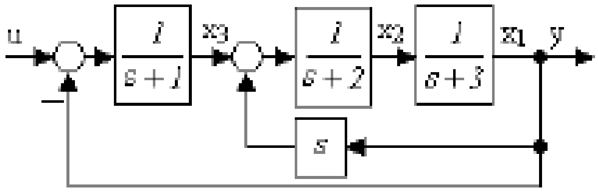
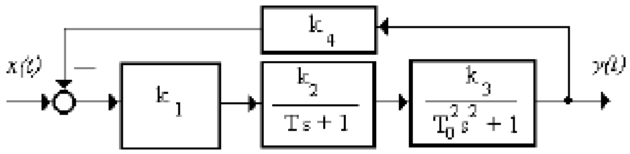
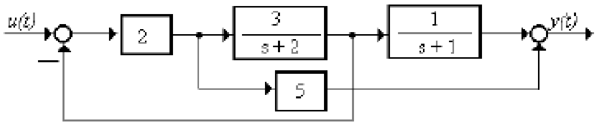
4.2-jadval

№	Tizimning strukturaviy sxemasi
1	
2	

4.2-jadvalning davomi

3	
4	
5	
6	
7	
8	
9	
10	
11	

4.2-jadvalning davomi

12	
13	
14	
15	
16	

Nazorat savollari

1. Struktura sxemasi nima?
2. Struktura sxemasi qay tartibda ulanadi?
3. Parallel va ketma-ket ulangan zvenolar uchun struktura sxemasi qanday bo‘ladi?
4. Teskari aloqa orqali ulangan zvenolardachi?

5-Amaliy mashg‘ulot
Boshqarish sistemalarining turg‘unligini tahlil qilish

Avtomatik boshqarish tizimlarining ishlash qobiliyatiga qo‘yilgan talab, ularning turli xil tashqi qo‘zg‘atuvchi ta‘siriga nosezgir bo‘lishiga mo‘ljallangan bo‘lishidir.

Agarda sistema turg‘un bo‘lsa, unda u tashqi qo‘zg‘atuvchi ta‘sirlarga bardosh bera oladi va o‘zining muvozanat holatidan chiqarilganda yana ma‘lum aniqlikda shu holatiga qaytib keladi. Agarda sistema noturg‘un bo‘lsa, unda u tashqi qo‘zg‘atuvchi ta‘sir natijasida muvozanat holati atrofida cheksiz katta amplitudaga ega bo‘lgan tebranishlar hosil qiladi yoki muvozanat holatidan cheksiz uzoqlashadi.

Agarda har qanday cheklangan kirish kattaligining absolyut qiymatida chiqish kattaligi ham cheklangan qiymatga ega bo‘lsa, bunday sistema *turg‘un* deb yuritiladi.

Rauss – Gurvits algebraik mezoni. Bu mezon 1877 yilda ingliz olimi Rauss va 1893 yilda nemis matematigi Gurvits tomonidan ta‘riflangan:

n-tartibli chiziqli tizimning turg‘un bo‘lishi uchun berilgan tizimning xarakteristik tenglamasida koeffitsiyentlardan tashkil topgan p ta aniqlovchilar musbat bo‘lishi zarur va yetarli:

$$a_0 p^n + a_1 p^{n-1} + a_2 p^{n-2} + ... + a_{n-1} p + a_n = 0 \qquad (5.1)$$

Bunda quyidagi qoidalarga asosan koeffitsiyent $a_0 > 0$ bo‘lishi kerak:

1) asosiy diagonal bo‘yicha o‘sish tartibida a_1 dan a_n gacha barcha koordinatalar ko‘chirib yoziladi;
2) aniqlovchining barcha ustunlari diagonaldan yuqoriga indekslari o‘sayotgan koeffitsiyentlar, diagonal elementlaridan pastga esa indekslari kamayuvchi koeffitsiyentlar bilan to‘ldiriladi;
3) eng katta tartibli Gurvits aniqlovchisi tizimning xarakteristik tenglamasi darajasiga to‘g‘ri keladi;
4) n dan katta indeksli koeffitsiyentlar nolga teng;
5) indekslari noldan kichik bo‘lgan koeffitsiyentlar nolga tenglashtiriladi;
6) oxirgi Δ_n aniqlovchi $a_n\Delta_{n-1}$ ga teng. Shunga muvofiq Gurvits aniqlovchilari quyidagicha bo‘ladi:
7)

$$\Delta_1 = a_1; \quad \Delta_2 = \begin{vmatrix} a_1 & a_3 \\ a_0 & a_2 \end{vmatrix}; \quad \Delta_3 = \begin{vmatrix} a_1 & a_3 & a_5 \\ a_0 & a_2 & a_1 \\ 0 & a_1 & a_3 \end{vmatrix}$$

va hokazo.

Gurvits aniqlovchisining umumiy ko‘rinishi esa:

$$\Delta_n = \begin{vmatrix} a_1 & a_3 & a_5 & a_7 & \dots & 0 \\ a_0 & a_2 & a_4 & a_6 & \dots & 0 \\ 0 & a_1 & a_3 & a_5 & \dots & 0 \\ 0 & a_0 & a_2 & a_4 & \dots & 0 \\ 0 & \dots & \dots & \dots & \dots & 0 \end{vmatrix}$$

Rauss-Gurvits mezoni asosida eng sodda tizimlar turg'unligining quyidagi shartlari kelib chiqadi: 1) agar birinchi va ikkinchi tartibli tizimlarda xarakteristik tenglamaning barcha koeffitsiyentlari musbat bo'lsa, bu tizimlar turg'un bo'ladi; 2) agar uchinchi tartibli tizimda xarakteristik tenglamaning barcha koeffitsiyentlari musbat bo'lib, $a_1 \cdot a_2 > a_0 \cdot a_3$ bo'lsa, tizim turg'un bo'ladi; 3) agar xarakteristik tenglamaning barcha koeffitsiyentlari musbat bo'lib, $a_1 \cdot a_2 \cdot a_3 > a_0 \cdot a_3^2 \cdot a_4 \cdot a_1^2$ bo'lsa, to'rtinchi tartibli tizim turg'un hisoblanadi.

Rauss-Gurvits mezonidan foydalanilganda Δ_1 dan Δ_n gacha barcha aniqlovchilarni hisoblashning keragi yo'q. Masalan, uchinchi tartibli tizimning turg'unligini aniqlash kerak bo'lsa, uchta aniqlovchidan birini topishning o'zi kifoya. a_4 va a_5 koeffitsiyentlar Δ_3 aniqlovchida nolga teng:

$$\Delta_2 < \begin{vmatrix} a_1 & a_3 \\ a_0 & a_2 \end{vmatrix} = a_1 a_2 - a_0 a_3 \ .$$

Agar Δ_2 aniqlovchi musbat bo'lsa, Δ_3 aniqlovchi ham musbat bo'ladi. $\Delta_3 = a_3 \Delta_2 > 0$, chunki $a_3 > 0$. Δ_1 aniqlovchi esa ma'lum $(\Delta_1 = a_1)$ va musbat (chunki $a_1 > 0$). Algebraik mezon beshinchi tartibdan oshmaydi va u kechikishsiz chiziqli tizimlar uchun ancha qulay.

Mixaylov geometrik mezoni. Chiziqli avtomatik rostlash tizimining turg'unlik mezoni A.V. Mixaylov tomonidan 1938 yilda taklif etilgan. Kompleks o'zgaruvchining tekisligidagi rostlash tizimining xarakteristik tenglamasi orqali aniqlanuvchi vektor tizimning xarakteristik tenglamasi (5.1) dagi ω kattalik mavhum $j\omega$ argument bilan almashtirish yo'li bilan topiladi:

$$L(j\omega) = a_n (j\omega)^n + a_{n-1}(j\omega)^{n-1} + \dots + a_1 (j\omega) + a_0 \qquad (5.2)$$

$j = \sqrt{-1}; \quad j^2 = -1; \quad j^3 = -j; \quad j^4 = 1; \dots$ ekanligini esga olamiz. (5.2) xarakteristik funksiya tarkibiga kirgan barcha juft darajali $j(\omega)$ qo'shiluvchilar haqiqiy, toq darajaligi esa mavhum kattalik bo'ladi. Demak:

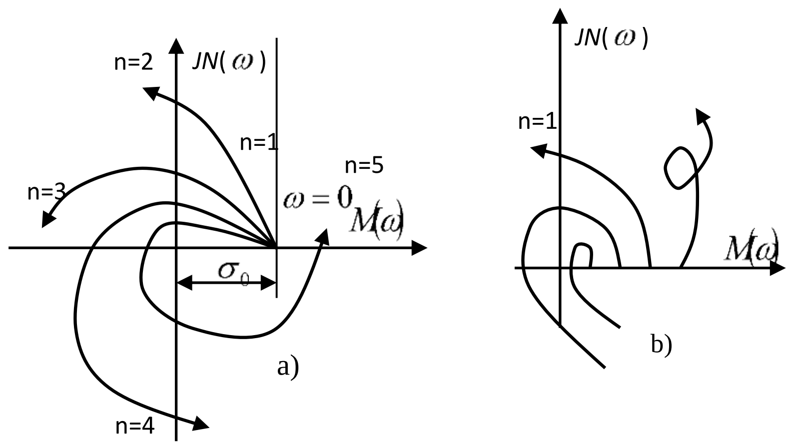
$$L(j\omega) = M(\omega) + jN(\omega),$$

bunda

$$M(\omega) = a_0 - a_2\omega^2 + a_4\omega^4 - \ldots,$$
$$N(\omega) = a_1 - a_3\omega^3 + a_5\omega^5 - \ldots.$$

Agar ω ni 0 dan ∞ gacha ketma-ket o‘zgartirsak, vektor Mixaylov godografi nomli egri chiziqni hosil qiladi. Kompleks tekislikdagi godograf shakli bo‘yicha tadqiq qilinayotgan tizimning turg‘unligi haqida fikr yuritish mumkin. Mixaylov kriteriysi quyidagicha ifodalanadi: Agar $L(j\omega)$ xarakteristik funksiyasining godografi ω ning 0 dan ∞ gacha o‘zgarishida musbat yo‘nalishda kompleks tekislikning n kvadrantlarining birontasini ham tushirib qoldirmay aylanib chiqsa (n – ko‘rilayotgan tizim xarakteristik tenglamasining darajasi), rostlash tizimi turg‘un bo‘ladi. Bu xususiy holda soat strelkasining harakatiga teskari yo‘nalish musbat hisoblanadi.

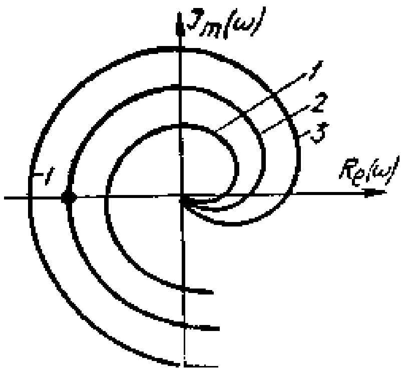
Agar (5.1) yoki (5.2) ifodalarda $\omega=0$ deb faraz qilinsa, $L(j\omega)=a_0$ bo‘ladi. Boshqacha qilib aytganda $\omega=0$ bo‘lsa, godograf haqiqiy o‘qni koordinata boshidan a_0 masofada turgan nuqtada kesib o‘tadi. Agar $M(\omega)$ o‘zgaruvchi ω ning juft, $N(\omega)$ esa toq funksiyasi ekanligini e‘tiborga olsak, godograf haqiqiy o‘qqa nisbatan simmetrik joylashadi degan xulosaga kelamiz. Shuning uchun ω ning 0 dan ∞ gacha o‘zgarishida godografning yarim tarmog‘ini qurishning o‘zi kifoya (5.1-rasm).



5.1 - rasm. Mixaylov godograflari:
a – turg‘un tizimlar uchun; b – noturg‘un tizimlar uchun

5.1-rasmda birinchi tartibdan beshinchi tartibgacha bo‘lgan turg‘un va noturg‘un tizimlar uchun Mixaylov godograflari ko‘rsatilgan. Birinchi tartibli tenglamaga – mavhum o‘qqa parallel bo‘lib, undan a_0 masofada turgan to‘g‘ri chiziq mos keladi. Yuqori tartibli tizimlarga egri chiziqlar mosdir. Mixaylov mezonidan kechikishga ega bo‘lgan turg‘un chiziqli tizimlarni o‘rganishda ham foydalanish mumkin.

Naykvist-Mixaylov chastota mezoni. Bu mezon 1932 yilda elektron kuchaytirgichlarning turg‘unligini tadqiq qilish uchun Naykvist tomonidan taklif etilgan. Avtomatik rostlash nazariyasida chastota mezoni 1936 yilda umumlashtirilgan holda qo‘llanilgan. Tutashmas tizimning tahlilida Naykvist-Mixaylov amplituda-faza mezonidan foydalanib, rostlash tizimining turg‘unligi haqida fikr yuritiladi. Turg‘unlikni bu metod bo‘yicha o‘rganishda tajriba usulida aniqlangan amplituda-faza tavsiflardan foydalaniladi. Nihoyat, mezon tizimning turg‘unlik darajasi haqida ma‘lumot olishga imkon beradi. Agar tizim noturg‘un bo‘lsa, Naykvist-Mixaylov mezoni tizimni stabillashtirish va to‘g‘rilovchi zveno hamda konturlar yordamida tutash tizimning istalgan tavsifiga erishish yo‘llarini ko‘rsatadi (5.1-rasm).



5.2-rasm. Turli tizimlar uchun amplituda-faza tavsiflarining namunalari:
1 – turg‘un tizimlar uchun; 2 – turg‘unlikka yaqin tizimlar uchun;
3 –noturg‘un tizimlar uchun

Bu mezonning ifodasi quyidagicha: tutashmas holatda turg‘un bo‘lgan avtomatik rostlash tizimi agar tutashmas tizimning amplituda faza tavsifi ω ning 0 dan ∞ gacha o‘zgarishida (-1,10) koordinatalarga ega bo‘lgan nuqtaga yetmasa, yopiq holatda ham turg‘un bo‘ladi.

5.2-rasmda turg‘un va noturg‘un, shuningdek, turg‘unlik chegarasida turgan tizimlarning ochiq holatidagi amplituda-faza tavsiflari keltirilgan. Birinchi tartibli differensial tenglamalar orqali tavsiflanuvchi tizimlarning AFX bir kvadrantda joylashadi. Ikkinchi tartibli differensial tenglamalar orqali tavsiflanuvchi tizimlarning AFX ikki kvadrantga joylashadi. Xarakteristik tenglamalarning koeffitsiyentlari musbat bo‘lsa, bu tizimlar turg‘un bo‘ladi.

5.1-misol. Gurvits kriteriyasi yordamida tizimning turg‘unligini baholang:

$$3p^4 + 4p^3 + 4p^2 + 2p + 1 = = 0.$$

Turg‘unlikning zaruriy sharti:

$A_0 = 3 > 0$, $A_1 = 4 > 0$, $A_2 = = 4 > 0$, $A_3 = 2 > 0$, $A_4 = 1 > 0$.

Turg‘unlikning yetarlilik sharti:

$$\Delta_1 = 4 > 0;$$

$$\Delta_2 = \begin{vmatrix} A_1 & A_3 \\ A_0 & A_2 \end{vmatrix} = \begin{vmatrix} 4 & 2 \\ 3 & 4 \end{vmatrix} = 16 - 6 = 10 > 0;$$

$$\Delta_3 = \begin{vmatrix} A_1 & A_3 & A_5 \\ A_0 & A_2 & A_4 \\ 0 & A_1 & A_3 \end{vmatrix} = \begin{vmatrix} 4 & 2 & 0 \\ 3 & 4 & 1 \\ 0 & 4 & 2 \end{vmatrix} = 32 + 0 + 0 - 0 - 12 - 16 = 4 > 0;$$

$$\Delta_4 = \begin{vmatrix} A_1 & A_3 & 0 & 0 \\ A_0 & A_2 & A_4 & 0 \\ 0 & A_1 & A_3 & 0 \\ 0 & A_0 & A_2 & A_4 \end{vmatrix} = \begin{vmatrix} 4 & 2 & 0 & 0 \\ 3 & 4 & 1 & 0 \\ 0 & 4 & 2 & 0 \\ 0 & 3 & 4 & 1 \end{vmatrix} = 1 \cdot \Delta_3 = 4 > 0.$$

Barcha shartlar bajarildi demak tizim turg‘un ekan.

5.2-misol. Mixaylov kriteriyasi yordamida

$$D(p) = 2p^3 + 9p^2 + 13p + 6.$$

tizimning turg‘unligini tekshiring.
Yechilishi. Xarakteristik polinomini yozamiz

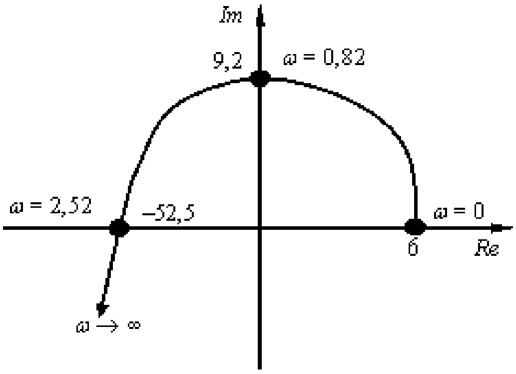
$$D(p) = 2p^3 + 9p^2 + 13p + 6.$$

P ni $j\omega$ ga almashtirib

$D(jw) = 2(jw)^3 + 9(jw)^2 + +13(jw) + 6 = -2jw^3 - 9w^2 + +13jw + 6 = (6 - 9w^2) + j(13w - 2w^3)$ ifodani olamiz.
$A(_{j\omega})$ haqiqiy va mavhum qismlarga ajratamiz

$Re(w) = 6–9w^2$; $Im(w) = 13w – 2w^3$.

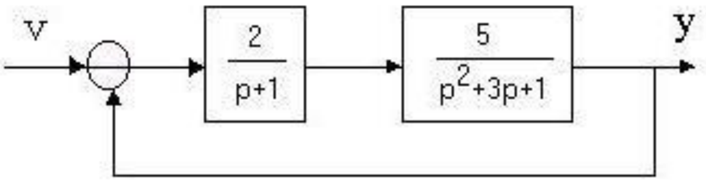
ω ni 0 dan to ∞ o‘zgartirib, Mixaylov godografini quramiz (5.3-rasm):



5.3-rasm. Mixaylov godografi

Bundan ko‘rinadiki, tizim turg‘un.

5.3 - misol. Naykvist kriteriyasi yordamida tizimning turg‘unligini tekshiring (5.4-rasm).



5.4-rasm. Yopiq bog‘lanishli tizim sxemasi

Yechilishi. Ochiq tizimning uzatish funksiyasini topamiz

$$W_p(p) = \frac{2}{p+1} \times \frac{5}{p^2+3p+1} = \frac{10}{p^3+4p^2+4p+1}$$

r ni $j\omega$ almashtirib, tizimning chastataviy xarakteristikasiga o‘tamiz:

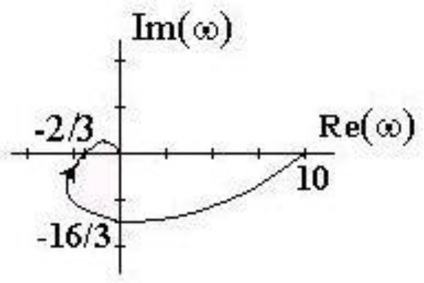
$$W_p(j\omega) = \frac{10}{(1-4\omega^2)+j(4\omega-\omega^3)}$$

Haqiqiy va mavhum qismlarga ajratamiz

$$\begin{cases} \mathrm{Re}(\omega) = \dfrac{10(1-4\omega^2)}{(1-4\omega^2)^2 + (4\omega - \omega^3)^2}; \\ \mathrm{Im}(\omega) = \dfrac{10(4\omega - \omega^3)}{(1-4\omega^2)^2 + (4\omega - \omega^3)^2}; \end{cases}$$

ω ni 0 dan to ∞ o‘zgartirib, ochiq tizimning AFX ni quramiz (5.5-rasm).

ω	0.5	2	∞
Im(ω)	16/3	0	0
Re(ω)	10	-2/3	0



5.5-rasm. Ochiq tizimning amplituda-faza xarakteristikasi

Shunday qilib, ochiq tizimning AFX si koordinata nuqtalarga (-1; *j*0) ega bo‘lmayapti, shuning uchun ochiq tizim turg‘un emas.

Topshiriqlar

Agar tizimning differensial tenglamalari quyidagi ko‘rinishga ega bo‘lsa, u holda tizimning turg‘unligini Gurvits, Naykvist va Mixaylov kriteriyalari yordamida tekshiring:

5.1-jadval

№	Obyektning differensial tenglamasi
1	$y''' + 7y'' - 5y' = 5u$
2	$y''' + 2y'' + y' = 2u$
3	$2y''' + y' + 3y = 10u$
4	$y''' + 4y'' + 2y' = 12u$
5	$4y''' + 4y'' + 2y' + y = 4u$
6	$4y''' + 4y'' + 2y' = 6u$
7	$5y''' + 4y'' + 2y' + 3y = 11u$

5.1-jadvalning davomi

8	$y''' + 2y' + 3y = 9u$
9	$7y''' + 10y'' + 2y' + y = 3u$
10	$3y'' + 5y' + y = 15u$
11	$13y'' + 8y' + 2y = 7u$
12	$2y''' + 4y'' + 8y' + y = 11u$
13	$5y''' + 2y' + 3y = 8u$
14	$4y'' + 2y' + 10y = 5u$
15	$5y''' + 4y'' + 13y = 2u$
16	$23y'' + 18y' + 2y = 9u$
17	$y''' + 22y'' + 3y = 5u$
18	$y''' - 15y' = 8u$
19	$y''' + 2y'' + 16y = 2u$
20	$3y''' + 17y'' - y' = 15u$
21	$3y'' + 28y' + 32y = 19u$
22	$y''' + 2y' = 11u$
23	$11y''' + y'' - 15y' = 6u$
24	$18y'' + 2y' + 12y = 9u$
25	$y''' + 10y'' - 8y' = 8u$
26	$y''' + 12y'' + y' = 4u$
27	$13y'' + 18y' + 21y = 2u$
28	$7y''' + 7y'' - 3y = 7u$
29	$9y''' + 7y'' + y = 12u$
30	$y''' + 8y' - 4y = 15u$

Nazorat savollari

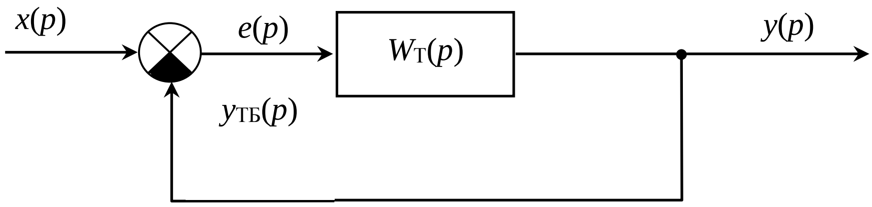
1. Dinamik sistemalarning turg‘unligi?
2. Turg‘unlikning Gurvits mezoni?
3. Turg‘unlikning chastotaviy mezonlari?
4. Turg‘unlikning Naykvist mezoni?

6-Amaliy mashg‘ulot

Korrektlovchi moslamalarni logarifm amplituda chastotaviy xarakteristika (LACHX) lar yordamida sintez qilish

Avtomatik sistemani tekshirganda o‘tkinchi jarayonning sifatini ta‘minlashga doir masalalarni yechishga to‘g‘ri keladi. O‘tkinchi jarayonning aniqligini va rostlash bir tekisligini xarakterlovchi sifat ko‘rsatkichlarga o‘tkinchi jarayon tezkorligi (o‘tkinchi jarayon vaqti), tebranishlar soni (o‘tkinchi jarayonning tebranishlar soni) hamda o‘tarostlash kiradi.

O‘zgarmas koeffitsiyentli chiziqli differensial tenglama bilan ifodalangan chiziqli sistema berilgan bo‘lsin (6.1-rasm).:



6.1-rasm. Chiziqli differensial tenglama bilan ifodalangan chiziqli sistema sxemasi

Kirish kattaligi $x(t)$ o‘zgarganda sistemaning chiqishidagi $y(t)$ kattalikning o‘zgarishini quyidagicha ifodalash mumkin

$$y(t) = y_э(t) + y_м(t)\,, \tag{6.1}$$

bunda $y(t)$ - sistemani ifoda etuvchi tenglamaning umumiy yechimi; $y_э(t)$ - shu yechimning erkin tashkil etuvchisi. Agar $y_э(t)$ karra ildizga ega bo‘lmasa, unda

$$y_э(t) = \sum_{i=1}^{n} C_i e^{p_i t} \tag{6.2}$$

bunda C_i - sistemaning parametrlari va boshlang‘ich shartlarga bog‘liq bo‘lgan o‘zgarmas son; p_i - berk sistemaning xarakteristik tenglamasi, $A(p) = 0$ ildizlaridir. $y_м(t)$ - kirish signali $x(t)$ning o‘zgarishiga bog‘liq bo‘lgan o‘tkinchi jarayonning qaror rejimini ifodalovchi majburiy tashkil etuvchidir.

(1) tenglamadan ko‘rinib turibdiki, o‘tkinchi jarayonning sifatini uning $y_э(t)$ va $y_м(t)$ tashkil etuvchilari yordamida aniqlash mumkin, shu nuqtai nazardan qaraganda rostlash jarayonining sifatini aniqlash yoki baholash ikki guruhga bo‘linadi.

Birinchi guruh. O‘tkinchi jarayon $y_э(t)$ning sifat ko‘rsatkichi.

Ikkinchi guruh. Sistemaning aniqligini belgilovchi o‘tkinchi jarayonning majburiy tashkil etuvchi xarakterlovchi ko‘rsatkichlari.

O‘tkinchi jarayon egri chizig‘i bo‘yicha aniqlangan sifat ko‘rsatkichlarini sistemaning sifatini *bevosita baholash usuli* deyiladi.

O‘tkinchi jarayon egri chizig‘ini tajriba hamda nazariy olish mumkin. Ayrim hollarda yuqori tartibli sistemalar uchun o‘tkinchi jarayon egri chizig‘ini aniqlash ancha qiyinchilik tug‘diradi. Shunday hollarda o‘tkinchi jarayon egri chizig‘ini aniqlamasdan turib shu jarayonning sifatini baholashga imkon beruvchi usulning sifat ko‘rsatkichlarini baholashning *bilvosita usuli* deyiladi.

6.1-misol. Berilgan uzatish funksiyasidan ketma-ket ulangan korrektrlovchi moslamaning LACHX sini toping.

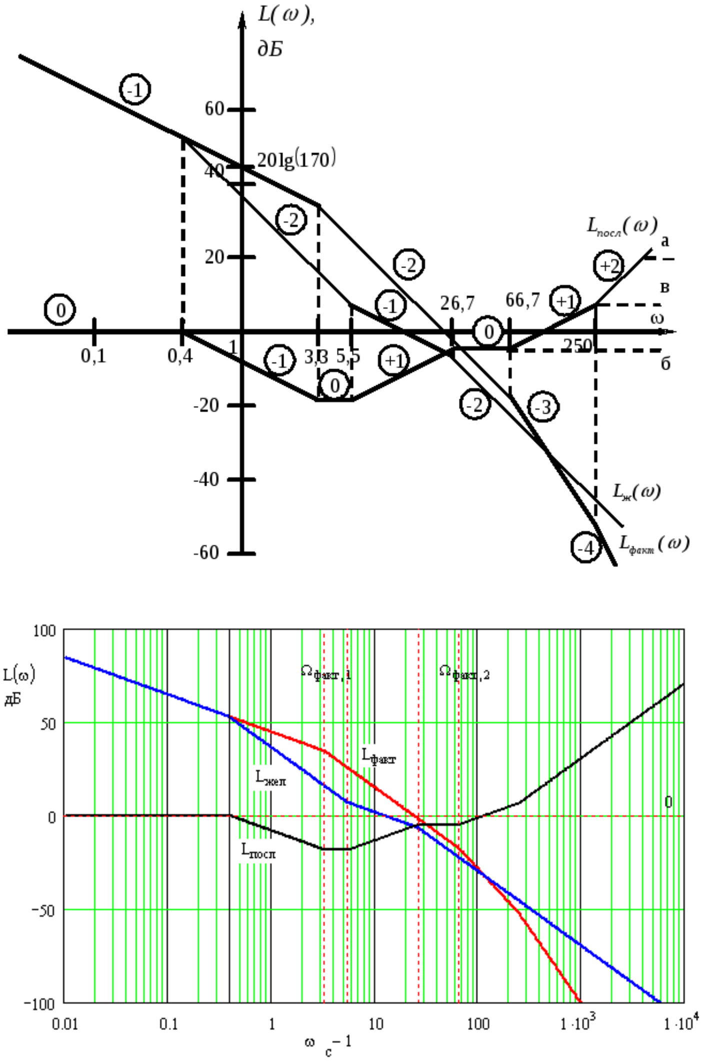
$$W_{посл}(p) = \frac{(0{,}3p+1)(0{,}182p+1)(0{,}015p+1)(0{,}004p+1)}{(2{,}56p+1)(0{,}038p+1)}.$$

$$\frac{T_{k.k4}}{T_{k.k5}} = \frac{0.038}{0.015} = 2.53,$$

U holda uzatish funksiyasi quyidagi ko‘rinishda bo‘ladi:

$$W_{посл}(p) = \frac{(0{,}3p+1)(0{,}182p+1)}{(2{,}56p+1)(0{,}038p+1)}$$

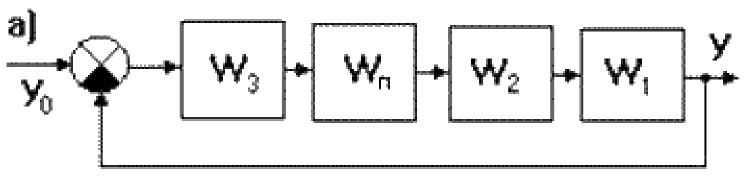
Uzatish funksiyasidan kelib chiqqan holda LACHX quyidagi ko‘rinishda bo‘ladi (6.2-rasm):



6.2-rasm.-Ketma-ket ulangan zvenoning LACHX sini aniqlash.

Topshiriqlar

Ketma-ket ulangan zvenolarning LACHX sini quring (6.3-rasm)..



6.3-rasm. Ketma-ket ulangan zvenolar

bu yerda:

$W_1 = \frac{K}{p}$; $W_2 = \frac{K_2}{Tp+1}$; $W_3 = \frac{K_3}{Tp+1}$; $W_4 = \frac{K_4}{Tp+1}$;

6.1-jadval

№	Obyektning uzatish funksiyasi
1	$K = 1; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 3s; T_3 = 5s; T_4 = 4s$
2	$K = 1; K_2 = 7; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 6s; T_3 = 5s; T_4 = 4s$
3	$K = 1; K_2 = 1; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 3s; T_3 = 1s; T_4 = 4s$
4	$K = 5; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 3s; T_3 = 5s; T_4 = 4s$
5	$K = 9; K_2 = 6; K_3 = 7; K_4 = 8$ $T = 2s; T_2 = 3s; T_3 = 6s; T_4 = 4s$
6	$K = 1; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 7s; T_2 = 3s; T_3 = 5s; T_4 = 4s$
7	$K = 1; K_2 = 4; K_3 = 6; K_4 = 9$ $T = 2s; T_2 = 3s; T_3 = 9s; T_4 = 4s$
8	$K = 5; K_2 = 7; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 3s; T_3 = 8s; T_4 = 4s$
9	$K = 1; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 0.2s; T_3 = 5s; T_4 = 0.4s$
10	$K = 1; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 12s; T_2 = 0.3s; T_3 = 5s; T_4 = 4s$
11	$K = 1; K_2 = 3; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 3s; T_3 = 0.55s; T_4 = 4s$
12	$K = 1; K_2 = 1.4; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 1.3s; T_3 = 5s; T_4 = 4s$
13	$K = 1; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 2.2s; T_2 = 3s; T_3 = 5s; T_4 = 1.4s$
14	$K = 1; K_2 = 4; K_3 = 2.6; K_4 = 8$ $T = 5s; T_2 = 0.13s; T_3 = 5s; T_4 = 4s$
15	$K = 1; K_2 = 4; K_3 = 6; K_4 = 1.8$ $T = 2s; T_2 = 2.3s; T_3 = 5s; T_4 = 4s$
16	$K = 1; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 6.3s; T_3 = 5s; T_4 = 2.s$
17	$K = 5; K_2 = 4; K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 0.3s; T_3 = 5s; T_4 = 1.4s$
18	$K = 1; K_2 = 4; K_3 = 2.6; K_4 = 8$ $T = 7s; T_2 = 2.3s; T_3 = 5s; T_4 = 4s$

6.1-jadvalning davomi

19	$K = 11; K_2 = 0.4;\ K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 0.3s;\ T_3 = 5s; T_4 = 0.4s$
20	$K = 1; K_2 = 4;\ K_3 = 6; K_4 = 8$ $T = 0.2s; T_2 = 3s;\ T_3 = 1.5s; T_4 = 1.4s$
21	$K = 1; K_2 = 1.4;\ K_3 = 6; K_4 = 8$ $T = 2s; T_2 = 1.2s;\ T_3 = 0.5s; T_4 = 4s$
22	$K = 8; K_2 = 4;\ K_3 = 6; K_4 = 8$ $T = 3.2s; T_2 = 2.3s;\ T_3 = 5s; T_4 = 40.s$

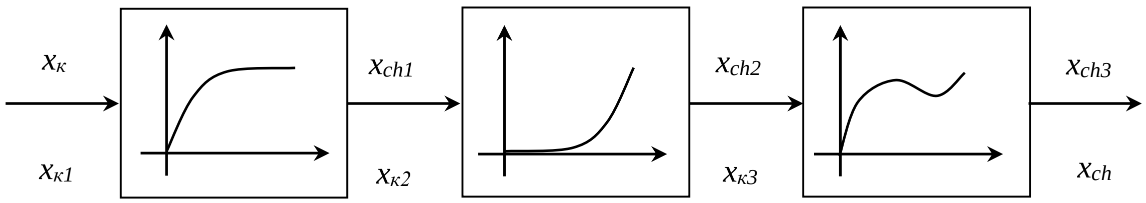
Nazorat savollari

1. Rostlash jarayonining sifatini aniqlash necha xil bo‘ladi?
2. O‘tkinchi jarayon nima?
3. Bevosita baholash usuli haqida ma‘lumot bering.
4. Bilvosita baholash usuli haqida ma‘lumot bering.
5. Sifat ko‘rsatkichlari deganda nimani tushunasiz?

7- Amaliy mashg‘ulot
Nochiziqli sistemalarning statik xarakteristikasini qurish

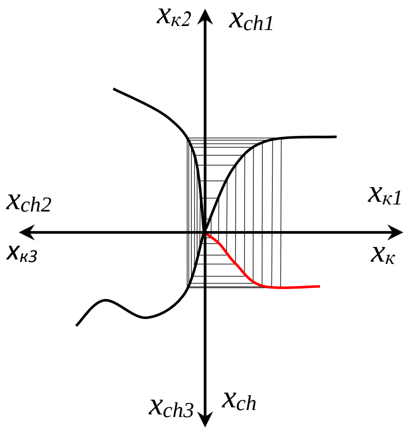
Sistemaning xususiyatlari ularning statik va dinamik xarakteristikalari orqali ifodalanadi. Statik xarakteristika deb sistemaning muvozanat holatida uning kirish va chiqish signallari orasidagi munosabatga aytiladi. Statik xarakteristikalar tenglama, jadval yoki grafik shakllarda berilishi mumkin. Nochiziqli sistemalarning statik xarakteristikalari uning tarkibiga kiruvchi elementning statik xarakteristikalariga va ulanish qoidalariga bog‘liq bo‘ladi.
Statik xarakteristikalari grafik shaklda berilgan elementlar ketma-ket ulangan bo‘lsin.

1. **Elementlar ketma-ket ulangan bo‘lsin** (7.1-rasm)**.**



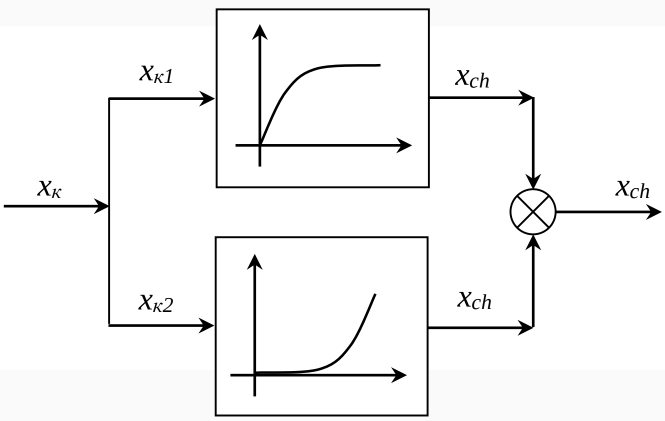
7.1-rasm. Ketma-ket ulangan nochiziqli statik xarakteristikalar

Sistemaning statik xarakteristikasini topish uchun to‘g‘ri chiziqli koordinatalar sistemasidan foydalanamiz (7.2-rasm):



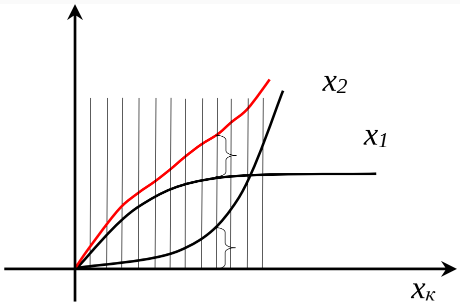
7.2-rasm. Ketma-ket ulangan nochiziqli sistemaning statik xarakteristikasini koordinata tekisligidagi yechimi grafikasi

Agar 2 ta statik xarakteristika ketma-ket berilgan bo‘lsa, K=1 ya‘ni uchinchi chorakdan 45° li burchak ostida o‘tkazib yuborladi. Sistemaning elementlar parallel ulangan bo‘lsin (7.3-rasm):



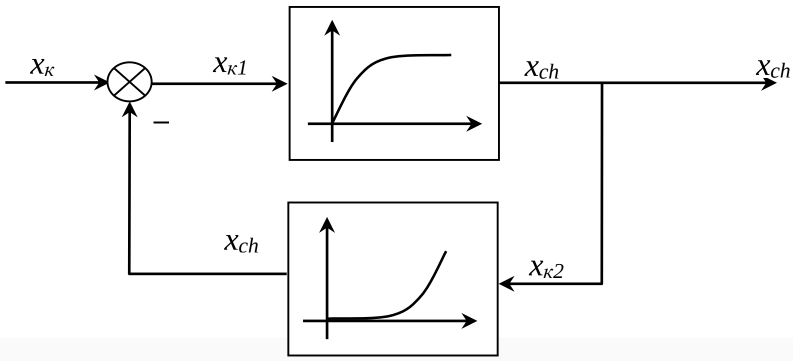
7.3-rasm. Parallel ulangan nochiziqli statik xarakteristikalar

Sistemaning statik xarakteristikasini topish uchun grafikni qo‘shish orqali umumiy grafik chiqariladi (7.4-rasm):

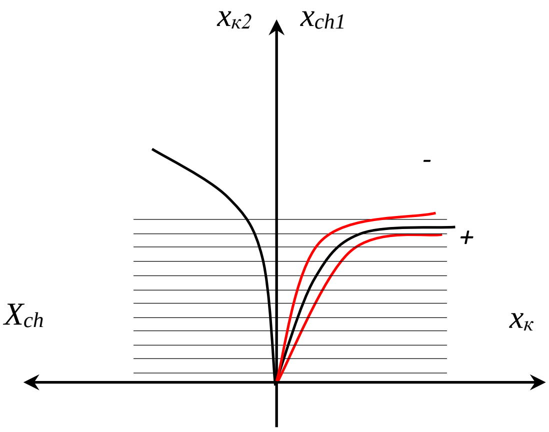


7.4-rasm. Parallel ulangan nochiziqli sistemaning statik xarakteristikasini koordinata tekisligidagi yechimi grafikasi

3. Sistemaning elementlari teskari aloqa orqali ulangan bo‘lsa (7.5-rasm):



7.5-rasm. Teskari aloqa orqali ulangan nochiziqli statik xarakteristikalar

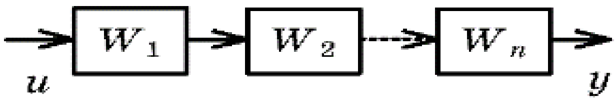


7.6-rasm. Teskari aloqa orqali ulangan nochiziqli sistemaning statik xarakteristikasini koordinata tekisligidagi yechimi grafikasi

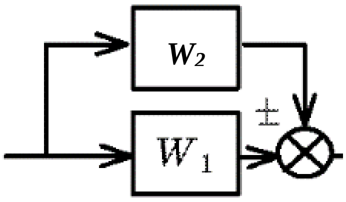
Topshiriqlar

Sistemaning umumiy statik xarakteristikasini toping.

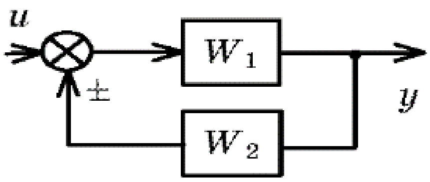
1)



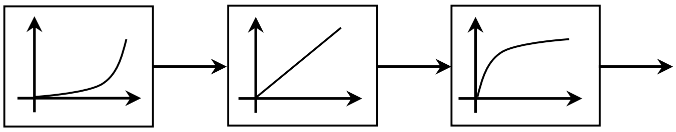
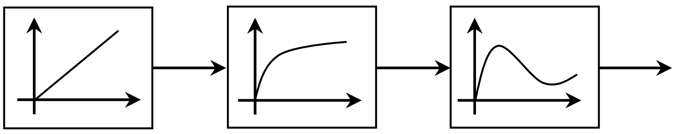
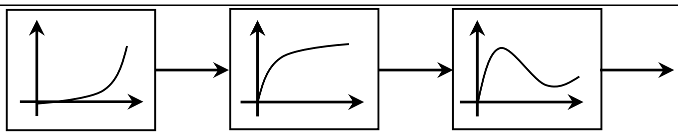
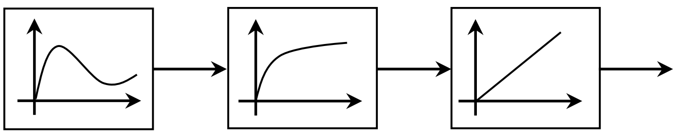
2)



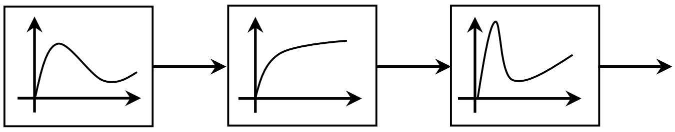
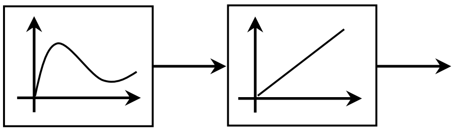
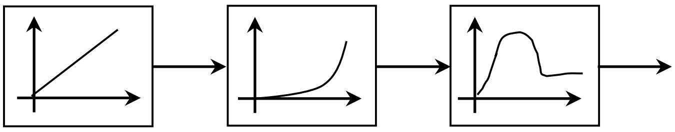
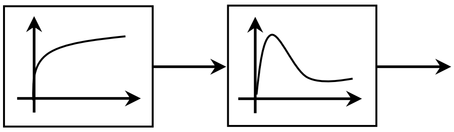
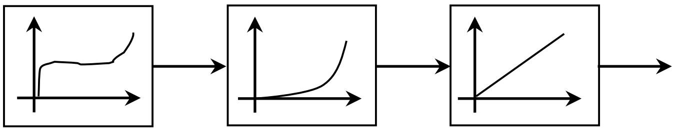
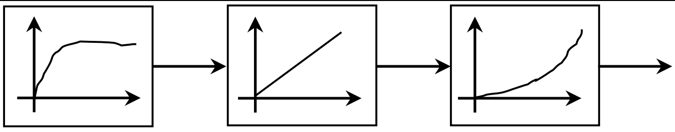
3)



7.1-jadval

№	Obyektning statik xarakteristikalari
1	
2	
3	
4	

7.1-jadvalning davomi

5	
6	
7	
8	
9	
10	

Nazorat savollari

1. Nochiziqli tizim nima?
2. Statik xarakteristika nima?
3. Nochiziqli elementlarning statik xarakteristikalari tavsiflang.
4. Musbat va manfiy teskari aloqa orqali ulangan nochiziqli sistemaning statik xarakteristikasini farqi nimada?

8 - Amaliy mashg'ulot
Garmonik balans usulida nochiziqli avtomatik boshqarish sistemalarini tahlil qilish

Bu usul dinamikasi ikki va undan yuqori tartibli nochiziqli differensial tenglama bilan yoziluvchi sistemalarni tekshirish, nochiziqli sistemalarning majburiy harakatini taqriban tahlil qilish, sistemasining turg'unligini mavjud bo'ladigan avtotebranishlar parametrlarini aniqlash imkonini beradi.

Avtotebranishni aniqlashning 2 usuli mavjud:

1) Analitik usul.
2) Chastotoviy usul (Goldfarb usuli).

1. Analitik usul.

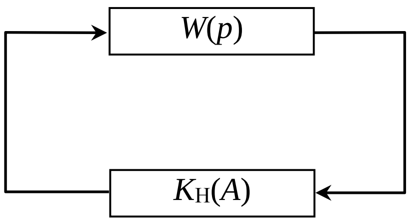
Ushbu usuldan foydalanishda sistemaning strukturasi quyidagi ko‘rinishga keltirib olinadi (8.1-rasm).

Bunda chiziqli qismning ko‘rinishi quyidagiga ega

$$W(p) = \frac{A(p)}{B(p)}.$$

Berk sistemaning uzatish funksiyasi topiladi

$$W_{\acute{A}}(p) = \frac{W(p)}{1 + W(p) \cdot K_H(A)}.$$



8.1-rasm. Berk sistemaning strukturali sxemasi

Berk sistemaning xarakteristik tenglamasini nolga tenglaymiz

$$1 + W(p) \cdot K_H(A) = 0,$$

$$1 + \frac{A(p)}{B(p)}\left[q(A) + \int q'(A)\right] = 0,$$

$$B(p) + A(p)\left[q(A) + \int q'(A)\right] = 0.$$

$p \to j\omega$ bilan almashtirib xarakteristik tenglamaning haqiqiy va mavhum qismlar topiladi. Haqiqiy va mavhum qismlar amplituda A va chastota ω ga bog‘liq munosabat ko‘rinishda bo‘ladi, ya‘ni

$$X(A, \omega) + jY(A, \omega) = 0$$

Ularni nolga tenglab, tenglamalar sistemasining hosil qilamiz

$$\begin{cases} X(A, \omega) = 0, \\ Y(A, \omega) = 0. \end{cases}$$

Agarda tenglamalar sistemasining yechimi haqiqiy va musbat qiymatga ega bo‘lsa, sistemada avtotebranish mavjud bo‘ladi.

2. Goldfarb usuli

Bu usul uncha murakkab bo‘lmagan sistemalar uchun qo‘llanilib, chiziqli qism filtrlilik xususiyatiga ega bo‘lishi kerak. Bunda sistema ikki qismga ajratib olinadi: chiziqli va nochiziqli.

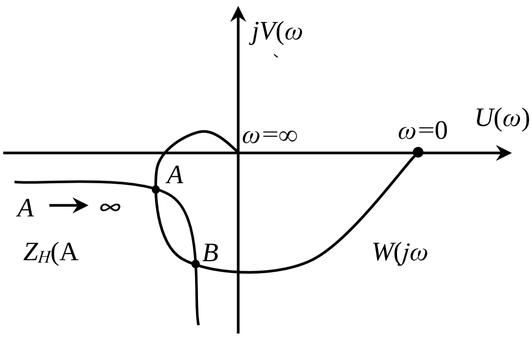
Avtotebranishni topish algoritmi quyidagidan iborat:

1. Chiziqli qismning AFXsi quriladi.
2. Nochiziqli elementning teskari uzatish funksiyasi topiladi:

$$Z_H(A) = -\frac{1}{K_H(A)} = -\frac{1}{q(A) + jq'(A)}.$$

Amplitudani 0 dan ∞ gacha o‘zgartirib, nochiziqli elementning teskari AFXsi quriladi.

2. Popov mezoni: Agarda ikkala AFX o‘zaro kesishsa sistemada o‘zaro avtotebranish mavjuddir (8.2-rasm).

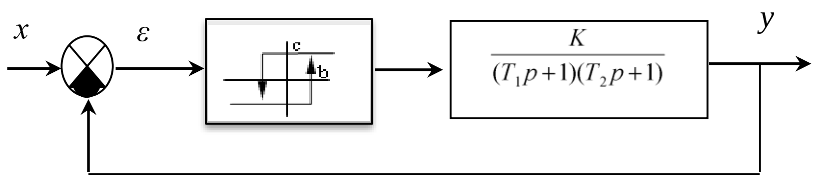


8.2-rasm. Sistemaning avtotebranish grafigi

Agarda amplituda 0 dan ∞ ga o‘zgarganda nochiziqli elementning AFXsi chiziqli qismning AFXsining konturiga kirsa shu nuqtada noturg‘un avtotebranish mavjud. Konturdan chiqadigan nuqtada turg‘un avtotebranish mavjud.

8.1-misol. Agar chiziqli qism parametrlari va nochiziqli zveno statistik xarakteristikasi ma‘lum bo‘lsa, 8.3-rasmda keltirilgan struktur sxemali nochiziqli sistemaning turg‘unligini tadqiq qiling.

a) strukturaviy sxema



8.3-rasm. Nochiziqli sistema struktur sxemasi

b) elementlarning uzatish koeffitsiyentlari va vaqt doimiyligi:

K = 1395 grad/s; T_1 = 0,25s; T_1 = 0,3 s.

d) nochiziqli element parametrlari: b = 3; c =5;

Avtotebranishlar hosil bo‘lishi imkoniyati quyidagi tartibda tekshiriladi:

Berilgan shartlar

$$\left.\begin{array}{l} \rightarrow W_{ch}(p) \rightarrow W_{ch}(j\omega) = U_{ch}(\omega) + jV_{ch}(\omega) \left| \begin{array}{l} \rightarrow U(\omega) \\ \rightarrow V(\omega) \end{array} \right. \\ \rightarrow W_n(A) = \dfrac{1}{\pi a} \displaystyle\int_0^{2\pi} f(A\sin\varphi)\sin\varphi \rightarrow Z_n(A) = -1/W_n(A) \end{array} \right\} \begin{array}{l} W_{ch}(j\omega) = Z_n(A) \rightarrow \\ \rightarrow A_a\omega_a \end{array}$$

Bu hisoblash sxemasiga asosan

$$W_{ch}(j\omega) = W_{ch}(p)\big|_{p=j\omega} = \left[\frac{K(1-\omega^2 T_1 T_2)}{T_1^2 T_2^2 \omega^4 - \omega^2 (T_1 + T_2) + 1} - \right.$$

$$\left. - j\frac{K\omega(T_1+T_2)}{T_1^2 T_2^2 \omega^4 - \omega^2 (T_1 + T_2) + 1} \right].$$

Son qiymatlari o‘rniga qo‘yib, topamiz.

$$U(\omega) = \frac{1395(1-0{,}075)}{0{,}005625\omega^4 - 0{,}55\omega^2 + 1};$$

$$V(\omega) = \frac{1395\omega(0{,}25+0{,}3)}{0{,}005625\omega^4 - 0{,}55\omega^2 + 1}.$$

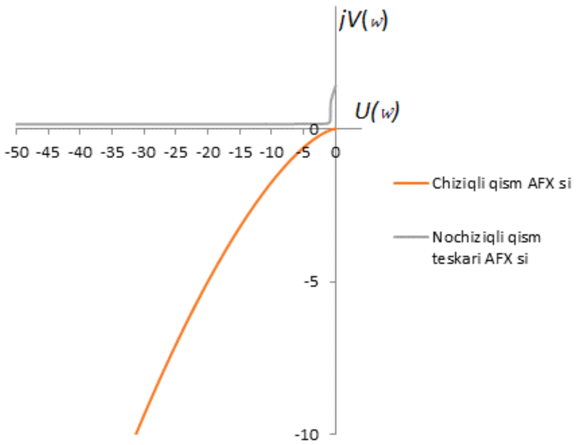
Berilgan nochiziqli elementning ekvivalent uzatish koeffitsiyenti W_n ni quyidagicha topiladi.

q(a)= $\frac{4c}{\pi a}\sqrt{1-\frac{b^2}{a^2}}$; q‘(a)= $-\frac{4c}{\pi a^2}$;

$$W_n = \frac{4c}{\pi a}\sqrt{1-\frac{b^2}{a^2}}\ j - \frac{4c}{\pi a^2};$$

$$Z_n = \frac{\pi a^2\sqrt{a^2-9}}{20(a^2-8)} + j\frac{\pi a^2}{20(a^2-8)}$$

Bu formulaga b va c ning son qiymatlarini qo‘yib va A ni 3 dan ∞ gacha o‘zgartirib, kompleks tekislikda $Z_n(A)$ ni chizamiz. Shu tekislikda ω ga 0 dan ∞ gacha qiymat berib, $W_{ch}(j\omega)$ ni quramiz (8.4-rasm). Rasmda chiziqli sistema va nochiziqli sistema AFXlari tasvirlangan.

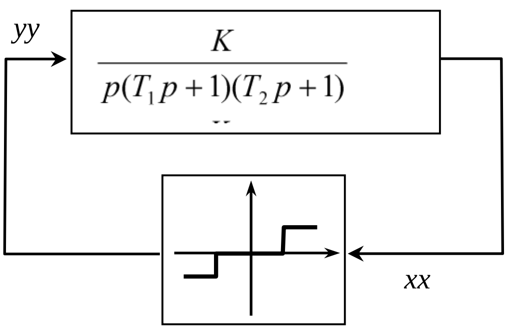


8.4-rasm. Chiziqli qism AFXsi va nochiziqli elementning garmonik xarakteristkasi

Goldfarb usuliga asosan chiziqli qism AFX si va nochiziqli qism teskari AFX si kesishsagina sistemada avtotebranish mavjud bo‘lar edi. Ko‘rilayotgan sistemada AFX lar kesishmaganligi tufayli sistemada avtotebranish mavjud emas.

Topshiriqlar

Keltirilgan nochiziqli sistemaning turg‘unligini tadqiq qiling (8.5-rasm).



8.5-rasm. Nochiziqli tizim sxemasi

8.1-jadval

№	Chiziqli qism parametrlari		
	k, sekund	T_1, sekund	T_2, sekund
1.	0.8	0.3	0.4
2.	0.2	0.3	0.5
3.	1	0.5	0.5
4.	0.3	0.2	0.3
5.	0.56	0.3	1
6.	0.6	0.5	0.5
7.	0.1	0.2	1.2
8.	0.8	1.02	0.65
9.	1	0.45	0.32
10	0.3	0.32	0.45
11	0.45	0.3	0.4
12	0.6	0.5	0.7
13	0.8	0.89	0.98
14	0.23	0.2	0.5
15	0.9	0.45	0.2
16	0.56	0.6	0.2
17	0.1	0.58	0.3
18	0.3	0.98	0.1
19	0.45	1	0.15
20	0.18	0.16	1
Nochiziqli zvenoning statistik xarakteristikasi			
b	*c*	*b*	*c*
0.25	110	1.6	102
0.2	100	0.87	98
0.3	110	1.08	100
0.1	90	1.02	110
0.5	120	0.96	99
0.6	95	0.5	105
0.25	110	0.6	106
0.37	100	0.32	110
0.42	98	0.15	98

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