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

NAMANGAN MUXANDISLIK-TEXNOLOGIYA INSTITUTI

«Fizika» kafedrasi

«Avtomatik boshqarish nazariyasi»

fanidan amaliy va mustaqil mashg`ulotlar uchun uslubiy ko`rsatma

Namangan– 2015

Ushbu uslubiy ko`rsatma 55211800 - «Avtomatlashtirish va boshqaruv» va 5311000 – «Texnologik jarayonlar va ishlab chiqarishni avtomatlashtirish va boshqarish (to`qimachilik, engil va paxta sanoati)» yo`nalishlari bakalavrlari uchun «Avtomatik boshqarish nazariyasi» fanidan amaliy va mustaqil ishlarini bajarishga mo`ljallangan bo`lib, chiziqli sistemalarni tadqiq etish masalalarini o`z ichiga olgan.

Uslubiy ko`rsatma – «Avtomatik boshqarish nazariyasi» fanining o`quv dasturi asosida tuzilgan.

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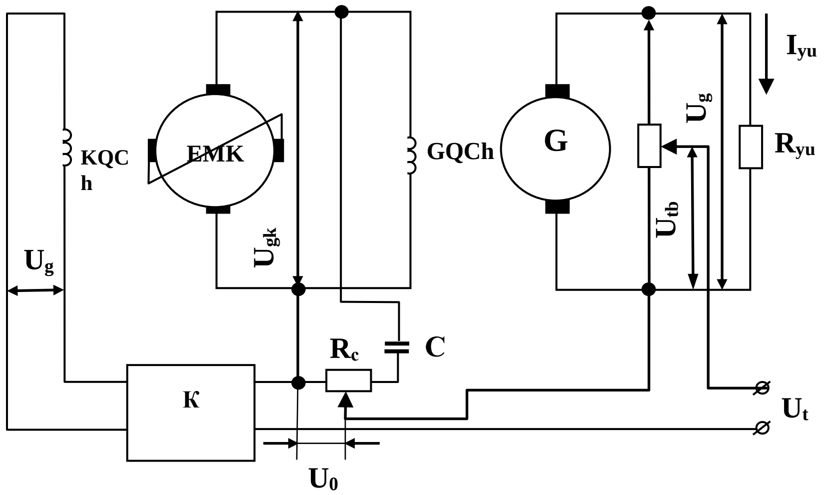
Bayonnoma №__ __ «_ _»____ ______2015 y.

1. Prinsipial sxemalar bo`yicha funksional sxemalar tuzish

1.1-masala

O`zgarmas tok generatori kuchlanishini avtomatik rostlash tizimining funksional sxemasini tuzish.

Rostlash tizimining prinsipial sxemasi 1.1-rasmda keltirilgan. Tizim quyidagicha ishlaydi: rostlanadigan kattalik – generator U_g kuchlanishiga proporsional teskari bog`lanish kuchlanishi $U_{t.b.}$ taqqoslash kuchlanishi $U_t$ bilan solishtiriladi. $U_t$ - $U_{t.b.}$ kuchlanishlar farqi elektron kuchaytirgich K, generator G ning qo`zg`atuvchisi hisoblangan ko`ndalang maydonli elektromashinaviy kuchaytirgichi EMK ning manba boshqarish chulg`ami BCh kirishiga keladi. Tizimning dinamik ustuvorligini ta`minlash uchun EMK kuchlanshi bo`yicha kondensator C va rostlovchi qarshilik R_s yordamida amalga oshiriladigan mo``tadillovchi mahalliy teskari bog`lanish nazarda tutilgan. Asosiy teskari bog`lanish kattaligi rostlagich qarshilik R_o orqali o`rnatiladi.



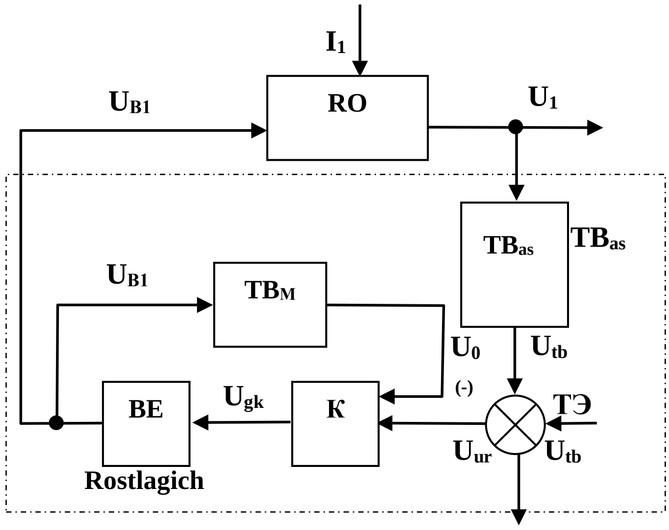
1.1-rasm. O`zgarmas tok generatori kuchlanishini avtomatik rostlash tizimining soddalashtirilgan prinsipial sxemasi

Avtomatik rostlash tizimini funksional bo`laklarga ajratganda, birinchi navbatda generator G ni ko`rsatamiz. Uni rostlash ob`ekti RO sifatida qaraymiz. Generatorga rostlovchi ta`sir hisoblangan qo`zg`atish kuchlanishi U_{gq} va to`lqinlantiruvchi ta`sir – I_{yu} yuklama toki ta`sir qiladi.

Rostlanadigan U_g kuchlanishi asosiy teskari bog`lanish elementi TB_{as} orqali $U_{t.b}$ kuchlanishiga aylantiriladi va taqqoslash elementi TE yordamida U_t kuchlanishi bilan solishtiriladi. Kuchaytirgich elementi sifatida elektron kuchaytirgich K qabul qilingan, EMK esa ushub holda bajaruvchi element BE hisoblanadi.

SR_s mo``tadillovchi konturni mahalliy teskari bog`lanish elementi $TB_m$ sifatida tasavvur qilamiz. Uning kirish kattaligi EMK kuchlanishi, chiqish kattaligi kuchaytirgich kirishiga beriladigan mahalliy teskari bog`lanish signali hisoblanadi U_t - $U_{t.b.}$ asosiy signaldan hisoblanadigan U_o kuchlanishidir.

Generator kuchlanishini rostlash tizimini keltirilgan elementlarga bo`lgach, 1.2-rasmda keltirilgan funksional sxema hosil bo`ladi.

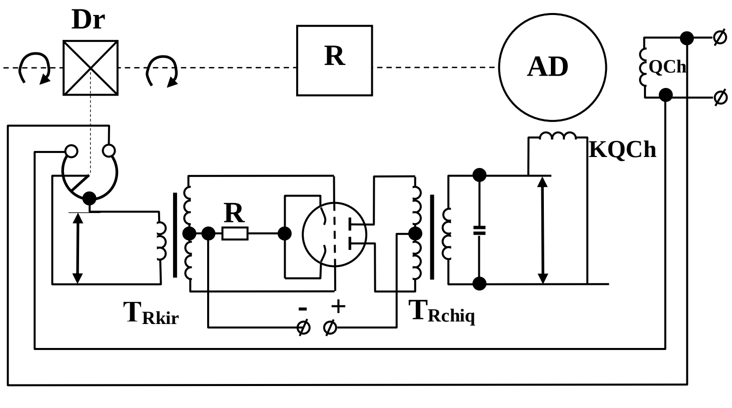


1.2-rasm. O`zgarmas tok generatori kuchlanishini avtomatik rostlash tizimining funksional sxemasi

1.2-masala

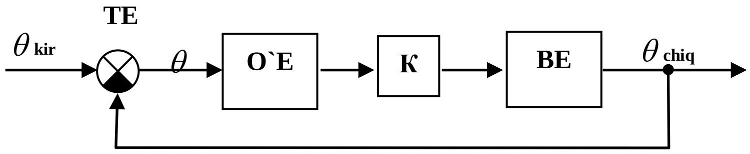
Ikki fazali asinxron dvigatelli AD oddiy kuzatuvchi tizimning funksional sxemasini tuzing.

Kuzatuvchi tizimning prinsipial sxemasi 1.3-rasmda keltirilgan. Tizim quyidagi prinsip bo`yicha ishlaydi. Tizimning kirish va chiqish o`qi holatini P potensiometr harakatlantirgichi bog`langan DR mexanik differensiali taqqoslaydi. Ikkilangan triod L asosida yig`ilgan bir kaskadli U lampali kuchaytirgichda P potensiometrdan olinadigan U_s kuchlanish kuchaytiriladi. Ikki fazali asinxron dvigatelning boshqaruvchi chulg`amiga kuchaytirgichning chiqish kuchlanishi $U_k$ beriladi. Asinxron dvigatelning boshqaruvchi chulg`ami potensiometr ulangan o`zgaruvchan kuchlanish manbaidan ta`minot oladi. Chiqish transformatorining ikkinchi chulg`amiga parallel ulangan S kondensator, $U_k$ kuchlanishini dvigatel qo`zg`atish chulg`amining kuchlanishiga moslashtirish vazifasini bajaradi.



1.3-rasm. Ikki fazali asinxron sodda dvigatelli kuzatuvchi tizimning prinsipial sxemasi

Mexanik diferensialni taqqoslash elementi TE, potensiometrni o`zgartiruvchi element O`E deb qabul qilsak, 1.4-rasmda keltirilgan funksional sxemaga ega bo`lamiz. Sxemada asinxron dvigatel reduktor bilan birga bitta bajaruvchi elementda BE joylashtirilgan.



1.4-rasm. Kuzatuvchi tizimning funksional sxemasi

1.3-masala

Asinxron taxogenerator ATG va ikki fazali AD asinxron dvigatelli kuzatuvchi tizimni funksional sxemasini tuzing.

Tizimning ishlash prinsipi 1.5-rasmdagi tasvir orqali izohlanishi mumkin. Kuzatuvchi tizimning kirish va chiqish o`qlari $P_1$ topshiriq va $P_2$ qayta ishlovchi potensiometrlarning harakatlantirgichiga bog`langan. $\Theta=\Theta_{kir}-\Theta_{chiq}$ xatoligiga proporsional potensiometrlardan olingan kuchlanish asinxron taxogeneratorning teskari bog`lanishidan olinadigan $U_0$ kuchlanishiga algebraik qo`shiladi va ikki kaskaddan iborat lampali kuchaytirgich kirishiga keladi. Birinchi kaskad fazoinversli bo`lib, L1 lampasida yig`ilgan. Birinchi kaskad dastlabki kuchaytirishni amalga oshiradi, ikki taktli so`nggi kaskadlar (L1, L2 lampalar)ni boshqaradi. Bu kaskadlar $Tr_{chiq}$ tranzistori orqali asinxron dvigatelning boshqaruvchi chulg`amida ishlaydi. Dvigatel` chulg`amidagi S kondensator ta`minot kuchlanishini boshqaruv chulg`amidagi kuchlanishga nisbatan 90^0 fazaga aylantiradi. Kuzatuvchi tizim boshqaruvchi va qayta ishlovchi signallar elektrik kattalik yig`indisi shaklida taqqoslanadigan distansion tizimlar qatoriga kiradi.

Tizimning funksional sxemasi 1.6,a-rasmda keltirilgan. Sxemada ikkita o`zgartiruvchi element O`E mavjudligi, kirish va chiqish o`qlaridan tashqari, ularga proporsional $P_1$ va $P_2$ potensiometrlardan olinadigan $U_{p1}$ va $U_{p2}$ kuchlanishlarning burilish burchagi taqqoslanadi. Tizimning qolgan elementlari – lampali kuchaytirgich, tizimning chiqish o`qining $\Omega_{чик}$ aylanish tezligini U_0 kuchlanishga aylantiruvchi asinxron taxogenerator yordamida amalga oshiriluvchi mahalliy va teskari bog`lanish va reduktorli dvigateldan iborat.

1.6,a-rasmda keltirilgan sxema bitta o`zgartiruvchi elementga ega ekvivalent sxemaga aylantirilishi mumkin (1.6,b-rasm). Bu sxemada kirish signallari bevosita taqqoslanadi. U_{p1} va U_{p2} kuchlanishlarini quyidagicha ifodalash mumkin:

$$U_{p1} = k_{n1}\Theta_{кир},\ U_{p2} = k_{n2}\Theta_{чик}$$

Bu erda, k_{n1}, k_{n2} – potensiometrni uzatish koeffisientlari.

Ikkinchi taqqoslash elementiga beriladigan potensiometr kuchlanishlarining farqi

$$U_p=U_{p1}-U_{p2} = k_{n1}\Theta_{кир} - k_{n2}\Theta_{чик} \qquad (1.1)$$

Muvofiqlashtirish bo`lmasa, nolga teng bo`lishi kerak. Bundan kelib chiqadiki:

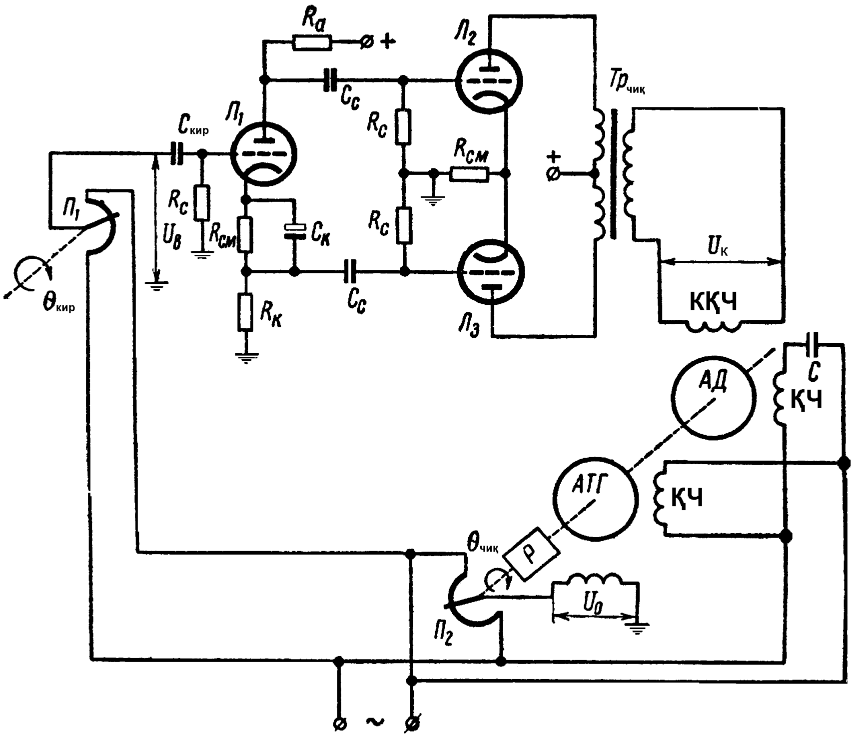
$$k_{n1}\Theta_{кир} = k_{n2}\Theta_{чик}$$

bunda, $\Theta_{кир} = \Theta_{чик}$, $k_{n1} = k_{n2} = k_n$ bo`lishi kerak.

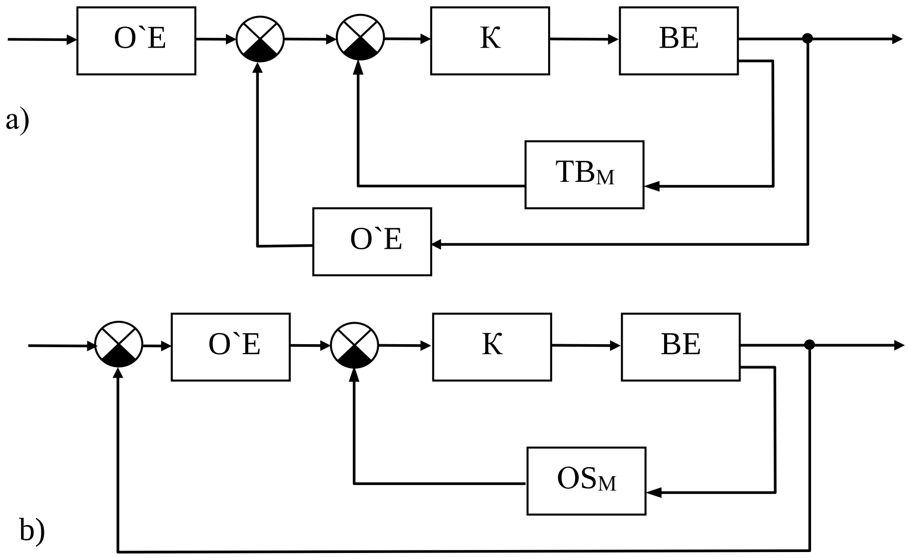
(1.1) ifodaga k_n ni qo`yib, quyidagi ifodaga ega bo`lamiz:

$$U_p = k_n\ (\Theta_{кир} - \Theta_{чик}) = k_n\ \Theta.$$

Bu esa 1.6,b-rasmda keltirilgan funksional sxemaga mos keladi.



1.5-rasm. Ikki fazali asinxron dvigatelli kuzatuvchi tizimning prinsipial sxemasi



1.6-rasm. Kuzatuvchi tizimning funksional sxemasi.

2. Differensial tenglamalar va bo`g`inlarning uzatish funksiyalari

2.1-masala

Elektr zanjirining (2.1-rasm) U_1 va U_2 kuchlanishga nisbatan uzatish funksiyasi va differensial tenglamasini toping.

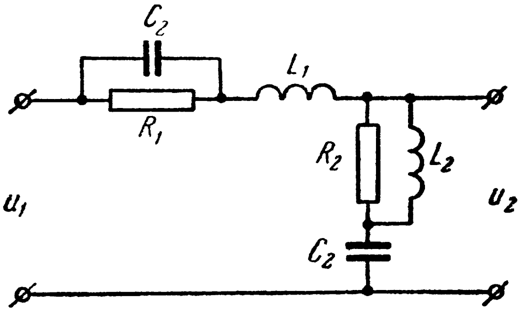
Echish: 2.1-rasmda keltirilgan elektr zanjirining uzatish funksiyasini topishda qarshilikning operator formasi – pL –induktiv, $\frac{1}{pC}$ –sig`im, R –aktiv qarshiliklardan (bu erda, $p = \frac{d}{dt}$ – differensiallash ramzi yoki operatori) foydalanish qulaydir.

2.1-rasmdagi elektr zanjirini ekvivalent sxemaga (2.2-rasm) aylantiramiz:

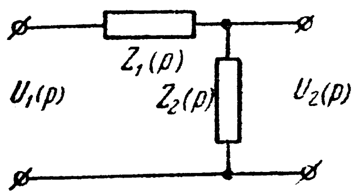
$$Z_1(p) = \frac{\frac{1}{pC_1} R_1}{R_1 + \frac{1}{pC_1}} + pL_1 = \frac{R_1(T_1 p^2 + T_{1L} p + 1)}{T_{1C} p + 1}, \tag{2.1}$$

$$Z_2(p) = \frac{R_2 L_2 p}{R_2 + L_2 p} + \frac{1}{C_2 p} = \frac{R_2(T_2^2 p^2 + T_{2L} p + 1)}{p(T_{2C} + T_2^2 p)}, \tag{2.2}$$

$$T_1 = \sqrt{C_1 L_1}, \; T_{2L} = \frac{L_1}{R_1}, \; T_{1C} = R_1 C_1, \; T_2 = \sqrt{C_2 L_2}, \; T_{2L} = \frac{L_2}{R_2}, \; T_{2C} = R_2 C_2 \text{ (sek)} \tag{2.3}$$



2.1-rasm. 1-masala uchun sxema



2.2-rasm. Ekvivalent sxema

Ketma-ket ulangan qarshiliklarda kuchlanish tushuvi qarshilikka proporsional bo`lgani uchun ekvivalent zanjirning uzatish funksiyasi quyidagicha topiladi:

$$W(p) = \frac{U_2(p)}{U_1(p)} = \frac{Z_{чик}(p)}{Z_{кир}(p)} = \frac{Z_2(p)}{Z_1(p) + Z_2(p)} \tag{2.4}$$

(2.1), (2.2) ni (2.4) ga qo`yib, elektr zanjirning uzatish funksiyasini topamiz:

$$W(p) = \frac{R_2(b_0 p^3 + b_1 p^2 + b_2 p^3 + b_3)}{R_2(b_0 p^3 + b_1 p^2 + b_2 p + b_3) + R_1(d_0 p^4 + d_1 p^3 + d_2 p^2 + d_3 p)} \tag{2.5}$$

$b_0 = T_2^2 T_{1C}$, $b_1 = T_2^2 + T_{2L} T_{1C}$, $b_2 = T_{2L} + T_{1C}$, $b_3 = 1$,

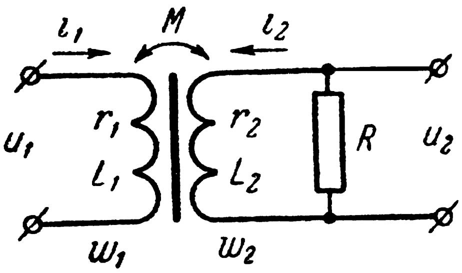
$d_0 = T_1^2 T_2^2$, $d_1 = T_1^2 T_{2C} + T_2^2 T_{1L}$, $d_2 = T_{1L} T_{2C} + T_2^2$, $d_3 = T_{2C}$,

Ko`rilayotgan elektr sxemaning kuchlanishga nisbatan differensial sxemasi quyidagi ko`rinishga ega:

$$[R(b_0 p^3 + ... + b_3) + R_1(d_0 p^4 + ... + d_3 p)]u_2(t) = R_2(b_0 p^3 + ... + b_3)u_1(t) \tag{2.6}$$

2.2-masala

Transformatorning (2.3-rasm) u_1 va u_2 kuchlanishga nisbatan differensial tenglamasi va uzatish funksiyasini toping. Transformatorning elektrik ko`rsatkichlari 2.3-rasmda keltirilgan.



2.3-rasm. 2.2-masala uchun sxema

<u>Echish:</u> Transformatorning birinchi va ikkinchi chulg`ami zanjiridagi kuchlanish muvozanatining differensial tenglamasi quyidagi ko`rinishga ega:

$$u_1 = r_1 i_1 + L_1 p i_1 + M p i_2 \tag{2.6}$$

$$0 = r_2 i_2 + L_2 p i_2 + M p i_1 + u_2 \tag{2.7}$$

Bu erda, r_1, L_1, i_1 – birlamchi chulg`am qarshiligi, induktivligi, toki; $r_2, L_2, i_2$ – ikkilamchi chulg`amning qarshiligi, induktivligi, toki; R –yuklamaning qarshiligi; u_1, u_2 –transformatorning kirish va chiqish kuchlanishlari; M -chulg`amlarning o`zaro induksiyaviy koeffisienti.

(2.6) tenglamadan tok ifodasini (2.7) ifodaga qo`ysak, transformatorning differensial tenglamasini topamiz:

$$[\frac{L_1 L_2 - M^2}{r_1(R+r_2)} p^2 + \frac{L_2 r_1 + L_1(R+r_2)}{r_1(R+r_2)} p + 1] u_2(t) = -\frac{MR}{r_1(R+r)} p u_1(t) \qquad (2..8)$$

yoki

$$[(T_1 T_2 - T_3^2) p^2 + (T_1 + T_2) p + 1] u_2(t) = -k\tau_1 p u_1(t) \tag{2.9}$$

Bu erda,

$$T_1 = \frac{L_1}{r_1},\ T_2 = \frac{L_2}{R+r_2},\ \tau_1 = \frac{M}{r_1},\ T_3 = \sqrt{\frac{M^2}{r_1(R+r_2)}}\ \text{(sek)},\ k = \frac{R}{R+r_2}.$$

Po`lat o`zakli transformatorlarda bog`lanish koeffisienti $\frac{M}{\sqrt{L_1 L_2}}$ birga yaqin bo`lgani uchun $M \approx \sqrt{L_1 L_2}$, $L_1 L_2 - M \approx 0$ yoki $T_1 T_2 - T_3^2 \approx 0$ bo`ladi. Bunda (2.9) transformatorning tenglamasi soddalashadi:

$$[(T_1 + T_2) p + 1] u_2(t) = -k\tau_1 p u_1(t) \tag{2.10}$$

Salt yurish rejimi uchun quyidagiga ega bo`lamiz:

$$(T_1 p + 1) u_2(t) = -\tau_1 p u_1(t)$$

(2.10) differensial tenglama asosida kuchlanish bo`yicha transformatorning uzatish funksiyasini quyidagicha yozish mumkin:

$$W(p) = \frac{U_2(p)}{U_1(p)} = -\frac{k\tau_1 p}{(T_1 + T_2) p + 1}$$

Bu ifodadan ko`rinib turibdiki, transformator inersial differensial bo`g`in hisoblanadi. Transformatorning differensial tenglamasidagi manfiy ishora chiqish kuchlanishining fazasi kirish kuchlanishidan $180^0$ ga farq qilishini ko`rsatadi.

<u>2.3-masala</u>

Sust RC elektr zanjirining (2.4-rasm) u_1 va u_2 kuchlanishga nisbatan differensial tenglamasi va uzatish funksiyasini toping.

Echish: Ko`prik elka toki

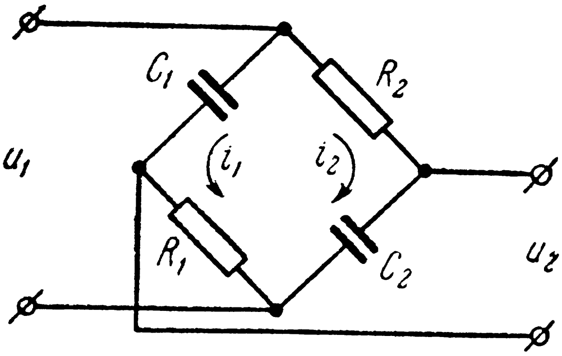
$$i_1 = \frac{u_1 C_1 p}{T_1 p + 1},\ i_2 = \frac{u_1 C_2 p}{T_2 p + 1},\ T_1 = R_1 C_1,\ T_2 = R_2 C_2,\ p = \frac{d}{dt}.$$

Unda,

$$u_2(t) = \frac{1}{C_2 p} i_2(t) - R_1 i_1(t) = \frac{1 - T_1 T_2 p^2}{(T_1 p + 1)(T_2 p + 1)} u_1(t)$$

Bu ifodadan differensial tenglama kelib chiqadi:

$$(T_1 p + 1)(T_2 p + 1) u_2(t) = (1 - \tau_1^2 p^2) u_1(t) \qquad (2.11)$$



2.4-rasm. 2.3-masala uchun sxema

Uzatish funksiyasi quyidagiga teng:

$$W(p) = \frac{1 - \tau_1^2 p^2}{(T_1 p + 1)(T_2 p + 1)} = \frac{1 - T_1 T_2 p^2}{(T_1 p + 1)(T_2 p + 1)} \qquad (2.12)$$

Bu erda, $\tau_1^2 = T_1 T_2$.

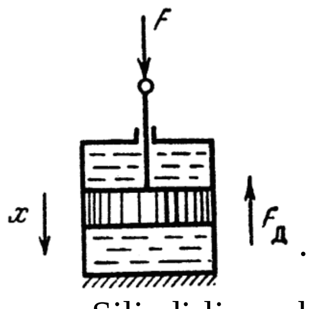
2.4-masala

Elektr zanjirda (2.4-rasm) $C_1 = C_2$, $R_1 = R_2$ bo`lganda, elektr zanjirning uzatish funksiyasini toping.

2.5-masala

Gidravlik dempferning (2.5-rasm) uzatish funksiyasini toping (Ҳarakat qiluvchi massalar ta`siri hisoblanmaydi, kirish kattaligi sifatida F kuch, chiqish kattaligi sifatida x porshen siljii olinsin).

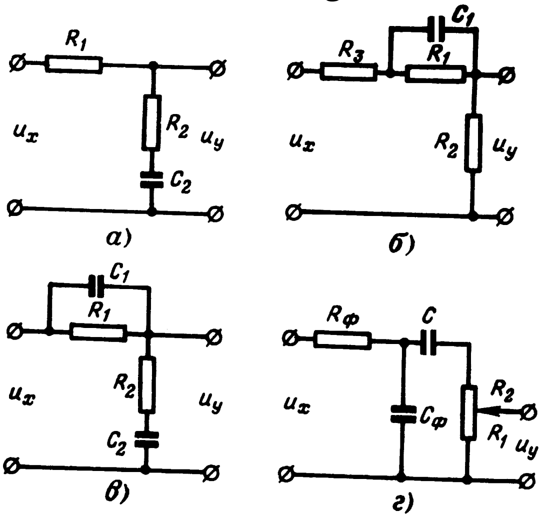
Echish: F kuchga qarshi $F_Д = c_1 x$ (c_1–dempferlash koeffisienti) dempferlash kuchi mavjud. Unda quyidagiga ega bo`lamiz: $px = kF$, bu erda $k = c_1^{-1}$. Bundan uzatish funksiyasi kelib chiqadi: $W(p) = \frac{X(p)}{F(p)} = \frac{k}{p}$



2.5-rasm. Silindirli porshen`

2.6-masala

2.6-rasmda keltirilgan tasvir konturlarning differensial tenglamasini toping.



2.6-rasm. 2.6-masala uchun rasm

3. Tuzilmaviy (strukturaviy) sxemalar va ularni o`zgartirish

3.1-masala

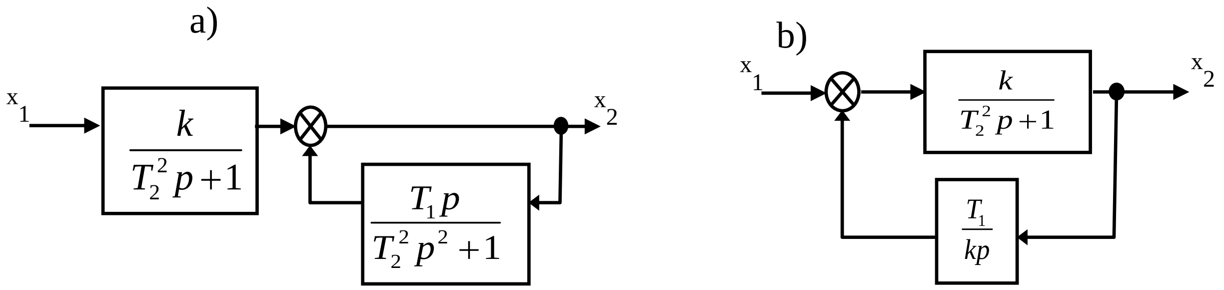
Quyidagi keltirilgan differensial tenglama orqali ifodalanadigan dinamik bo`g`inni teskari bog`linishli ketma-ket va differensial bo`g`inga o`zgartiring:

$$(T_2^2 p + T_1 p + 1)x_2 = \kappa x_1 \qquad (3.1)$$

Echish: (3.1) differensial tenglamani quyidagi shaklga keltiramiz:

$$x_2 = \frac{k}{T_2^2 p^2 + 1} x_1 - \frac{T_1 p}{T_2^2 p^2 + 1} x_2 \qquad (3.2)$$

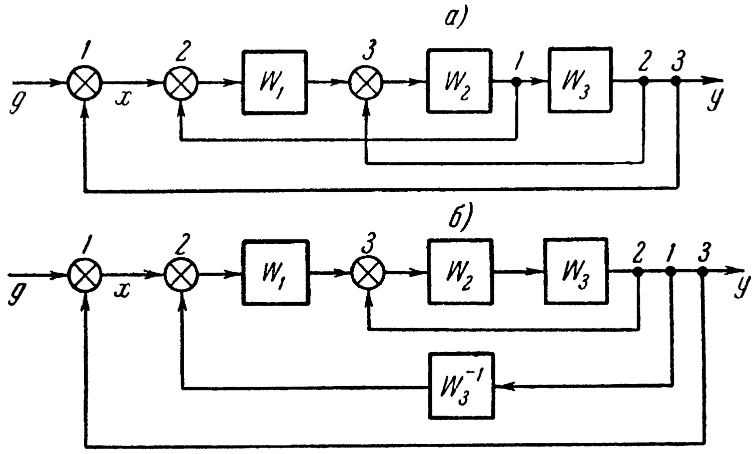
(3.2) tenglama bo`yicha tuzilmaviy sxema tuzamiz (3.1,a-rasm). Bu sxemadagi jamlovchi yoki taqqoslash elementini ko`chiramiz. Sxemani soddalashtirib, 3.1,b-rasmdagi sxemaga kelamiz.



3.1-rasm. 3.1-masala uchun tuzilmaviy sxema

3.2-masala

Tuzilmaviy sxemasi 3.2,a-rasmda keltirilgan avtomatik tizimdagi yopiq tizimning uzatish sxemasini toping.



3.2-rasm. 3.2-masala uchun tuzilmaviy sxema

Echish: 3.2,a-rasmdagi kesishgan bog\`liqlardan xolos bo\`lib olamiz. Buning uchun 1-tugunni signal harakati bo\`yicha $W_3$ bo\`g\`inidan olib o\`tamiz (3.2,b-rasm). Olingan tuzilmaviy sxema bo\`yicha uzatish funksiyasini topamiz:

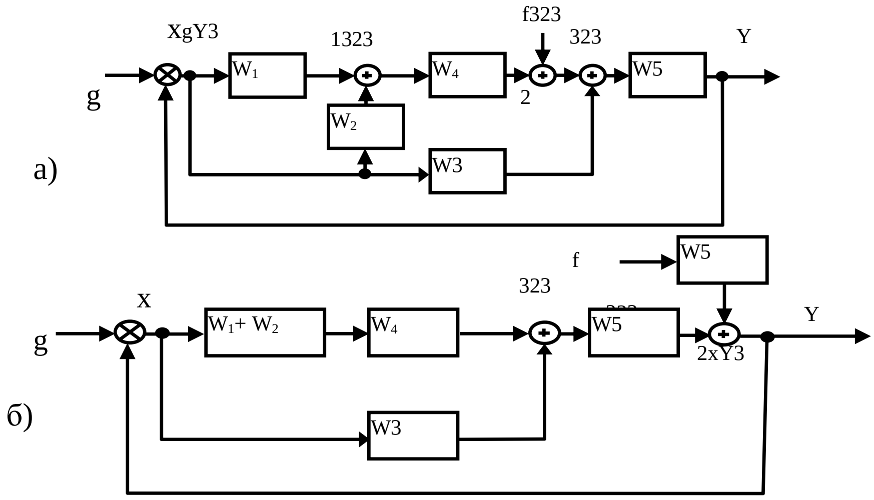
$$\Phi(p)=\frac{W_1W_2W_3}{1+W_1W_2+W_1W_2W_3}$$

3.3-masala

3.3,a-rasmda tuzilmaviy sxemasi ko\`rsatilgan avtomatik tizimni differensial tenglamasini y(t) boshqaruvchi va f(t) toydiruvchi kattaliklarga nisbatan toping. Bunda,

$$W_1(p)=k_1,\ W_2(p)=\tau p,\ W(p)=k_3,\ W_4=\frac{k_4}{T_1p+1},\quad W_5=\frac{k_5}{T_2{}^2p^2+T_3+1}$$

Echish: Birinchi navbatda avtomatik tizimning F_1(r) toydiruvchi ta\`sir bo\`yicha uzatish funksiyasini topamiz. Buning uchun 2-jamlovchini W_5 bo\`g\`inidan o\`tkazib va $W_1$ va $W_2$ bo\`g\`inlarini birlashtiramiz (3.3,b-rasm).



3.3-rasm. 3.3-masala uchun tuzilmaviy sxema

Berilgan va toydiruvchi ta\`sir bo\`yicha yopiq tizimning uzatish funksiyasini topamiz:

$$W(p)=\frac{Y(p)}{G(p)}=[(W_1+W_2)W_4+W_3]W_5$$

va toydiruvchi ta`sir bo`yicha:

$$W(p)=\frac{Y(p)}{F(p)}=W_5(p)$$

unda,

$$\Phi_f(p)=\frac{H(p)}{F(p)}=\frac{W_f(p)}{1+W(p)}=\frac{d_0p+d_1}{a_0p^3+a_1p^2+a_2p+a_3}$$

Bu erda, Y(P), F(p) – y(t) boshqaruvchi va f(t) toydiruvchi ta`sirning ifodasi, $p=c+jw$ – kompleks o`zgaruvchi,

$d_0=k_5T_1,\ d_1=k_5,\ a_0=T_1T_2^2,\ a_1=T_2^2+T_1T_3,\ a_2=T_1+T_3+k_4k_5\tau+k_3k_5T_1,$

$a_3=1+k_3k_5+k_1k_4k_5$

bu erdan differensial tenglama kelib chiqadi:

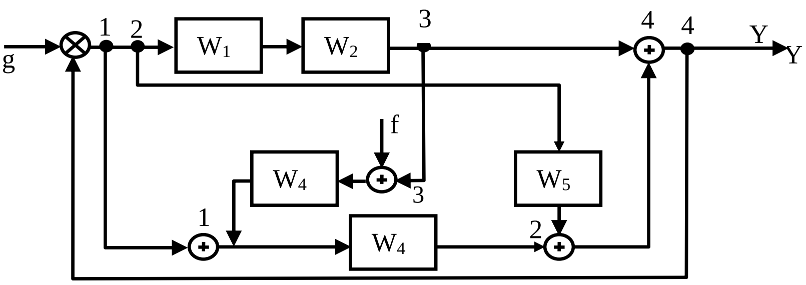
$$(a_0p^3+a_1p^2+a_2p+a_3)y(t)=(d_0p+d_1)f(t),\quad p=\frac{d}{dt}$$

<u>3.4-masala</u>

3.4,a-rasmda keltirilgan avtomatik tizimning boshqaruvchi va toydirma ta`sirga nisbatan uzatish funksiyasini toping.

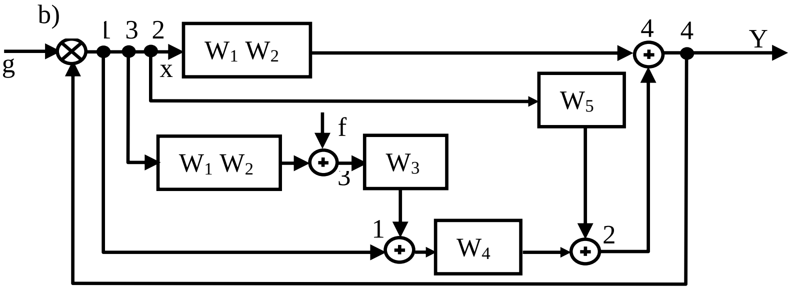
<u>Echish:</u> Tuzilmaviy sxemani soddalashtiramiz(3.4,b,v,g-rasm). 3.4,g-rasmga binoan quyidagilarni topamiz:

a)

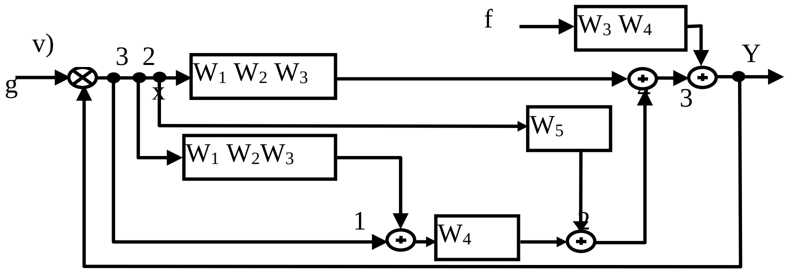


$W(p)=W_1W_2+(1+W_1W_2W_3)W_4+W_5,\qquad W_f(p)=W_3W_4$

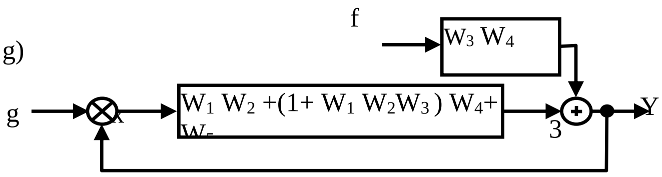
b)



v)



g)



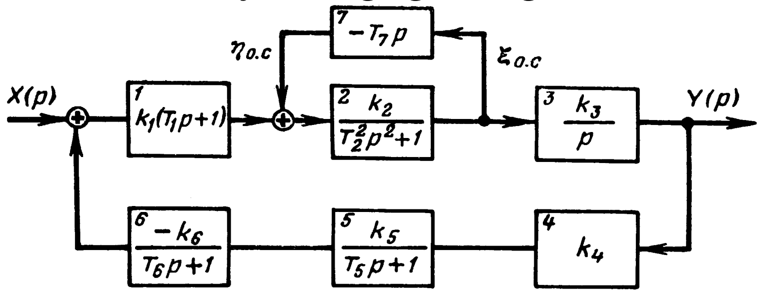
3.4-rasm. 3.4-masala uchun tuzilmaviy sxema

3.5-masala

3.5-rasmda keltirilgan tuzilmaviy sxema uchun

a) signal yo`nalishi bo`yicha tugunni tugun orqali va bo`g`in orqali ko`chirish qoidasi, shuningdek signalga teskari yo`nalishda jamlovchini jamlovchi va bo`g`in orqali ko`chirish qoidalarini qo`llab 2-bo`g`inda-gi 7-teskari bog`lanishni 5-bo`g`inga ko`chiring;

b) yangi sxemada ishlash rejimi o`zgargan bo`g`inlarni ko`rsating.



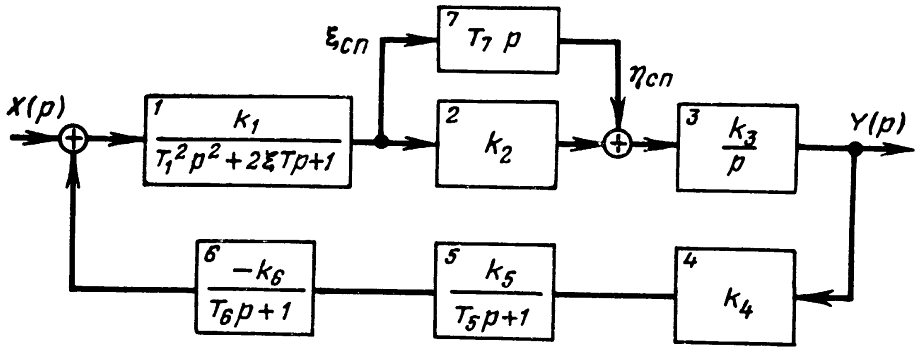
3.5-rasm. 3.5-masala uchun tuzilmaviy sxema

3.6-masala

3.6-rasmda keltirilgan tuzilmaviy sxema uchun

a) 2-bo`g`indagi 7-parallel bog`lanishni 5-bo`g`inga ko`chiring;

b) berilgan va bajarilgan sxemaning ekvivalik shartlariga baho bering.



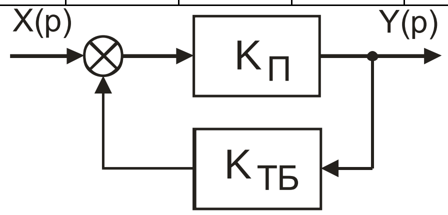
3.6-rasm. 3.6-masala uchun tuzilmaviy sxema

3.7-masala

$W(p) = k_{П}$ uzatish funksiyali kuchaytiruvchi bo`g`in teskari bog`lanishga ega (3.7-rasm). Jadvalda keltirilgan $k_{П}$ va $k_{Т.Б.}$ qiymatlarida k kuchaytirish koeffisientini aniqlang.

Ko`rsatkich	Variantlar							
	1	2	3	4	5	6	7	8
$k_{П}$	10	10	10	10	10	10	10	30
$k_{Т.Б.}$	0,01	0,09	0,099	0,2	1	10	20	100

Teskari bog`lanish belgisi	+	+	+	+	-	-	-	-



3.7-rasm. 3.7-masala uchun tuzilmaviy sxema

4. Dinamik bo`g`inlar tavsifi

4.1 Bo`g`inlarning amplituda-faza (xarakteristika) tavsiflari

<u>4.1-masala</u>

Quyidagi uzatish funksiyasiga ega bo`g`inning amplituda-faza tavsifini toping:

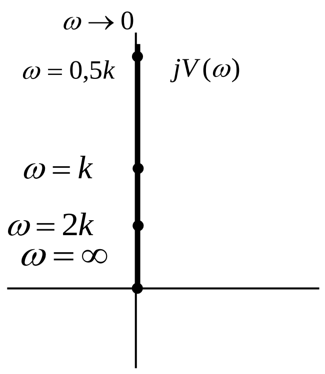
$$W(p) = \frac{k}{p}$$

<u>Echish:</u> Bo`g`inning amplituda-faza tavsifini topishda p Laplas operatorini $j\omega$ bilan almashtiramiz:

$$W(p) = \frac{k}{j\omega}$$

Bo`g`inni aniq va mavhum qismlarga ajratamiz: $U(\omega) = 0$ –aniq qism, $V(j\omega) = \frac{k}{\omega}$ – mavhum qism. ω ga qiymat berib jadval tuzamiz va jadval asosida tavsif yasaymiz:

ω	$V(j\omega)$	$U(\omega)$
$0{,}5k$	2	0
k	1	0
$2k$	0,5	0
∞	0	0



4.1-rasm. Integral bo`g`inning amplituda-faza tavsifi

<u>4.2-masala</u>

Quyidagi uzatish funksiyasiga ega bo`g`inning amplituda-faza tavsifini toping:

$$W(p) = \frac{k}{p^2}$$

4.3-masala

4.2-rasmda keltirilgan RC zanjirining amplituda-faza tavsifini toping (R=1 kOm, S=10 mkF).

<u>Echish:</u> Zanjirning chastotaviy uzatish funksiyasi quyidagiga teng:

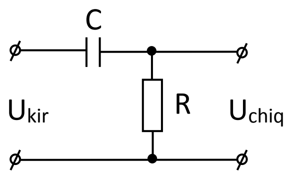
$$W(j\omega) = \frac{j\omega T}{1 + j\omega T} \tag{4.1}$$

Bu erda, $T = RC = 10^3 \cdot 10^{-5} = 10^{-2}\,c$

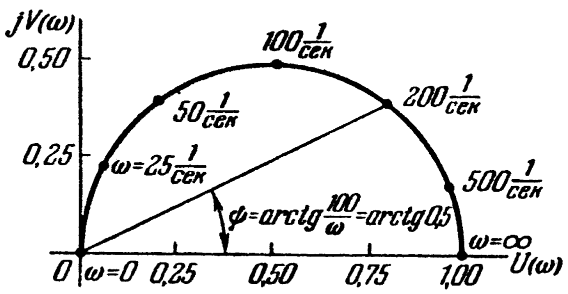
(4.1) ifodani quyidagi ko`rinishga keltirib olamiz (aniq va mavhum qismlarga ajratamiz):

$$W(j\omega) = U(\omega) + jV(\omega) = \frac{\omega^2 T^2}{1 + \omega^2 T^2} + j\frac{\omega T}{1 + \omega^2 T^2} = \frac{10^{-4}\omega^2}{1 + 10^{-4}\omega^{-2}} + j\frac{10^{-2}\omega}{1 + 10^{-4}\omega^2} \tag{4.2}$$

ω ga qiymat berib, $U(\omega)$ aniq va $V(\omega)$ mavhum qismlarning qiymatlarini aniqlab, amplituda-faza tavsifi quriladi (4.3-rasm).



4.2-rasm. Differensial bo`g`in



4.3-rasm. Differensial bo`g`in va uning amplituda-faza tavsifi

Kompleks sonning argumenti quyidagiga teng:

$$\psi = \arg W(j\omega) = arctg\,\frac{1}{\omega T} = arctg\,\frac{100}{\omega} \tag{4.3}$$

4.4-masala

Quyidagi uzatish funksiyasiga ega aperiodik bo`g`inning amplituda-faza tavsifini toping:

$$W(p) = \frac{k}{1 + Tp} = \frac{5}{1 + 0.1p}$$

4.5-masala

Quyidagi uzatish funksiyasiga ega ikkinchi tartibli aperiodik bo`g`inning amplituda-faza tavsifini toping:

$$W(p) = \frac{k}{(1 + T_1 p)(1 + T_2 p)},\quad k = 8,\quad T_1 = 80\ \text{мсек},\quad T_2 = 12\ \text{мсек}$$

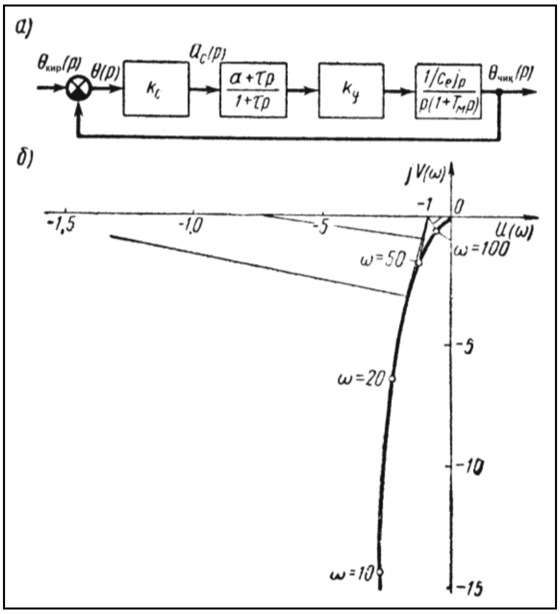
4.6-masala

Quyidagi uzatish funksiyasiga ega tebranma bo`g`inning amplituda-faza tavsifini toping:

$$W(p)=\frac{k}{1+2\xi Tp+T^2p^2)},k=1,\;\; \xi=0{,}15,\;\; T=0{,}02\;\;сек$$

4.7-masala

4.4-rasmda keltirilgan sust differensial konturli kuzatuvchi tizimning amplituda-faza tavsifini quring.



4.4-rasm. Sust differensial konturli kuzatuvchi tizimning amplituda-faza tavsifi

Tizim ko`rsatkichlari:

$k_c=28\;\;в/рад;\;\; k_y=1158;\;\; c_e=0.18\dfrac{в}{рад/сек};\;\; j_p=400;\;\; T_м=0.04сек;\;\; \alpha=0,333;\;\; \tau=0,01сек$ T

izimning uzatish funksiyasi:

$$W(p)=\frac{k_ck_y\dfrac{1}{c_ej_p}(\alpha+\tau p)}{p(1+\tau p)(1+T_мp)}=\frac{D(\alpha+\tau p)}{p(1+\tau p)(1+T_мp)},\;\; D=\frac{k_ck_y}{c_ej_p}$$

4.8-masala

Aperiodik bo`g`inning amplituda-chastota, faza-chastota va amplituda-faza tavsiflarini tuzing.

Uzatish koeffisientini $k=1$, vaqt o`zgarmassini $\mathrm{T}=2.5;0.5$ **сек** deb olamiz.

Aperiodik bo`g`inning uzatish funksiyasi quyidagiga teng:

$$W(p)=\frac{k}{1+Tp}$$

p operatorini $j\omega$ ga almashtirib, amplituda-chastota va faza-chastota tavsiflariga mos ravishda ega bo`lamiz:

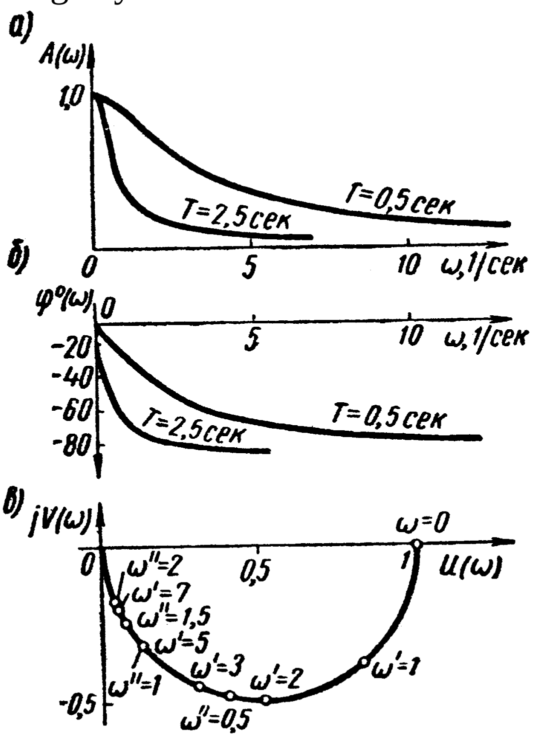
$$A(\omega)=\frac{1}{\sqrt{1+\omega^2T^2}}$$
$$\varphi(\omega)=\arg[W(j\omega)]=-arctg\omega T$$

ω ga qiymatlar berib, $A(\omega)$ va $\varphi(\omega)$ni topamiz. Xisoblashlarning natijasi 4.1-jadvalda ko`rsatilgan. Bu jadvalga muvofiq $A(\omega)$ va $\varphi(\omega)$ tavsiflari quriladi (4.5-rasm).

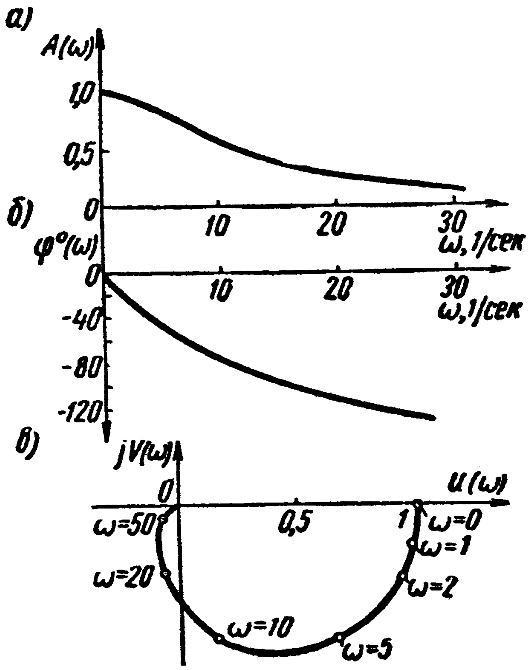
4.1-jadval

T = 2.5			T = 0.5		
ω	$A(\omega)$	$\varphi(\omega)$	ω	$A(\omega)$	$\varphi(\omega)$
0.5	0.622	$-51^{0}6'$	1	0.895	$-26^{0}36'$
1	0.372	$-68^{0}24'$	2	0.708	-46^{0}
1.5	0.258	$-75^{0}6'$	3	0.554	$-56^{0}18'$
2	0.195	$-78^{0}48'$	5	0.372	$-68^{0}12'$
2.5	0.158	-81^{0}	7	0.279	-74^{0}
3	0.127	$-82^{0}6'$	10	0.196	$-78^{0}42'$
20	0.02	$-86^{0}30'$	50	0.04	$-87^{0}48'$

Aperiodik bo`g`inning amplituda-faza tavsifi (4.5-rasm) to`rtinchi kvadrantda joylashgan, diametri $k$ kesimga teng, haqiqiy o`qda $(\frac{k}{2}; j0)$ koordinata markazida joylashgan yarim doirani ifoda etadi.



4.5-rasm. Aperiodik bo`g`inning chastotaviy tavsiflari: a– ampli-tuda; b–faza; v– amplituda-faza.



4.6-rasm. Ketma-ket ulangan aperiodik bo`g`inning chastotaviy tavsiflari: a – amplituda; b – faza; v – amplituda-faza.

4.9-masala

Ikkita ketma-ket ulangan aperiodik bo`g`inning amplituda-chastota, faza-chastota va amplituda-faza tavsiflarini tuzing.

Umumiy uzatish koeffisientini $k = k_1 = k_2 = 1$, vaqt o`zgarmasini $T_1 = 0.05\ сек; T_2 = 0.12\ сек$ deb olamiz.

Aperiodik bo`g`inning uzatish funksiyasi quyidagiga teng:

$$W(p) = \frac{k}{(1+T_1p)(1+T_2p)}$$

p operatorini $j\omega$ ga almashtirib, amplituda-chastota va faza-chastota tavsiflariga mos ravishda ega bo`lamiz:

$$A(\omega) = |W(j\omega)| = \frac{k}{\sqrt{\left(1+\omega^2T_1^2\right)(1+T_2^2\omega^2)}} = \frac{1}{\sqrt{(1+0.05^2\omega^2)(1+0.12^2\omega^2)}}$$

$$\varphi(\omega) = \arg[W(j\omega)] = -(arctg\omega T_1 + arctg\omega T_2)$$
$$= -(arctg0.05\omega + arctg0.12\omega)$$

ω ga qiymatlar berib, $A(\omega)$, $\varphi(\omega)$va $W(j\omega)$ni topamiz. Xisoblashlar natijasi 4.2-jadvalda ko`rsatilgan. Bu jadvalga muvofiq $A(\omega)$, $\varphi(\omega)$ va $W(j\omega)$ tavsiflari quriladi (4.6-rasm).

4.2 -jadval

ω	$A(\omega)$	$\varphi(\omega)$
1	0.99	-10^0
2	0.968	-19^0
5	0.83	-45^0
10	0.572	$-76^0 30'$
20	0.272	$-112^0 30'$
50	0.061	$-148^0 30'$
0	1	0

4.2. Bo`g`inlarning logorifmik amplituda-faza (xarakteristika) tavsiflari

4.10-masala

Quyidagi uzatish funksiyasiga ega aperiodik bo`g`inning logarifmik amplituda faza tavsifini toping:

$$W(p) = \frac{100}{1+0,05p} \tag{4.4}$$

Echish: (1) ifodaga mos keluvchi logarifmik amplituda tavsifi quyidagiga teng:

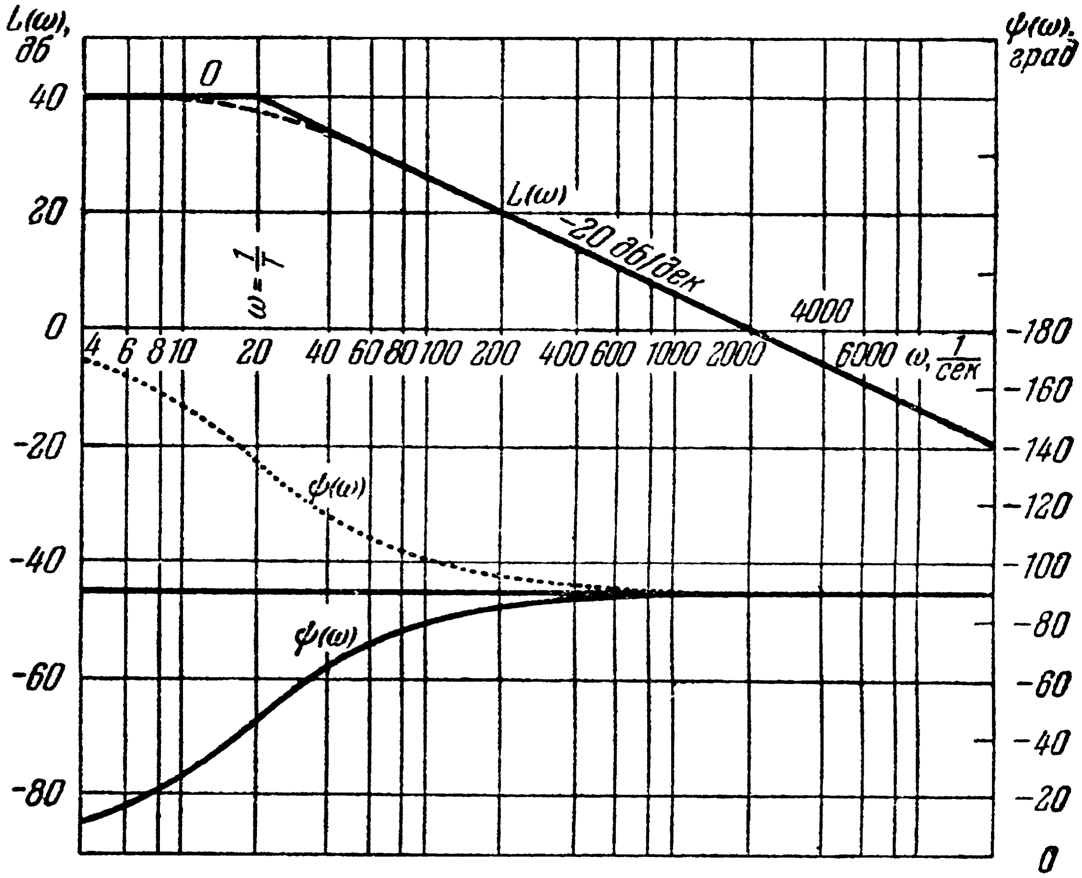
$$L(\omega) = 20\lg|W(j\omega)| = 20\lg\frac{k}{\sqrt{1+(\omega T)^2}} \tag{4.5}$$

(4.4) ifodaga mos keluvchi asimptotik logarifmik amplituda tavsif 4.6-rasmda ko`rsatilgan. Abssissa o`qi bo`yicha $\omega T$ kattaligi logarifmik masshtabda, ordinata o`qi bo`yicha $L(\omega)$ kattaligi desibelda joylashtirilgan.

(4.5) ifodaga muvofiq asimptotik L.A.T. (logarifmik amplituda tavsifi) $\omega T = 1$ nuqtada sinishga ega. Sinishdan chap tarafda tavsif gorizontal chiziq bo`ladi va $20lgk$ balandlikda joylashadi. Sinishdan o`ng tarafda $-20lgk$ og`ishga ega. Chastota o`qi bilan tavsifning kesishish nuqtasi, ya`ni $\omega_к$ kesishish chastotasi quyidagi tenglikdan aniqlanadi:

$$L(\omega_к) \approx 20lg\frac{k}{\omega_к T} = 0 \text{ yoki } \omega_к = \frac{k}{T}.$$

Tavsifning eng katta og`ish nuqtasi $\omega T = 1$ nuqtaga to`g`ri keladi, (4.5) ifodadan hisoblansa, 3 dB ga teng. $\omega T = 0.5$ va $\omega T = 2$ da tavsifning qiymati taxminan 1dB ga, $\omega T = 1 \pm 1$ hududda tavsifning og`ishi juda kichik bo`ladi.



4.7-rasm. Tizimning logarifmik tavsiflari

Bo`g`inning faza tavsifi (4.4) ifodaga muvofiq aniqlanadi:

$$\psi(\omega) = argW(j\omega) = -arctg\omega T \qquad (4.6)$$

Kichik chastotalar hududida $\varphi(\omega) \to 0$ faza nolga intiladi, katta chastotalar hududida $\psi(\omega) \to 90^0$ ga intiladi, $\omega T = 1$ da $\psi(\omega) = 45^0$ ga teng. (4.6) ifodadan faza tavsifi, $\omega T = 1$, $\psi(\omega) = 45^0$ nuqtaga nisbatan simmetrikligi aniqlanadi.

(4.4) ifodada keltirigan aperiodik bo`g`inning faza tavsifi (4.5) ifodaga muvofiq quriladi (4.7-rasm).

Tavsifni qurishda quyidagi jadvaldan foydalanildi:

ωT	0	0,05	0,1	0,2	0,5	1	2	5	10	20	∞
$\psi(\omega T)$, град	0	$-2^0 50'$	$-5^0 40'$	$-11^0 20'$	$-26^0 30'$	-45^0	$-63^0 30'$	$-78^0 40'$	$-84^0 20'$	$-87^0 10$	-90^0

4.11-masala

Quyidagi uzatish funksiyasiga ega aperiodik bo`g`inning $L = 20\lg[W(j\omega)]$ logarifmik amplituda i $\psi(\omega)$ faza tavsifini toping:

$$W(p) = \frac{100}{1 + 0,05p}$$

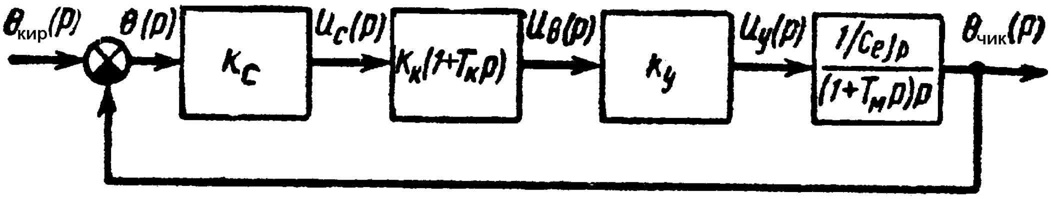
4.12-masala

Quyidagi uzatish funksiyasiga ega aperiodik bo`g`inning $L = 20\lg[W(j\omega)]$ logarifmik amplituda i $\psi(\omega)$ faza tavsifini toping:

$$W(p) = \frac{32}{(1+0,01p)(1+0,22p)}$$

4.13-masala

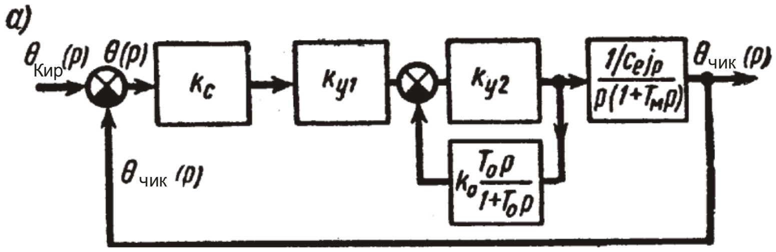
4.8–rasmda keltirilgan tuzilmaviy sxemaning $L = 20\lg[W(j\omega)]$ logarifmik amplituda i $\psi(\omega)$ faza tavsifini toping.



4.8-rasm. O`zgaruvchan tok rostlagichli kuzatuvchi tizimning tuzilmaviy sxemasi

4.14-masala

4.9–rasmda keltirilgan tuzilmaviy sxemaning $L = 20\lg[W(j\omega)]$ logarifmik amplituda i $\psi(\omega)$ faza tavsifini toping.



4.9-rasm. O`zgaruvchan tok rostlagichli kuzatuvchi tizimning tuzilmaviy sxemasi

4.15-masala

Quyidagi uzatish funksiyasiga ega aperiodik bo`g`inning $L = 20\lg[W(j\omega)]$ logarifmik amplituda i $\psi(\omega)$ faza tavsifini toping

$$W(p) = \frac{100}{1+0,05p}$$

5. Tizimlarning (sistemalarning) turg`unligi

5.1 Raus-Gurvisa mezoni bo`yicha tizim turg`unligini tekshirish

5.1-masala

Avtomatik rostlash tizimi turg`unligini Gurvisa mezoni bo`yicha tekshiring.

Tizimning tavsifiy tenglamasi quyidagi ko`rinishga ega:

$$p^3 + 1.48p^2 + 4.6p + 4 = 0$$

Gurvisa mezoni bo`yicha uchinchi darajali tenglamalar uchun (ijobiy koeffisientlardan tashqari) quyidagi tenglik bajarilishi lozim:

$$\Delta_2 = a_1 a_2 - a_0 a_3 > 0$$

Bu erda, Δ_2 – ikkinchi darajali aniqlik.

Bu holda $a_0=1$; $a_1=1,48$; $a_2=4,6$; $a_3=4$.

$\Delta_2 = 1.48*4.6 - 1*4 = 2.8 > 0$

Demak, tizim turg`un.

5.2-masala

Avtomatik rostlash tizimi turg`unligini Gurvisa mezoni bo`yicha tekshiring.

Tizimning tavsifiy tenglamasi quyidagi ko`rinishga ega:

$$p^6+0.212p^5+2.42p^4+36.2p^3+228p^2+1408=0$$

Gurvisa mezoni bo`yicha oltinchi darajali tenglamalar uchun (ijobiy koeffisientlardan tashqari) quyidagi tenglik bajarilishi lozim:

$\Delta_2 = a_1a_2 - a_0a_3 > 0;$

$\Delta_3 = a_3(a_1a_2 - a_0a_3) - a_1^2a_4 > 0;$

$\Delta_4 = (a_1a_2 - a_0a_3)(a_3a_4 - a_2a_5) - (a_1a_4 - a_0a_5)^2 > 0;$

$\Delta_5 = a_3(a_1a_2 - a_0a_3) - a_1(a_1a_4 - a_0a_5) > 0;$

$\Delta_6 = (a_1a_2 - a_0a_3)[a_5(a_4a_3 - a_2a_5) + a_6(2a_1a_5 - a_3^2)] + (a_1a_4 - a_0a_5)[a_1a_2a_6 - a_5(a_1a_4 - a_0a_5)] - a_1^3a_6^2 > 0$

Bu erda, Δ_2, Δ_3, Δ_4, Δ_5, Δ_6 – ikkinchi, uchinchi, to`rtinchi, beshinchi, oltinchi daraja aniqlagichlari.

Bu holda yuqoridagi shartlar bajarilmasligi sababli tizim turg`un emas.

5.3-masala

Avtomatik rostlash tizimi turg`unligini Raus mezoni bo`yicha tekshiring.

Tizimning tavsifiy tenglamasi quyidagi ko`rinishga ega:

$$0.0008p^5+0.03p^4+1.36p^3+4p^2+52.5p+50=0$$

Raus jadvalini tuzamiz:

$a_0=0.0008$	$a_2=1.36$	$a_4=52.5$
$a_1=0.03$	$a_3=4$	$a_5=50$
$b_1=\frac{1.36*0.03-4*0.0008}{0.03}=1.25$	$b_2=\frac{52.5*0.03-50*0.0008}{0.03}=51.2$	$b_3=0$
$c_1=\frac{4*1.25-0.03*51.2}{1.25}=2.77$	$c_2=\frac{1.25*50-0.03*0}{1.25}=50$	$c_3=0$
$d_1=\frac{2.77*51.2-50*1.25}{2.77}=28.6$	$d_2=\frac{2,77*0-1,25*0}{2.77}=0$	$d_3=0$
$e_1=\frac{28.6*50-2.77*0}{28.6}=50$	$e_2=0$	$e_2=0$

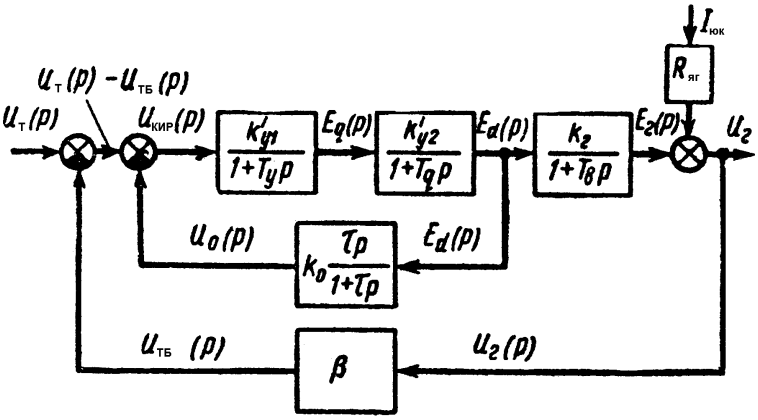
Jadvaldagi qiymatlardan quyidagi xulosaga kelish mumkin:

$a_0>0$, $a_1>0$, $b_1>0$, $c_1>0$, $d_1>0$, $e_1>0$ bo`lgani uchun tizim turg`un.

5.4-masala

Generator kuchlanishini avtomatik rostlash tizimi turg`unligini Gurvisa mezoni bo`yicha tekshiring.

Rostlash tizimining tuzilmaviy sxemasi 5.1-rasmda keltirilgan.



5.1-rasm. Generator kuchlanishini avtomatik rostlash tizimining tuzilmaviy sxemasi

Tuzilmaviy sxemani soddalashtirib, quyidagi ko`rinishga ega bo`lamiz:

$$a_0p^4 + a_1p^3 + a_2p^2 + a_3p + a_4 = 0$$

bu erda,

$a_0 = 0,256*10^{-6}; a_1 = 0,167*10^{-3}; a_2 = 0,0244; a_3 = 0,54; a_4 = 41.$

Gurvisa mezoni bo`yicha to`rinchi darajali tenglamalar uchun (ijobiy koeffisientlardan tashqari) quyidagi tenglik bajarilishi lozim:

$\Delta_3 = a_3(a_1a_2 - a_0a_3) - a_1^2a_4 > 0;$

Koeffisientlar qiymatini yuqoridagi formulaga qo`yib, quyidagini hosil qilamiz:

$\Delta_3 = 0,54(0,167*10^{-3} \cdot 0,0244 - 0,256*10^{-6} \cdot 0,54) - (0,167*10^{-3})^2 \cdot 41 = 0,98*10^{-6} > 0;$

Demak, tizim turg`un.

5.5-masala

Gurvisa mezoni bo`yicha kuzatuvchi tizim turg`unligini tekshiring.

Tizimning tavsifiy tenglamasi quyidagi ko`rinishga ega:

$0,0003p^4 + 0,0337p^3 + 0,43p^2 + 51,2p + 24,8 = 0$

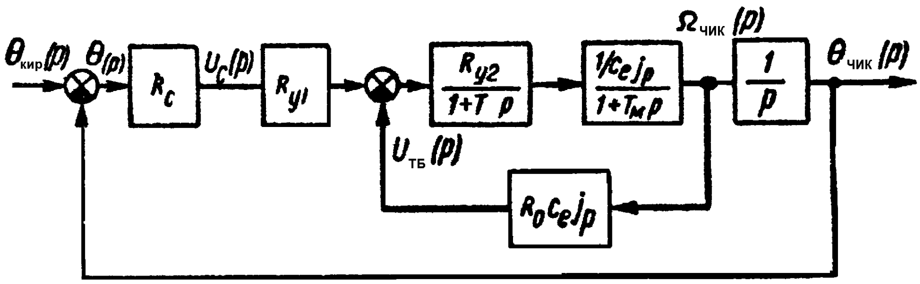
5.6-masala

Ikki ko`rsatkich tekisligida tezlik bo`yicha teskari bog`lanishli tizimning turg`unlik chegarasini aniqlang.

Tizimning tuzilmaviy sxemasi 5.2–rasmda ko`rsatilgan. $k_{y1}$ birinchi kaskad kuchaytirgichi va $k_0$ teskari bog`lanish koeffisienti funksiyalarining turg`unlik chegarasini topamiz.

Tizim ko`rsatkichlari:

$k_c = 0.4\frac{в}{град}; k_{y2} = 5.2; c_e = 0,014\ \frac{в}{град/сек};\ j_p = 297;\ T_q = 0.06$ сек; $T_м = 0,1$сек.



5.2-rasm. Tezlik bo`yicha teskari bog`lanishli tizimning tuzilmaviy sxemasi

Avval, yopiq tizimning uzatish funksiyasini topish kerak:

$$W_1(p) = \frac{\frac{k_{y2}}{1+T_q p} * \frac{\frac{1}{c_e jp}}{1+T_m p}}{1 + \frac{k_{y2}}{1+T_q p} * \frac{\frac{1}{c_e jp}}{1+T_m p} * k_0 c_e * jp}$$

Ushbu ifodani soddalashtirgandan so`ng, quyidagiga ega bo`lamiz:

$$W_1(p) = \frac{\frac{k_{y2}}{c_e jp}}{(1+T_q p)(1+T_m p)+k_{y2}k_0}$$

Ochiq tizimning uzatish funksiyasi:

$$W(p) = k_c k_{y1} W_1(p) \cdot \frac{1}{p} = \frac{k_c k_{y1} k_{y2} \frac{1}{c_e jp}}{[(1+T_q p)(1+T_m p)+k_{y2}k_0]p}$$

$D = k_c k_{y1} k_{y2} \frac{1}{c_e jp}$ belgilashni kiritamiz va ochiq tizimning yakuniy uzatish funksiyasiga ega bo`lamiz:

$$W(p) = \frac{D}{T_q T_m p^3 + (T_q + T_m)p^2 + (1+k_{y2}k_0)p}$$

Bu uzatish funksiyasi tizimning tavsifiy tenglamasini topamiz:

$$a_0 p^3 + a_1 p^2 + a_2 p + a_3 = 0$$

Bu erda,

$$a_0 = T_q T_m; a_1 = T_q + T_m; a_2 = 1 + k_{y2}k_0; a_3 = D = \frac{k_c k_{y2} k_{y1}}{c_e jp}$$

Tizim ko`rsatkichlarining sonli qiymatlarini yuqoridagi ifodaga qo`yamiz:

$a_0 = 0{,}06 * 0{,}1 = 0{,}006;$

$a_1 = 0{,}06 + 0{,}1 = 0{,}16;$

$a_2 = 1 + 5{,}2\kappa_0;$

$a_3 = D = \frac{0.4*5.2}{0.014-297} k_{y1}$

Gurvisa bo`yicha turg`unlik shartlari:

$a_0 > 0; a_1 > 0; a_2 > 0; a_3 > 0;$

$\Delta_2 = a_1 a_2 - a_0 a_3 > 0;$

Birinchi to`rtta shart $k_0 > 0, k_{y1} > 0$ bo`lganda bajariladi. So`nggi shartdan quyidagiga ega bo`lamiz: $0.16(1+5.2k_0) - 0.006 \cdot 0.5k_{y1} > 0$

bu erdan,

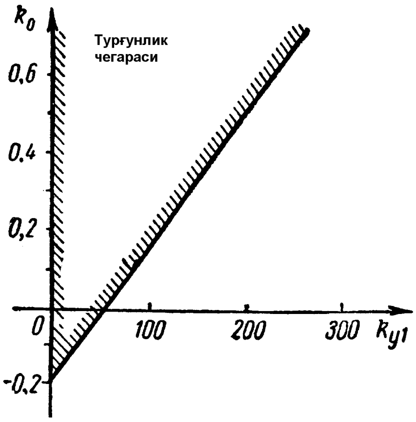
$k_0 > 0.0036k_{y1} - 0.192$

Bu tengsizlik tizim turg`unligi shartini ifoda qiladi. Turg`unlik chegarasi (-0.192; j0) koordinatali nuqtadan arctg 0.0036 burchak ostida (-0.192; j0) koordinatali nuqtadan o`tuvchi quyidagi tenglama bilan aniqlanadi:

$k_0 = -0{,}192$ qiymati turg`unlik chegarasi hisoblanadi. Buni quyidagi tenglama ham isbotlab turibdi:

$a_2 = 1 + 5.2k_0 > 0; \Rightarrow k_0 > -\frac{1}{5.2} = -0.192$

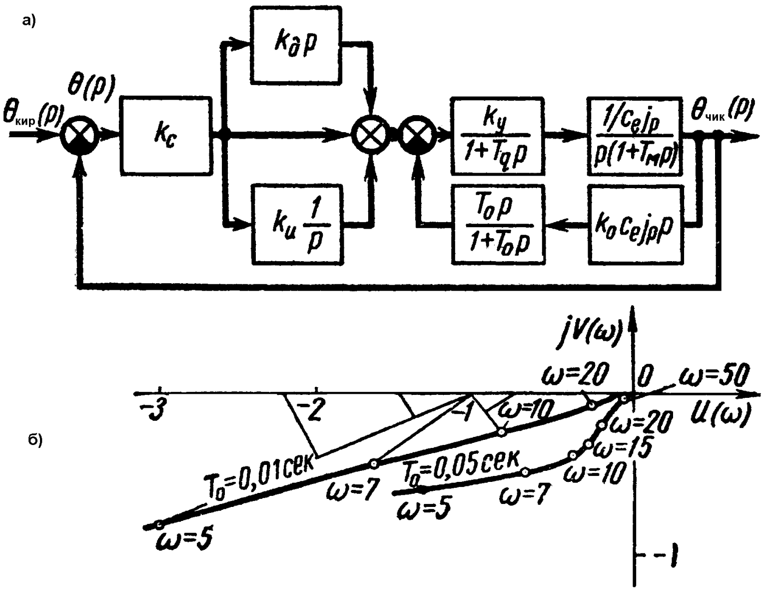
k_0, k_{y1} ko`rsatkichlari tekisligidagi turg`unlik chegarasi 5.3-rasmda ko`rsatilgan.



5.3-rasm. k_0, k_{y1} ko`rsatkichlari tekisligidagi kuzatuvchi tizimning turg`unlik chegarasi

5.7-masala

5.4-rasmda tasvirlangan tezlik bo`yicha teskari bog`lanshga ega, integrallovchi va differensiallovchi bo`g`inli kuzatuvchi tizimning Raus mezoni bo`yicha turg`unligini tekshiring.



5.4-rasm. Tezlik bo`yicha teskari bog`lanshga ega, integrallovchi va differensiallovchi bo`g`inli kuzatuvchi tizim tuzilmaviy sxemasi

$$k_c = 50\frac{\text{в}}{\text{град}}; k_y = 200; k_и = 1\frac{1}{\text{с}}; k_0 = 0{,}1; k_д = 0{,}01\text{сек}; c_e = $$
$$= 0{,}7\ \frac{\text{в}}{\text{град/сек}};\ j_p = 143; T_q = 0.12\ \text{сек};\ T_0 = 0{,}1\text{сек}.$$

Tavsifiy tenglama:

$a_0p^5 + a_1p^4 + a_2p^3 + a_3p^2 + a_4p + a_5 = 0$

5.8-masala

Tizim tavsifiy tenglamasi quyidagi ko`rinishga ega:

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

Tizim turg`unligini aniqlang.

5.9-masala

Tizimning tavsifiy tenglamasi quyidagi ko`rinishga ega:

$$5p^3 + 2p^2 - 3p + 1 = 0$$

Tizim turg`unligini aniqlang.

5.10-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p) = \frac{K}{p(1+Tp)}$$

Yopiq tizim turg`unligining shartini aniqlang.

5.11-masala

Ochiq tizimning uzatish funksiyasi:

$$W(p) = \frac{K}{p^2}, K = 100сек^{-2}$$

Ochiq tizim turg`unligini aniqlang.

5.12-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p) = \frac{K}{p^2(1+Tp)},$$

$K = 20сек^2$ – tizimning tezlik bo`yicha koeffisienti;

$T = 0,01сек$ – vaqt o`zgarmasi;

Yopiq tizim turg`unligini aniqlang.

5.13-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p) = \frac{K}{p^2(1+T_1p)(1+T_2p)},$$

$K = 50сек^2$ – yopiq tizimning umumiy uzatish koeffisienti;

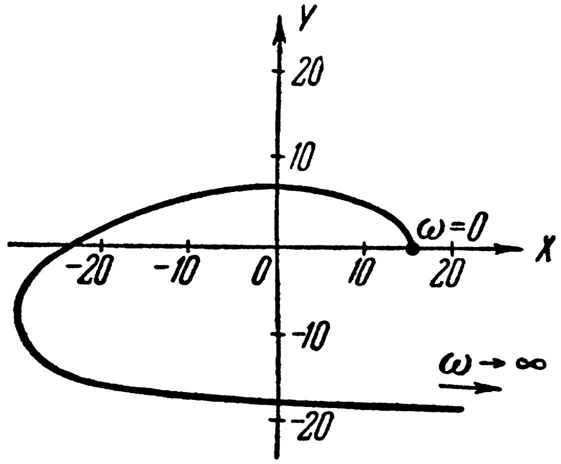
$T_1 = 1сек, T_2 = 0,05сек$ – vaqt o`zgarmassi.

Yopiq tizim turg`unligining aniqlang.

5.2 Mixaylov mezoni bo`yicha tizim turg`unligini tekshirish

5.14-masala

Avtomatik boshqarish tizimi to`rtinchi tartibli tavsifiy tenglamaga ega. Mixaylov chizig`i 5.5-rasmda keltirilgan. Avtomatik tizim turg`unligini aniqlang.



5.5-rasm. 5.14-masala uchun Mixaylov chizig`i

Echish: Chiziq Mixaylov mezoni talablarini bajargani, ya`ni koordinata choraklarini ketma-ket bosib o`tgani sababli tizim turg`undir.

5.15-masala

Quyidagi uzatish funksiyasiga ega elektromexanik kuzatuvchi tizimning Mixaylov mezoni bo`yicha turg`unligini aniqlang:

$$W(p) = \frac{K}{p(1+T_y p)(1+T_м p)}$$

$K = 58сек^2 -$ yopiq tizimning umumiy uzatish koeffisienti;

$T_м = 0,57сек -$dvigatelning vaqt o`zgarmasi.

$T_y = 0,01сек -$ kuchaytirgichning vaqt o`zgarmasi.

Echish: yopiq tizimning tavsifiy polinomi:

$$D(p) = p(1+T_y p)(1+T_м p) + K = T_y T_м p^3 + (T_y + T_м)p^2 + p + K$$

Mixaylov chizig`ini qurish uchun $D(j\omega)$ funksiyasining mavhum va haqiqiy qismlarini ajratib olamiz:

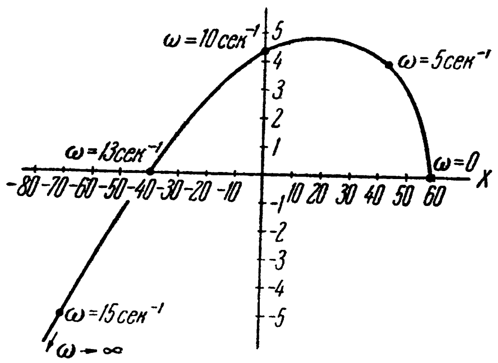
$X(\omega) = \operatorname{Re} D(j\omega) = K - (T_y + T_м)\omega^2 = 58 - 0.58\omega^2$

$Y(\omega) = \operatorname{Im} D(j\omega) = \omega - T_y T_м \omega^3 = \omega - 5,7 \cdot 10^{-3}\omega^3$

$X(\omega)$ va $Y(\omega)$ni ω chastotaning bir nechta qiymatlari uchun hisoblaymiz va jadvalga kiritamiz.

$\omega, сек^{-1}$	$X(\omega)$	$Y(\omega)$
0	58	0
5	44	4
10	0	4.5
13	-40	0
15	-70	-5
∞	-∞	-∞

Jadvaldagi ma`lumotlarga asoslanib, Mixaylov chizig`ini tuzamiz (5.6-rasm). Mixaylov chizig`i kvadrantlardan ketma-ket o`tmoqda. Demak, tizim turg`un.



5.6-rasm. 5.15-masala uchun Mixaylov chizig`i

5.16-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p) = \frac{K}{-1+Tp},$$

K – yopiq tizimning kuchaytirish koeffisienti

$T > 0$ – vaqt o`zgarmasi.

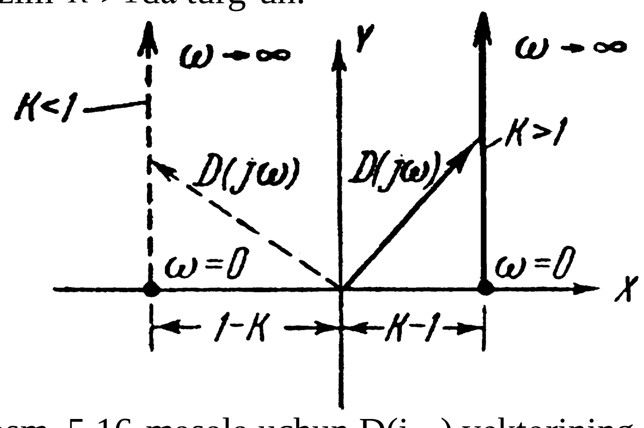
Mixaylov mezonidan foydalanib, tizim turg`unligi shartini toping.

Echish: yopiq_tizimning tavsifiy polinomi uzatish funksiyasini mahraj va kasrdagi polinomlarning yig`indisiga teng:

$D(j\omega)$ vektorini tavsifiy polinomda r ni $j\omega$ ga almashtirib hosil qilamiz:

$$D(j\omega) = j\omega T + K - 1 = X(\omega) + jY(\omega), X(\omega) = K - 1, Y(\omega) = \omega T$$

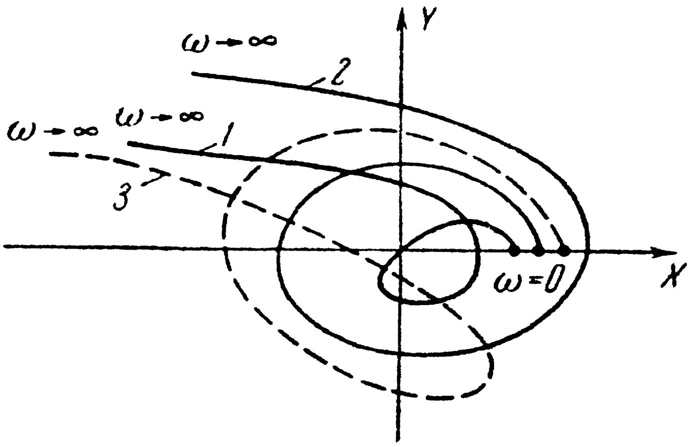
Tizim turg`un bo`lishi uchun $D(j\omega)$ vektori ω chastotasi 0 dan ∞ gacha o`zgarganda, $\varphi = \frac{\pi}{2}$ burchakka o`zgarishi etarli va kerak (5.7-rasm). $K < 1$ da Mixaylov chizig`i ikkinchi kvadrantda joylashgan va $\omega$ chastotasi 0 dan $\infty$gacha o`zgarganda $D(j\omega)$ vektorning o`zgarish burchagi $\varphi = -\frac{\pi}{2}$ ga, $K > 1$ da esa, $\varphi = \frac{\pi}{2}$ ga teng. Demak, yopiq tizim $K > 1$da turg`un.



5.7-rasm. 5.16-masala uchun D(jω) vektorining godografi

5.17-masala

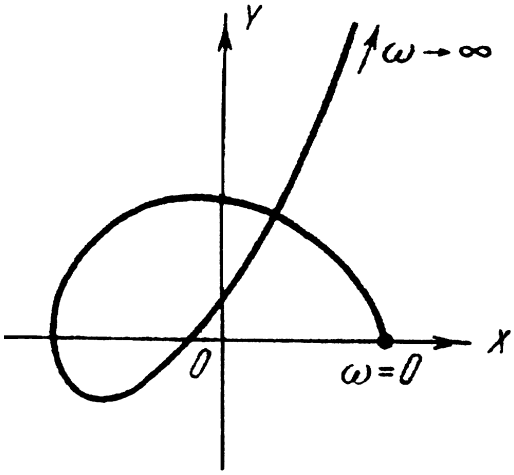
Avtomatik boshqaruv tizimining tavsifiy polinomi oltinchi tartibga ega. 5.8–rasmda tizimning turli ko`rsatkichlari uchun Mixaylov chizig`i berilgan. Tizim turg`unligini aniqlang.



5.8-rasm. 5.17-masala uchun Mixaylov chizig`i

5.18-masala

Avtomatik boshqaruv tizimining tavsifiy polinomi oltinchi tartibga ega. 5.9–rasmda tizimning Mixaylov chizig`i keltirilgan. Tavsifiy tenglamaning musbat va manfiy mavhum qismlaridagi ildizlar sonini aniqlang.



5.9-rasm. 5-masala uchun Mixaylov chizig`i

Echish: ω chastotasi 0 dan ∞gacha o`zgarganda $D(j\omega)$ vektori o`zgarish burchagi:

$$\varphi = n\frac{\pi}{2} - l\pi \qquad (5.1)$$

Bu erda, n–tavsifiy tenglamaning tartibi; l–musbat mavhum qismdagi ildizlar soni.

ω chastotasi 0 dan ∞gacha o`zgarganda $D(j\omega)$ vektori o`zgarish burchagi $\varphi = \frac{\pi}{2}$ ga teng ekanligi 5.9-rasmdan ko`rinadi.

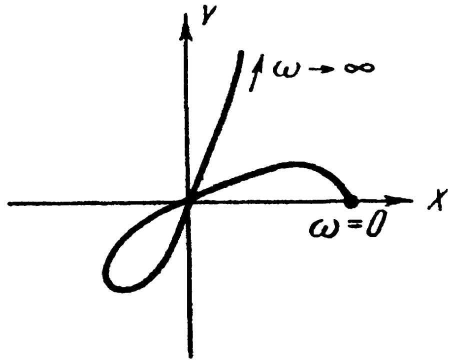
(5.1) ifodaga burchakning qiymati n=5 va qo`yib, musbat mavhum qismdagi ildizlar soniga ega bo`lamiz:

$$l = \frac{5\frac{\pi}{2} - \frac{\pi}{2}}{\pi} = 2$$

Mixaylov chizig`i koordinata boshidan o`tmaydi, shuning uchun manfiy mavhum qismdagi ildizlar soni $n - l = 5 - 2 = 3$ ga teng.

5.19-masala

5.10-rasmda beshinchi tartibli avtomatik boshqaruv tizimining Mixaylov chizig`i berilgan. Tavsifiy tenglama ildizlarining ildiz tekisligida joylashishini tuzing.



5.10-rasm. 5.19-masala uchun Mixaylov chizig`i

5.20-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p)=\frac{K}{p(1+T_1p)(1+T_2p)(1+T_3p)}$$

Bu erda, K -yopiq tizimning umumiy uzatishi koeffisienti,

$T_1=0.5сек, T_2=0,1сек, T_3=0,02сек$ vaqt o`zgarmaslari.

Mixaylov mezoni yordamida tizim turg`unlik chegarasida bo`ladigan yopiq tizimning umumiy uzatish koeffisienti K qiymatini aniqlang.

Echish: yopiq tizimning tavsifiy ko`p hadi:

$$D(p)=p(1+T_1p)(1+T_2p)(1+T_3p)+K=T_1T_2T_3p^4+(T_1T_2+T_1T_3+T_2T_3)p^3+(T_1+T_2+T_3)p^2+p+K$$

T_1,T_2,T_3 larning o`rniga qiymatlarini qo`yib, quyidagiga ega bo`lamiz:

$$D(p)=p(1+T_1p)(1+T_2p)(1+T_3p)+K=10^{-3}p^4+62\cdot10^{-3}p^3+610\cdot10^{-3}p^2+p+K$$

$D(j\omega)$ vektorini tavsifiy polinomda r ni $j\omega$ ga almashtirib hosil qilamiz:

$$D(j\omega)=X(\omega)+jY(\omega)$$

$$X(\omega)=K-610\cdot10^{-3}\omega^2+10^{-3}\omega^4,$$

$$Y(\omega)=\omega-62\cdot10^{-3}\omega^3$$

Tizim turg`unlik chegarsida bo`lganda, koordinata boshidan o`tadi:

$$X(\omega)=K-610\cdot10^{-3}\omega^2+10^{-3}\omega^4=0 \qquad (5.2)$$

$$Y(\omega)=\omega-62\cdot10^{-3}\omega^3=0 \qquad (5.3)$$

Bu ifodadan chastota qiymatini topamiz:

$$\omega-62\cdot10^{-3}\omega^3=0$$

$$\omega(1-62\cdot10^{-3}\omega^2)=0$$

$$62\cdot10^{-3}\omega^2=1 \qquad (5.4)$$

$$\omega^2=(62\cdot10^{-3})^{-1}сек^{-2}$$

(5.4) ni (5.2) ifodaga qo`yib, K ni qiymatini topamiz:

$$K=\frac{610\cdot10^{-3}}{62\cdot10^{-3}}-\frac{10^{-3}}{62^2\cdot10^{-6}}=9,6$$

5.21-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p)=\frac{K}{p(1+\xi T_1p+T_1^2p^2)(1+T_2p)(1+T_3p)}$$

Bu erda, K–yopiq tizimning umumiy uzatishi koeffisienti, ξ–dempferlash koeffisienti;

$T_1 = 0.05 сек, T_2 = 0,2 сек, T_3 = 0,1 сек$ vaqt o`zgarmaslari.

Mixaylov mezoni yordamida tizim turg`unlik chegarasida bo`ladigan K yopiq tizimning umumiy uzatish koeffisienti qiymatini aniqlang.

5.22-masala

Avtomatik tizim turg`unligini Mixaylov mezoni yordamida aniqlang. Tizimning tavsifiy tenglamasi:

$$a_0 p^5 + a_1 p^4 + a_2 p^3 + a_3 p^2 + a_4 p + a_5 = 0$$

Bu erda,

$$a_0 = 0,15 \cdot 10^{-2} сек^5, a_1 = 5 \cdot 10^{-2} сек^4, a_2 = 0,6 сек^3, a_3 = 4 сек^2, a_4 = 20 сек, a_5 = 500$$

5.23-masala

Avtomatik tizimning tavsifiy ko`phadi:

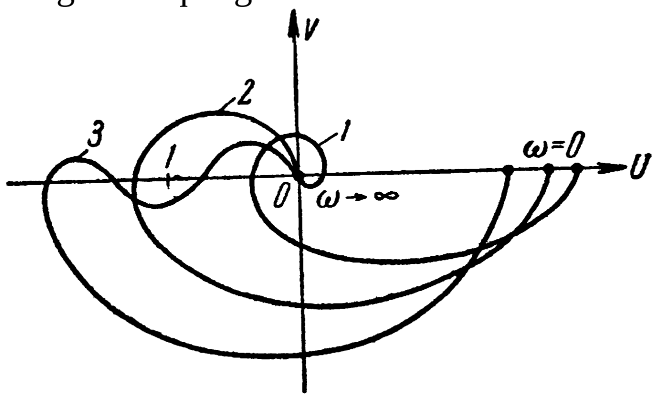
$$D(p) = 2 \cdot 10^{-4} p^6 + 80 \cdot 10^{-4} p^5 + 3 \cdot 10^{-1} p^4 + 1,24 p^3 + 10 p^2 + 40 p + 34$$

Tizim turg`unligini aniqlang.

5.3 Naykvist mezoni bo`yicha tizim turg`unligini tekshirish

5.24-masala

Ochiq holda turg`un tizimning amplituda-faza tavsifi 5.11-rasmda keltirilgan. Yopiq tizimning turg`unligini aniqlang.



5.11-rasm. 5.24-masala uchun A.F.T.

5.25-masala

Elektromexanik kuzatuvchi tizimning yopiq holdagi uzatish fuknsiyasi:

$$W(p) = \frac{K}{p(1+T_м p)(1+T_у p)}$$

Bu erda, $K = 100 сек^{-1}$–kuzatuvchi tizimning tezlik bo`yicha zichligi, $T_м = 0,02 сек$ – dvigatel o`zgarmas vaqti; $T_у = 0,02 сек$–kuchaytirgich o`zgarmas vaqti.

Naykvist mezonidan foydalanib, elektromexanik tizimning turg`unligini aniqlang.

Echish: amplituda-faza tavsifini (AFT) qurish uchun amplituda chastota tavsifi $A(\omega)$ni va faza chastota tavsifi $\psi(\omega)$ni aniqlab olamiz:

$$A(\omega)=|W(j\omega)|=\left|\frac{K}{j\omega(1+j\omega T_м)(1+j\omega T_у)}\right|=\frac{K}{\omega\sqrt{1+(\omega T_м)^2}\sqrt{1+(\omega T_у)^2}}=\frac{100}{\omega\sqrt{1+(\omega\cdot 0,1)^2}\sqrt{1+(\omega\cdot 0,02)^2}},$$

$$\psi(\omega)=\arg W(j\omega)=\arg\frac{K}{j\omega(1+j\omega T_м)(1+j\omega T_у)}=-90^0+\psi_1+\psi_2,$$

$\psi_1(\omega)=-arctg\omega T_м=arctg0.1\omega,$

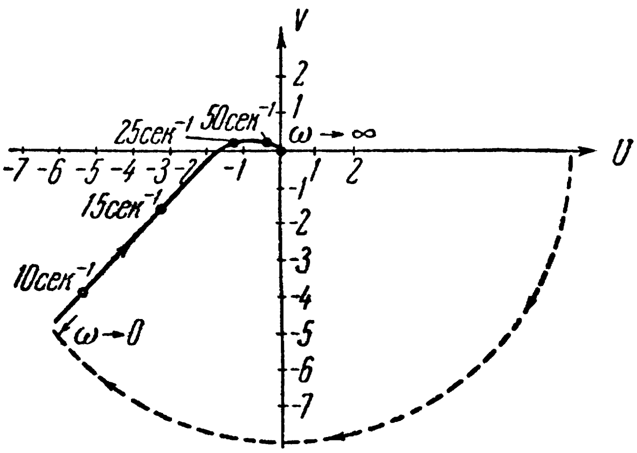
$\psi_2(\omega)=-arctg\omega T_у=-arctg0.02\omega.$

$A(\omega),\psi(\omega),\psi_1(\omega)$, $\psi_2(\omega)$ ni ω chastotani bir nechta qiymatlari uchun hisoblab, jadval tuzamiz:

5.1-jadval

$\omega, сек^{-1}$	0	5	10	15	25	50	100
A	∞	18	6.9	3.56	1.32	0.28	0.045
ψ, град	-90	-122	-144	-153	-184	-214	-238
ψ_1, град	0	-26	-45	-56	-68	-79	-84
ψ_2, град	0	-6	-11	-17	-26	-45	-64

Ushbu jadvalga asoslanib, AFTni quramiz (5.12-rasm).



5.12-rasm. Yopiq tizimning AFT

Yopiq tizimi AFT si (-1,0) nuqtadan o`tmoqda. Demak, tizim turg`un emas.

5.26-masala

Naykvist turg`unlik mezonidan foydalanib, 5.25-masalada berilgan tizimni quyidagi ko`rsatkichlar uchun turg`unligini tekshiring:

a) $K=50сек^{-1}, T_м=0,1сек, T_у=0,025сек$

b) $K=200сек^{-1}, T_м=0,02сек, T_у=0,002сек$

v) $K=50сек^{-1}, T_м=0,1сек, T_у=0,005сек$

5.27-masala

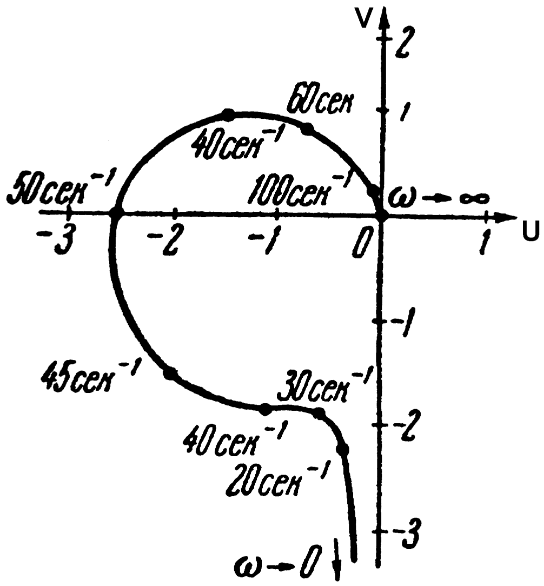
Bir o`qli gireskopik mo``tadillashtirgichning ochiq holdagi uzatish funksiyasi:

$$W(p)=\frac{K}{p(1+2\xi T_Г p+T_Г{}^2p^2)}$$

$K=40сек^{-1}, T_Г=0,02сек, \xi=0,15$

Naykvist mezonidan foydalanib, girostabilizatorning yopiq holatdagi turg`unligini aniqlang.

Echish: tizimning ochiq holatdagi AFTsi 5.13-rasmda keltirilgan. Girostabilizator turg`un emas.



5.13-rasm. 4-masala uchun AFT

5.28-masala

Statik turg`un ob`ektni ochiq holatdagi uzatish funksiyasi:

$$W(p)=\frac{K(1+\tau p)}{p(1+T_1 p)(1+T_0^2 p^2)}$$

Bu erda, $K=1$–ochiq tizimning kuchaytirish koeffisienti,

$\tau=0{,}1сек$–rostlovchi qurilmaning o`zgarmas vaqti; $T_1=0{,}2сек$–bajaruvchi qurilmaning o`zgarmas vaqti, $T_0=0{,}5сек$–ob`ektning o`zgarmas vaqti.

Naykvist mezonidan foydalanib, yopiq tizimning turg`unligini aniqlang.

Echish: ochiq tizimning amplituda chastota tavsifi:

$$A(\omega)=\frac{K\sqrt{1+(\omega\tau)^2}}{\sqrt{1+(\omega T_1)^2}\cdot\left|1-(\omega_0 T_0)^2\right|}=\frac{\sqrt{1+(0{,}1\omega)^2}}{\sqrt{1+(0{,}2\omega)^2}\cdot\left|1-(0{,}5\omega)^2\right|}.$$

Faza chastota tavsifi:

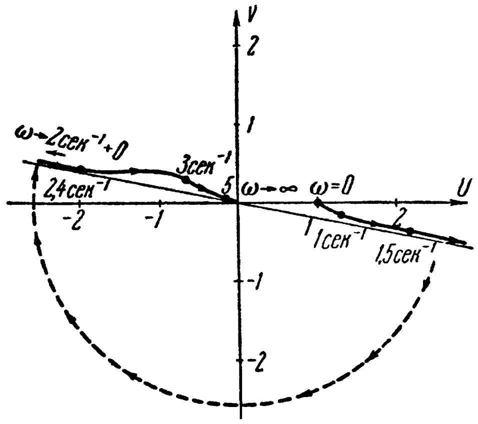
$$\psi(\omega)=\begin{cases} arctg\,\omega\tau-arctg\,\omega T_1=arctg\,0.1\omega-arctg\,0.2\omega,\ \omega<\dfrac{1}{T_0}=2сек^{-1}да \\ arctg\,\omega\tau-arctg\,\omega T_1-180^0=arctg\,0.1\omega-arctg\,0.2\omega-180^0,\ \omega>\dfrac{1}{T_0}=2сек^{-1}да \end{cases}$$

$A(\omega),\psi(\omega)$ ni ω chastotani bir nechta qiymatlari uchun hisoblab, jadval tuzamiz:

5.2-jadval

$\omega, сек^{-1}$	0	1	1.5	$\omega\to 2-0$	$\omega\to 2+0$	2.4	3	5	∞
A	1	1.33	2.2	∞	∞	2.1	0.7	1.15	0
$\psi, град$	0	-6	-9	-11	-191	-192	-204	-198	-180

Jadvaldagi ma`lumotlarga asoslanib, ochiq tizimning AFT sini quramiz (5.14-rasm).



5.14-rasm. 5-masala uchun AFT

Yopiq tizimi AFT si (-1,0) nuqtadan o`tmoqda. Demak, tizim turg`un emas.

5.29-masala

Yopiq tizimning uzatish funksiyasi:

$$W(p)=\frac{K(1+\tau p)}{p(1+T_1 p)(1+T_2 p)(1+T_0^2 p^2)}$$

bu erda, $K=1$–ochiq tizimning kuchaytirish koeffisienti,

$\tau=0,4сек$ – rostlovchi qurilmaning o`zgarmas vaqti;

$T_1=0,2сек, T_2=0,1сек$–bajaruvchi qurilmaning o`zgarmas vaqti,

$T_0=0,5сек$–ob`ektning o`zgarmas vaqti.

Naykvist mezonidan foydalanib, yopiq tizim turg`unligini aniqlang.

5.30-masala

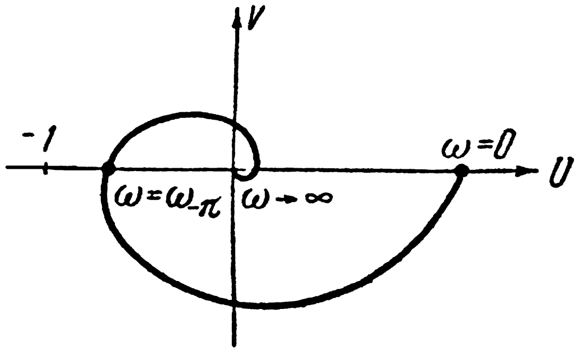
Yopiq tizimning uzatish funksiyasi:

$$W(p)=\frac{K}{(1+Tp)^n}$$

Bu erda, $K>0, T>0, n>0$

Naykvist mezonidan foydalanib, yopiq tizim turg`unligini aniqlang.

Echish: ochiq tizimning AFT si 5.15-rasmda keltirilgan.



5.15-rasm. 7-masala uchun AFT

Tizimning faza chastotaviy tavsifi:

$\psi(\omega)=-n\,arctg\,\omega T$

$\psi(\omega)=-n\,arctg\,\omega T=-\pi$

da $\omega=\omega_{-\pi}$ chastota qiymatini aniqlaymiz:

$$\omega_{-\pi}=\frac{tg\frac{\pi}{n}}{T}$$

Tizim turg`un bo`lishi uchun quyidagi shart bajarilishi etarli:

$$\left|W(j\omega)\right|_{\omega=\omega_{-\pi}} = \left.\frac{K}{(\sqrt{1+(\omega T)^2})^n}\right|_{\omega=\omega_\pi} < 1$$

Ushbu ifodadan turg`unlik shartini aniqlaymiz:

$$K < (\sqrt{1+tg^2\frac{\pi}{n}})^n = \frac{1}{\cos^n\frac{\pi}{n}}.$$

<u>5.31-masala</u>

Yopiq tizimning uzatish funksiyasi:

$$W(p) = \frac{K}{p(1+Tp)^n}$$

bu erda, $K > 0, T > 0$

Naykvist mezonidan foydalanib, yopiq tizimning turg`unligini aniqlang.

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