Asinxron motor reaktiv quvvatining filtr-kompensatsiya qurilmasini uch fazali elektromagnit tok oʻzgartkichlari

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Dolzarblik: hozirda elektr qurilmalarini nazorat qilish va boshqarishda yarim oʻtkazgichli elementlardan keng foydalanilmoqda, bu esa elektr energiyaning sifat koʻrsatkichiga taʼsir koʻrsatuvchi nosimmetrik va nosinusoidal toklarning miqdorini oshishiga olib keladi. Nosimmetrik va nosinusoidal toklar elektr qurilmalarini reaktiv quvvatining oshishiga, haddan tashqari qizishiga, ish samaradorligini kamayishiga va tarmoqdagi boshqa qurilmalarning ish faoliyatiga ham salbiy taʼsir koʻrsatadi. Nosimmetrik va nosinusoidal toklarning miqdorini standartlarda belgilangan qiymatlardan oshmasligini taʼminlash muhim hisoblanadi.

Maqsad: asinxron motorlarda nosimmetrik va yuqori garmonika toklarini miqdorini filtr-kompensatsiya qurilmalari orqali kompensatsiyalash va filtrlashda uch fazali elektromagnit tok oʻzgartkichidan olingan elektr signallar asosida nazorat qilish va boshqarish aniqligini, tezkorligini va ishonchliligini oshirish hisobiga elektr energiyasining sifat koʻrsatkichlariga boʻlgan salbiy taʼsirlarni kamaytirishdan iborat.

Usullar: uch fazali elektromagnit tok oʻzgartkichi modelini ishlab chiqishda Proteus dasturidan foydalaniladi va CASSYLAB qurilmasi orqali amaliy tadqiqot olib boriladi.

Natijalar: asinxron motor reaktiv quvvatining filtr-kompensatsiya qurilmasini uch fazali elektromagnit tok oʻzgartkich yordamida nazorat qilish va boshqarish blogi, boshqaruv blokining qaror qabul qilish algoritmi ishlab chiqilgan. Proteus dasturida uch fazali elektromagnitli tok oʻzgartkich chiqish signali asosida asinxron motorning stator toki va quvvat koeffitsietini aniqlash modeli yaratilgan va CASSYLAB qurilmasi orqali manba kuchlanishi, asinxron motor uch fazali elektromagnit tok oʻzgartkichning chiqish kuchlanishi va ular orasidagi faza siljish burchagi grafiklari olinib tahlil qilingan.

Kalit soʻzlar: asinxron motor, reaktiv quvvat, filtr-kompensatsiya qurilmasi, tok oʻzgartkichi, chiqish signali, fazalar siljish burchagi, yuqori garmonika, algoritm, sezgir element, induktiv element, sigʻim element.

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Трехфазные электромагнитные преобразователи тока фильтрокомпенсирующего устройства реактивной мощности асинхронного двигателя

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Актуальность: в настоящее время полупроводниковые элементы широко используются для контроля и управления электрическими устройствами, что приводит к увеличению количества несимметричных и несинусоидальных токов, влияющих на показатели качества электроэнергии. Симметричные и несинусоидальные токи также негативно влияют на увеличение реактивной мощности электроустановок, перегрев, снижение эффективности работы и работоспособности различных устройств в сети. Важно контролировать, чтобы величина симметричных и несинусоидальных токов не превышала значений, установленных стандартами.

Цель: компенсация токов несимметричных и высших гармоник в асинхронных двигателях фильтрокомпенсирующими устройствами, а также снижение их негативного влияния на показатели качества электроэнергии путём повышения точности, быстродействия и надежности контроля и управления электрическими сигналами, получаемыми от трехфазного электромагнитного преобразователя тока при фильтрации.

Методы: при разработке модели трехфазного электромагнитного преобразователя тока используется программное обеспечение Proteus, а тематическое исследование проводится с помощью устройства CASSYLAB.

Результаты: разработаны блоки управления и контроля фильтрокомпенсирующего устройства реактивной мощности асинхронного двигателя с помощью трехфазного электромагнитного преобразователя тока, алгоритм принятия решения блока управления. Программой Proteus на основе выходного сигнала трехфазного электромагнитного преобразователя тока была создана модель для определения тока статора и коэффициента мощности асинхронного двигателя, а с помощью устройства CASSYLAB были получены и проанализированы графики напряжения источника, выходного напряжения трехфазного электромагнитного преобразователя тока асинхронного двигателя и угла сдвига фазы между ними.

Ключевые слова: асинхронный двигатель, реактивная мощность, фильтрокомпенсирующее устройство, преобразователь тока, выходной сигнал, угол сдвига фаз, верхняя гармоника, алгоритм, чувствительный элемент, индуктивный элемент, емкостной элемент.

Three-phase electromagnetic current transducers of asynchronous motor reactive power filter-compensation device

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Relevance: currently, semiconductor elements are widely used in the control and management of electrical devices, which leads to an increase in the number of symmetrical and non-sinusoidal currents affecting the quality of electricity. Symmetrical and non-sinusoidal currents also negatively affect the increase in the reactive power of electrical installations, overheating, reduced operational efficiency and the operability of other devices in the network. It is important to ensure that the value of symmetrical and non-sinusoidal currents does not exceed the values set by the standards.

Purpose: to compensate for the magnitude of currents of symmetrical and high harmonics in asynchronous motors through filter compensating devices and reduce the negative impact on electricity quality indicators by increasing the accuracy, speed and reliability of monitoring and control based on electrical signals received from a three-phase electromagnetic current transducer during filtration.

Methods: when developing a model of a three-phase electromagnetic current transducer, Proteus software is used, and a case study is carried out using a CASSYLAB device.

Results: a control and control unit has been developed for a filter compensating device for reactive power of an asynchronous motor using a three-phase electromagnetic current transducer, an algorithm for making a decision of the control unit. In the Proteus program, based on the output signal of a three-phase electromagnetic current transducer, a model was created to determine the stator current and the power factor of an asynchronous motor, and using the CASSYLAB device, graphs of the source voltage, output voltage of a three-phase electromagnetic current transducer of an asynchronous motor and the phase shift angle between them were obtained and analyzed.

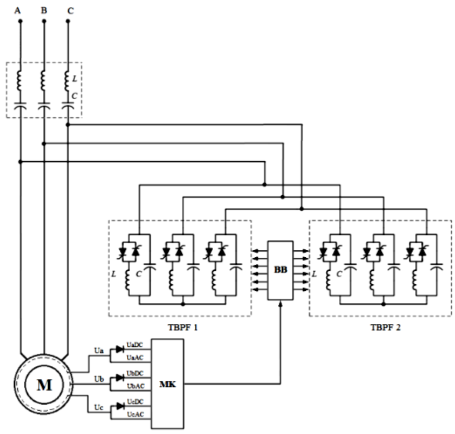
Keywords: asynchronous motor, reactive power, filter compensating device, current transducer, output signal, phase shift angle, upper harmonic, algorithm, sensing element, inductive element, capacitive element.

1. Kirish (Introduction)

Filtr-kompensatsiya qurilmalari asosan induktiv va sig'im elementlaridan tashkil topgan bo'lib, garmonik buzilishlarning miqdori passiv, aktiv va gibrid filtrlar yordamida kamaytiriladi. Hozirda garmonik buzilishlarni filtrlashda yuqori ishonchlilik, samaradorlik, arzon narx va oddiy konfiguratsiyaga ega bo'lganligi sababli passiv filtrlar keng qo'llanilmoqda. Bundan tashqari passiv filtrlar yordamida reaktiv quvvatni kompensatsiyalash ham mumkin. Odatda passiv filtrlar qarshilik, kondensator va induktiv elementlardan tashkil topadi va ularning ishlashi uchun tashqi quvvat manbai kerak bo'lmaydi. Passiv filtrlarning ko'plab turli topologiyalari mavjud bo'lib, ko'p hollarda parallel filtr konfiguratsiyasi eng afzal filtr topologiyalari hisoblanadi [1-4, 10]. Hozirgi kunda keng tarqalgan filtr-kompensatsiya qurilmasi bu, takomillashtirilgan gibrid passiv filtr bo‘lib, har bir faza uchun mos bo‘lgan ketma-ket passiv va tiristorlar bilan boshqariladigan parallel passiv filtrlardan iborat. Takomillashtirilgan gibrid passiv filtrlar, an’anaviy gibrid filtrlarga nisbatan reaktiv quvvatni kompensatsiya qilish va yuqori garmonikalarni filtrlash ko‘rsatkichlari aniqroqdir [3, 12].

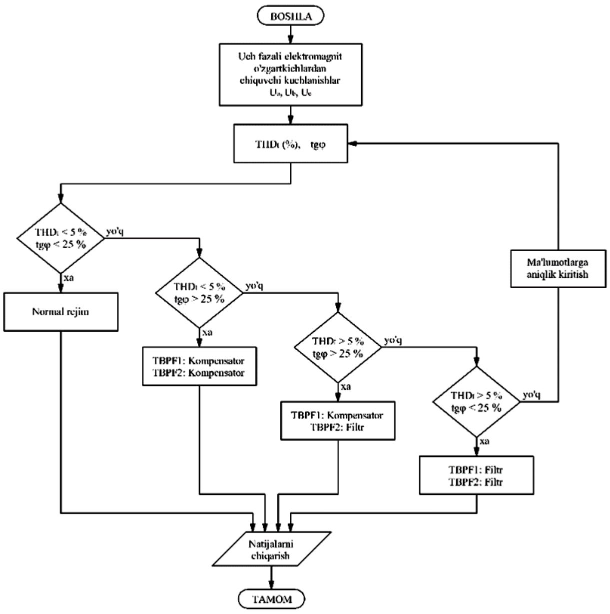
2. Materiallar va metodlar (Materials and Methods)

Har bir faza uchun mos, stator chulg‘amlari joylashish tartibida pazlarga joylashtirilgan uch fazali elektromagnit tok o‘zgartkich signali asosida, takomillashtirilgan gibrid passiv filtrlar yordamida asinxron motor reaktiv quvvatining nosimetrik va nosinusoidal toklari filtrlanadi va kompensatsiya-lanadi. Bunda uch fazali elektromagnit tok o‘zgartkichdan chiquvchi kuchlanish signali mikroprotses-sor (MK) yordamida belgilgan kattaliklar aniqlanadi, ya’ni yuqori garmonikalarning qiymatlari va nosimmetrik toklar sababli yuzaga keluvchi tarmoq kuchlanishi va chiqish kuchlanish signali orasidagi burchak [4-6, 13].



1-rasm. Asinxron motor reaktiv quvvatining filtr-kompensatsiya qurilmasini uch fazali elektromagnit tok o‘zgartkich yordamida nazorat qilish va boshqarish
Fig.1. Control and management of the filter-compensation device of the asynchronous motor reactive power using a three-phase electromagnetic current Switch

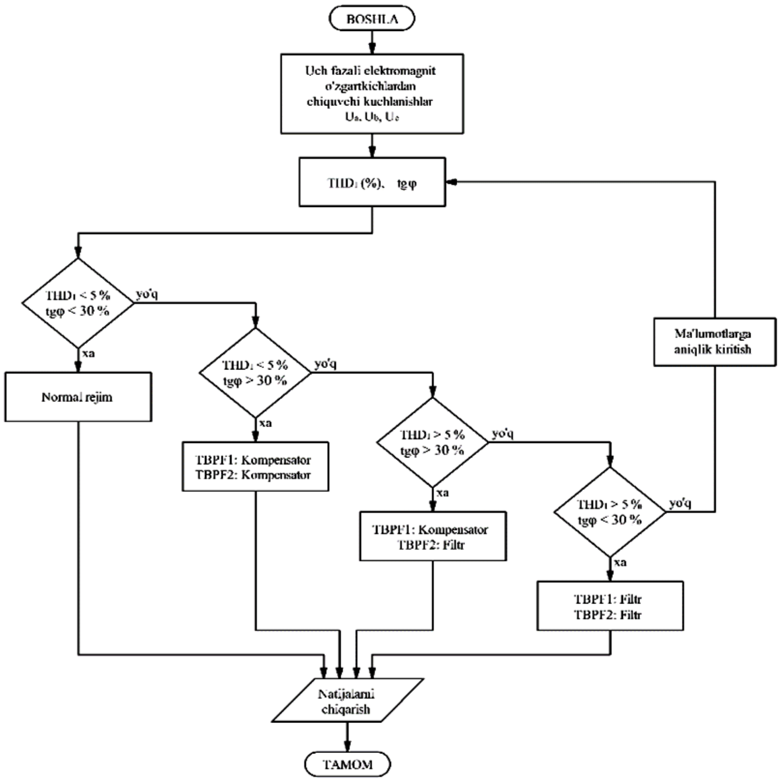
Aniqlangan signallarga asosan mikroprotsessor boshqarish blokiga (BB) ma’lumotlarni yuboradi. Boshqarish bloki esa mikroprotsessordan kelgan signal asosida, birinchi tiristorli boshqarishli passiv fitr (TBPF1) va ikkinchi tiristorli boshqarishli passiv fitr (TBPF2) larni boshqaradi (1-rasm) [8,17-20].



2-rasm. Asinxon motor reaktiv quvvatining filtr-kompensatsiya qurilmasi boshqaruv blokining qaror qabul qilish algoritmi (0.4 kV kuchlanish uchun)
Fig.2. The decision-making algorithm of the control unit of the filter-compensation device of the asinkhan motor reactive power (for a voltage of 0.4 kV)

0.4 kV kuchlanish ta’minot manbaiga ulangan asinxron motor reaktiv quvvatining filtr-kompensatsiya qurilmasi quyidagi algoritmga asosan nazorat qilinadi va boshqariladi (O‘zbekiston

Respublikasi Adliya vazirligining 1864-sonli nizomi va xalqaro elektr va elektronika muhandislari institutining IEEE 1159-2019 standartlariga asosan) [14, 18-22].



3-rasm. Asinxon motor reaktiv quvvatining filtr-kompensatsiya qurilmasi boshqaruv blokining qaror qabul qilish algoritmi (6÷10 kV kuchlanishlar uchun)
Fig.3. Asinxon motor jet power filter-compensation Device Control Unit decision-making algorithm (for voltages of 6÷10 kV)

Algortimga asosan asinxon motor reaktiv quvvatining filtr-kompensatsiya qurilmasi boshqaruv blokining qaror qabul qilishi, umumiy garmonik buzilish THD_I ning qiymati va quvvat parametrlarining nisbati tgφ orqali aniqlanadi (2-rasm).

1. (THD_I<5 % va tgφ<25 %) Filtr-kompensatsiya qurilasi normal rejimda ishlaydi, chunki garmonik buzilish va quvvat parametrlarining nisbati belgilangan me'yor oralig'ida.
2. (THD_I<5 % va tgφ>25 %) Filtr-kompensatsiya qurilmasining har ikki tiristorli boshqarishli passiv filtrlari kompensator rejimda ishlaydi, chunki garmonik buzilish qiymati belgilangan me'yorda va quvvat parametrlarining nisbati esa belgilangan me'yordan yuqori.
3. (THD_I>5 % va tgφ>25 %) Filtr-kompensatsiya qurilmasi filtr va kompensator rejimda ishlaydi, chunki garmonik buzilish va quvvat parametrlarining nisbati belgilangan me'yordan yuqori.
4. (THD_I>5 % va tgφ<25 %) Filtr-kompensatsiya qurilmasi filtr rejimda ishlaydi, chunki garmonik buzilish qiymati belgilangan me'yordan yuqori va quvvat parametrlarining nisbati belgilangan me'yor oralig'ida.

(6÷10) kV kuchlanish manbaiga ulangan asinxron motor reaktiv quvvatining filtr-kompensatsiya qurilmasi esa quyidagi algoritm orqali, THD_I<5 % va tgφ<30 % belgilangan me'yorlar asosida nazorat qilinadi va boshqariladi (3-rasm) [12, 13].

Asinxron motor uch fazali elektromagnit tok o'zgartkich signali asosida quvvat koeffitsientini aniqlash:

Sezgir element xalqalarini turli ulanish sxemalariga ega asinxron motor uch fazali elektromagnit tok o'zgartkichlaridan chiquvchi signallar va tarmoq kuchlanishlari fazalari orasidagi burchakning qiymatiga asosan asinxron motorning reaktiv quvvati kompensatsiya qilinadi [12, 15-19].

Stator tokini ifodalovchi chiqish kuchlanish signali va tarmoq kuchlanishi orasidagi burchak hamda stator tokining qiymatini matematik hisoblashda stator chulg'amlariga beriluvchi manba kuchlanishlari va sezgir elementdan chiquvchi kuchlanish ko'rinishidagi signallar, algebraik shaklga o'tkaziladi bunda asinxron motor statori har bir fazasidagi tokning aktiv va reaktiv tashkil etuvchi qiymatlari quyidagi formulalar orqali aniqlanadi [5-10, 21].

$$I_A = \frac{\left(\frac{U_{0.A}}{\sqrt{2}} \cdot \cos(-90^0) + j \cdot \frac{U_{0.A}}{\sqrt{2}} \cdot \sin(-90^0)\right) - \frac{w_4}{w_1} \cdot \left(\frac{U_{0.a}}{\sqrt{2}} \cdot \cos(\beta_a - 90^0) + j \cdot \frac{U_{0.a}}{\sqrt{2}} \cdot \sin(\beta_a - 90^0)\right)}{R_{A.1} + jX_{A.1}};$$

$$I_B = \frac{\left(\frac{U_{0.B}}{\sqrt{2}} \cdot \cos(30^0) + j \cdot \frac{U_{0.B}}{\sqrt{2}} \cdot \sin(30^0)\right) - \frac{w_5}{w_2} \cdot \left(\frac{U_{0.b}}{\sqrt{2}} \cdot \cos(\beta_b + 30^0) + j \cdot \frac{U_{0.b}}{\sqrt{2}} \cdot \sin(\beta_b + 30^0)\right)}{R_{B.1} + jX_{B.1}}; \quad (1)$$

$$I_C = \frac{\left(\frac{U_{0.C}}{\sqrt{2}} \cdot \cos(-210^0) + j \cdot \frac{U_{0.C}}{\sqrt{2}} \cdot \sin(-210^0)\right) - \frac{w_6}{w_3} \cdot \left(\frac{U_{0.c}}{\sqrt{2}} \cdot \cos(\beta_c - 210^0) + j \cdot \frac{U_{0.c}}{\sqrt{2}} \cdot \sin(\beta_c - 210^0)\right)}{R_{C.1} + jX_{C.1}};$$

$$I_{A.aktiv} = \frac{\frac{U_{0.A}}{\sqrt{2}} \cdot \cos(-90^0) - \frac{w_4}{w_1} \cdot \frac{U_{0.a}}{\sqrt{2}} \cdot \cos(\beta_a - 90^0)}{R_{A.1} + jX_{A.1}}; \qquad I_{A.reaktiv} = \frac{j \cdot \left(\frac{U_{0.A}}{\sqrt{2}} \cdot \sin(-90^0) - \frac{w_4}{w_1} \cdot \frac{U_{0.a}}{\sqrt{2}} \cdot \sin(\beta_a - 90^0)\right)}{R_{A.1} + jX_{A.1}};$$

$$I_{B.aktiv} = \frac{\frac{U_{0.B}}{\sqrt{2}} \cdot \cos(30^0) - \frac{w_5}{w_2} \cdot \frac{U_{0.b}}{\sqrt{2}} \cdot \cos(\beta_b + 30^0)}{R_{B.1} + jX_{B.1}}; \qquad I_{B.reaktiv} = \frac{j \cdot \left(\frac{U_{0.B}}{\sqrt{2}} \cdot \sin(30^0) - \frac{w_5}{w_2} \cdot \frac{U_{0.b}}{\sqrt{2}} \cdot \sin(\beta_b + 30^0)\right)}{R_2 + jX_2}; \quad (2)$$

$$I_{C.aktiv} = \frac{\frac{U_{0.C}}{\sqrt{2}} \cdot \cos(-210^0) - \frac{w_6}{w_3} \cdot \frac{U_{0.c}}{\sqrt{2}} \cdot \cos(\beta_c - 210^0)}{R_{C.1} + jX_{C.1}}; \qquad I_{C.reaktiv} = \frac{j \cdot \left(\frac{U_{0.C}}{\sqrt{2}} \cdot \sin(-210^0) - \frac{w_6}{w_3} \cdot \frac{U_{0.c}}{\sqrt{2}} \cdot \sin(\beta_c - 210^0)\right)}{R_{C.1} + jX_{C.1}};$$

$$I_A = \sqrt{I_{A.aktiv}^2 + I_{A.reaktiv}^2};$$
$$I_B = \sqrt{I_{B.aktiv}^2 + I_{B.reaktiv}^2}; \quad (3)$$
$$I_C = \sqrt{I_{C.aktiv}^2 + I_{C.reaktiv}^2}.$$

Yuqoridagi formulalar orqali sezgir elementdan chiquvchi signalning qiymatiga asosan asinxron motorning statoridagi kuchlanish hamda tok kuchi orasidagi faza siljish burchagi quyidagicha topiladi.

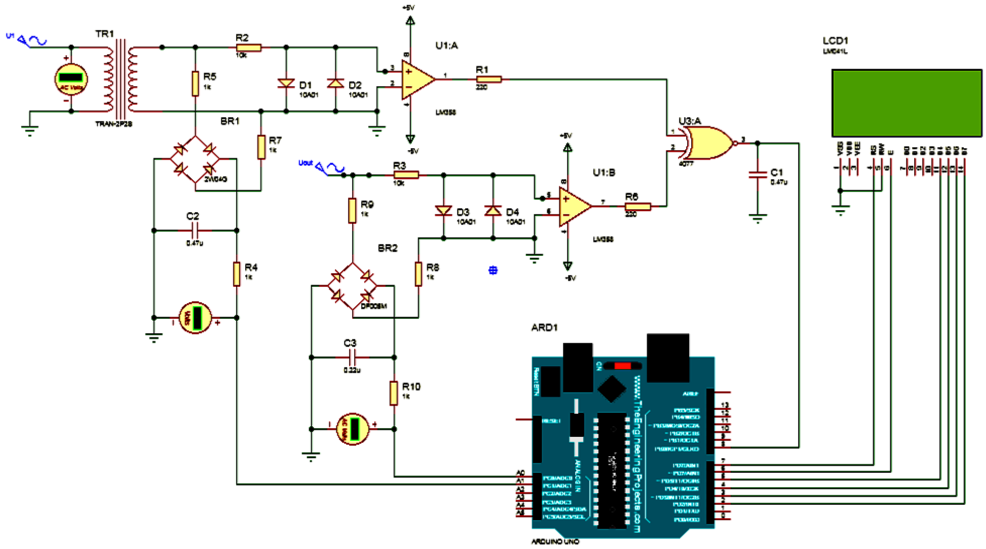
$$\varphi_A = \left(90^0 + arctg\left(\frac{I_{A.reaktiv}}{I_{A.aktiv}}\right)\right);$$
$$\varphi_B = \left(90^0 + arctg\left(\frac{I_{B.reaktiv}}{I_{B.aktiv}}\right)\right); \quad (4)$$
$$\varphi_C = \left(90^0 + arctg\left(\frac{I_{C.reaktiv}}{I_{C.aktiv}}\right)\right).$$

CASSYLAB qurilmasi orqali amaliy tadqiqot ishlari olib borildi, unga asosan 4AA63A4Y3 tipli qisqa tutashgan rotorli asinxron motorning nominal ish rejimida manba kuchlanishi, asinxron motor uch fazali tok oʻzgartkichi kuchlanish signali va ular orasidagi faza siljish burchagi aniqlandi.

Tadqiqot natijasida amaliy aniqlangan maʼlumotlar va yuqorida keltirilgan ifodalar asosida Proteus dasturida uch fazali elektromagnit tok oʻzgartkichi signali asosida asinxron motor statorining toki va quvvat koeffitsientini aniqlash modeli yaratildi, buning uchun Arduino UNO mikrokontrolleridan foydalanildi (4-rasm). Manba kuchlanish parametrlarini aniqlashda kuchlanish transformatori yordamida kuchlanish miqdori kamaytirildi, bir fazali toʻgʻirlagich sxemasi orqali Arduinoning analog piniga ulandi, bu orqali mikrokontroller yordamida manba kuchlanishini bilish imkoniyati mavjud boʻldi. Bundan tashqari operatsion kuchaytirgich orqali manba kuchlanishining faza siljish burchagini bilish uchun zero cross nuqtalari aniqlandi.

Asinxron motor uch fazali elektromagnit tok oʻzgartkichdan kuchlanish koʻrinishida chiquvchi signalning parametrlarini aniqlashda ham manba kuchlanish parametrlarini aniqlash sxemalaridan foydalanildi va uning kuchlanish qiymati va faza siljish burchagi aniqlandi. Manba kuchlanishi va chiqish kuchlanish faza siljish burchagining farqini aniqlashda XNOR mantiqiy elementidan foydalanildi va undan chiquvchi signal Arduinoning raqamli piniga ulandi. Manba kuchlanishi va chiqish kuchlanishi parametrlari va yuqoridagi formulalarga asosan Arduino IDE da stator toki va quvvat koeffitsientini aniqlash dastur kodi yozildi va aniqlangan parametrlar LCD 16x4 monitorga uzatildi. LCD monitorda manba kuchlanishi, asinxron motorning statoriga joylashtirilgan sezgir elementdan chiquvchi kuchlanish, asinxron motor statorining toki va asinxron motorning quvvat koeffisienti joy olgan (A faza uchun) [3, 12, 19-21].

Asinxron motorning stator pazlariga joylashtirilgan sezgir elementdan kuchlanish koʻrinishida chiquvchi signalning qiymati, asinxron motorning statorida hosil boʻlgan tokning qiymatiga proporsionaldir.



4-rasm. Proteus dasturida, uch fazali elektromagnitli tok o‘zgartkich signali asosida asinxron motorning stator toki va quvvat koeffitsietini aniqlash modeli
Fig. 4. In the Proteus program, a model for determining the stator current and power coefficient of an asynchronous motor based on a three-phase electromagnet current Switch signal

3. Natijalar (Results)

Uch fazali elektromagnit tok o‘zgartkich chiqish signallari asosida asinxron motorning reaktiv quvvatiga ta’sir ko‘rsatuvchi yuqori garmonika toklari quyidagicha aniqlandi (1-Jadval) [12, 14, 17].

1-Jadval. Asinxron motorning reaktiv quvvatiga ta’sir ko‘rsatuvchi yuqori garmonika toklari
Table 1. High harmonic currents affecting the reactive power of the asynchronous motor

k	Tok transformatori, Ia (A)	Har bir faza uchun mos bitta sezgir element xalqali uch fazali elektromagnit tok o‘zgartkich, Ua (V)	Har bir faza uchun mos ikkita sezgir element xalqa-larga ega, ketma-ket ulangan uch fazali elektromagnit tok o‘zgartkich, Ua (V)	Har bir faza uchun mos ikkita sezgir element xalqa-larga ega, parallel ulangan uch fazali elektromagnit tok o‘zgartkich, Ua (V)	Har bir faza uchun mos ikkita sezgir element xalqa-larga ega, differensial ulangan uch fazali elektromagnit tok o‘zgartkich, Ua (V)
1	0,8996	2,4948	2,4635	4,9577	4,9326
3	0,0410	0,1924	0,2343	0,3034	0,2963
5	0,0192	0,0363	0,0376	0,0431	0,0512
7	0,0074	0,0443	0,0543	0,0267	0,0264
9	0,0036	0,1267	0,0823	0,0524	0,0473
11	0,0039	0,0442	0,0387	0,0184	0,0182
13	0,0020	0,0053	0,0442	0,0106	0,0104
15	0,0013	0,0029	0,0054	0,0078	0,0068
17	0,0010	0,0042	0,0056	0,0061	0,0052
19	0,0007	0,0016	0,0033	0,0053	0,0042
21	0,0000	0,0024	0,0031	0,0047	0,0037
23	0,0000	0,0005	0,0052	0,0036	0,0025
25	0,0000	0,0009	0,0055	0,0043	0,0027
27	0,0000	0,0005	0,0053	0,0033	0,0023
29	0,0000	0,0019	0,0034	0,0030	0,0020
31	0,0000	0,0017	0,0011	0,0011	0,0011
33	0,0000	0,0006	0,0037	0,0006	0,0005
35	0,0000	0,0004	0,0030	0,0012	0,0011
37	0,0000	0,0013	0,0020	0,0018	0,0017
39	0,0000	0,0004	0,0044	0,0017	0,0016
41	0,0000	0,0003	0,0028	0,0017	0,0015
43	0,0000	0,0004	0,0006	0,0017	0,0014
45	0,0000	0,0006	0,0013	0,0021	0,0019
47	0,0000	0,0006	0,0032	0,0015	0,0014
49	0,0000	0,0009	0,0012	0,0006	0,0005

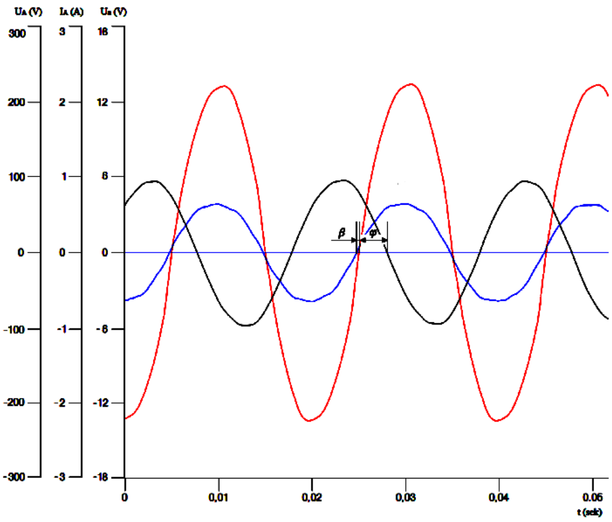
Bir vaqtning o‘zida filtr-kompensatsiya qurilmalari yuqori garmonika toklarini filtrlash va reaktiv quvvatni kompensatsiyalash uchun ishlatilinadi. Asosan filtr-kompensatsiya qurilmalarida induktiv va sig‘im elementlaridan tashkil topgan o‘zaro ketma-ket va parallel ulangan gibrid passiv filtrlardan foydalaniladi. Parallel passiv filtrlar chiziqli bo‘lmagan yuklama toklarini fitrlash va kompensatsiyalash uchun mos kelsa, ketma-ket passiv filtrlar esa chiziqli bo‘lmagan kuchlanishlarni filtrlash uchun ishlatilinadi. Shuning uchun gibrid passiv filtrlar bir vaqtning o‘zida reaktiv quvvatni kompensatsiyalaydi va garmonik buzilishlarni filtrlaydi [10-15, 18].

Bir vaqtning o‘zida filtr-kompensatsiya qurilmalari yuqori garmonika toklarini filtrlash va reaktiv quvvatni kompensatsiyalash uchun ishlatilinadi. Asosan filtr-kompensatsiya qurilmalarida induktiv va sig‘im elementlaridan tashkil topgan o‘zaro ketma-ket va parallel ulangan gibrid passiv filtrlardan foydalaniladi. Parallel passiv filtrlar chiziqli bo‘lmagan yuklama toklarini fitrlash va kompensatsiyalash uchun mos kelsa, ketma-ket passiv filtrlar esa chiziqli bo‘lmagan kuchlanishlarni filtrlash uchun ishlatilinadi. Shuning uchun gibrid passiv filtrlar bir vaqtning o‘zida reaktiv quvvatni kompensatsiyalaydi va garmonik buzilishlarni filtrlaydi [10-15, 18].

4. Muhokama (Discussion)

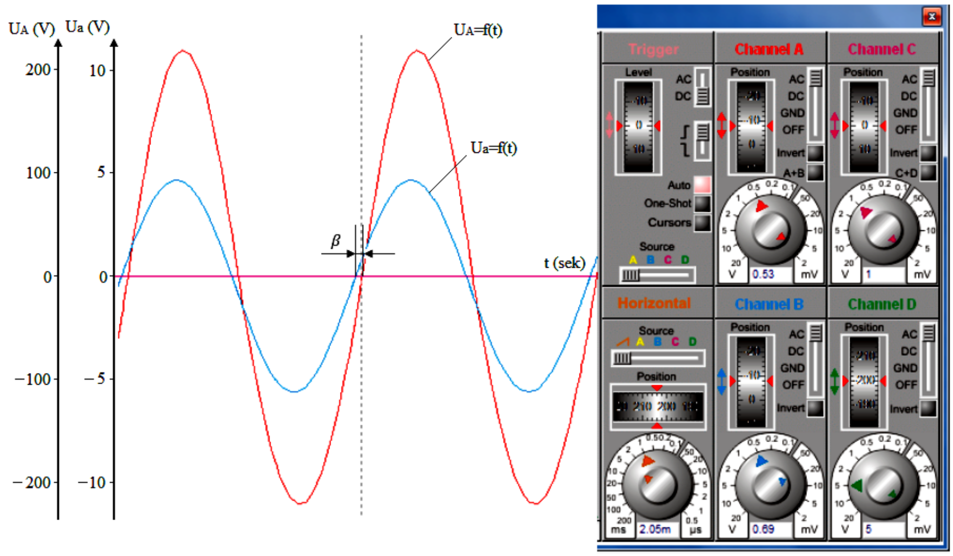
CASSYLAB qurilmasi orqali 4AA63A4Y3 tipli qisqa tutashgan rotorli asinxron motorning nominal ish rejimida aniqlangan ma’lumotlari keltirilgan (A faza uchun). Bunda U_A-A faza manba kuchlanishi, U_a-A faza uchun mos asinxron motor uch fazali elektromagnit tok o‘zgartkichidan kuchlanish ko‘rinishida chiquvchi signal, I_A-asinxron motorning stator toki (A faza), β-manba kuchlanishi va chiqish kuchlanishi orasidagi faza siljish burchagi (5-rasm). Asinxron motor statorining A fazasidagi tokning qiymati I_1=0.91 A, shu faza uchun mos, xalqalari differensial ulangan sezgir elementidan chiqgan kuchlanishning qiymati U_a=4.56 V va manba kuchlanishi va chiqish kuchlanishi orasidagi faza siljish burchagi β=-9.92° aniqlandi (A faza manba kuchlanishining boshlang‘ich fazasi α=0° deb oligan) [5-10, 12].

Proteus dasturida 4AA63A4Y3 tipli qisqa tutashgan rotorli asinxron motorning nominal ish rejimidagi A faza manba kuchlanishi, A faza uchun mos asinxron motor uch fazali tok o‘zgartkichidan kuchlanish ko‘rinishida chiquvchi signal, manba kuchlanishi va chiqish kuchlanishi orasidagi faza siljish burchagi aniqlandi (6-rasm). Asinxron motorning A fazasidagi tokning qiymati I_1=0.9 A, shu faza uchun mos sezgir elementdan chiqgan kuchlanishning qiymati U_A=4.6 V va manba kuchlanishi va chiqish kuchlanishi orasidagi faza siljish burchagi β=-9.89 ° aniqlandi (A faza manba kuchlanishining boshlang‘ich fazasi α=0° deb oligan) [15-20, 13].



5-rasm. CASSYLAB qurilmasi orqali aniqlangan manba kuchlanishi, asinxron motor uch fazali elektromagnit tok o‘zgartkichning chiqish kuchlanishi va ular orasidagi faza siljish burchagi grafiklari (A faza uchun)

Fig.5. The source voltage determined by the CASSYLAB device, the output voltage of the asynchronous motor three-phase electromagnetic current Switch, and the Phase Shift angle graphs between them (Phase A)



6-rasm. Proteus dasturi orqali aniqlangan manba kuchlanishi, asinxron motor uch fazali elektromagnit tok o‘zgartkichning chiqish kuchlanishi va ular orasidagi faza siljish burchagi grafiklari (A faza uchun)

Fig.6. The source voltage determined by the Proteus program, the output voltage of the asynchronous motor three-phase electromagnetic current Switch, and the Phase Shift angle graphs between them (A for Phase)

Tok o‘zgartkichdan chiquvchi kuchlanish signali asosida quyidagi kattaliklar aniqlandi. Tadqiqotlar asinxron motorning A fazasi misolida ko‘rib chiqildi.

Asinxron motor stator tokining qiymati:

1. I_A=0.87 A, Katalogdagi qiymat.
2. I_A=0.91 A, CASSYLAB qurilmasi yordamida amaliy aniqlangan qiymat.
3. I_A=0.9 A, Proteus dasturida aniqlangan qiymat.

Asinxron motorning quvvat koeffitsientining qiymati:

1. cosφ=0.65, Katalogdagi qiymat.
2. cosφ=0.653, CASSYLAB qurilmasi yordamida aniqlangan qiymat.
3. cosφ=0.65, Proteus dasturida aniqlangan qiymat.

Manba kuchlanishi va uch fazali elektromagnit tok o‘zgartkich chiqish kuchlanishi orasidagi faza siljish burchagi qiymatlari:

1. β_1=-9.92°, CASSYLAB qurilmasi yordamida aniqlangan qiymat.
2. β_1=-9.89°, Proteus dasturida aniqlangan qiymat.

Asinxron motor sezgir elementidan chiquvchi kuchlanishning qiymati:

1. U_a=4.56 V, CASSYLAB qurilmasi yordamida aniqlangan qiymat.
2. U_a=4.6 V, Proteus dasturida aniqlangan qiymat.

Yuqoridagi 5-rasm va 6-rasmlarda keltirilgan natijalarni tahlil qilsak, uch fazali elektromagnit tok o‘zgartkichni chiqish kuchlanishi qiymati, manba kuchlanishi va asinxron motor stator chulg‘ami qarshiliklari o‘zgarmagan holda stator chulg‘amidan o‘tayotkan tok kuchiga bog‘liq funksiya ekanligini ko‘ramiz. Asinxron motor manba kuchlanishining o‘zgarmas holatida chiqish signalining qiymati tokiga va quvvat koeffitsientiga proporsionalligini ko‘rishimiz mumkin.

5. Xulosa (Conclusions)

Asinxron motorning ish davri mobaynida yuklama qiymatining oshishi uning stator tokining oshishiga, bu esa chiqish kuchlanishi bilan manba kuchlanishi orasidagi faza siljish burchagining oshishiga, chiqish kuchlanishini va quvvat koeffitsientini kamayishiga olib keldi. Bundan ko‘rinadiki manba kuchlanishi bilan sezgir elementdan chiquvchi kuchlanish orasidagi faza siljish burchagining oshishi quvvat koeffisientini kamayishiga sabab bo’ladi. Asinxron motor uch fazali elektromagnit tok o‘zgartkich signali orqali asinxron motor stator tokining qiymati va quvvat koeffitsienti yuqoridagi tadqiqotlar orqali tahlil qilindi. CASSYLAB qurilmasi orqali asinxron motorning sezgir elementidan chiquvchi kuchlanish qiymati va manba kuchlanishi bilan faza siljish burchagi amaliy topildi. Aniqlangan qiymatlar asosida Proteus va Arduino dasturlari yordamida asinxron motorning stator tok kuchi va quvvat koeffitsientini aniqlash modeli ishlab chiqilib uch fazali elektromagnit tok o‘zgartkichning chiqish kuchlanishi va ular orasidagi faza siljish burchagi grafiklari olindi.

ADABIYOT

1. Akagi H. Active harmonic filters // Proceedings of the IEEE. T. 93. 2005. № 12, pp. 2128-2141.
2. Alahakoon D., Yu X."Advanced analytics for harnessing the power of smart meter big data," in Intelligent Energy Systems (IWIES), 2013 IEEE International Workshop on, pp. 40-45.
3. Anthony H., Eng P. How harmonics have contributed to many power factor misconceptions // White Paper: MIRUS-TP003-A January 15, 2014, P: 2-8.
4. Debruyne C., Desmet J., Derammelaere S., Vandevelde L. Derating factors for direct online induction machines when supplied with voltage harmonics: A critical view. In Proceedings of the 2011 IEEE International Electric Machines & Drives Conference (IEMDC), Niagara Falls, ON, Canada, 15–18 May 2011. pp. 1048 – 1052.
5. Dixon J., Moran L., Rodriguez J., Domke R. Reactive power compensation technologies // State-of-the-art review. Proc. IEEE 2005 (93) pp. 2144–2164.
6. Farid K., Mouna L., Abdelaziz Kh., Mohamed B. A Comparison of Symmetrical and Asymmetrical Three-Phase H-Bridge Multilevel Inverter for DTC Induction Motor Drives // IEEE Transactions on Energy Conversion, Institute of Electrical and Electronics Engineers, 2011, 26 (1), pp.64-72.
7. Garcia C.A., Garcia G.P., Collantes R., Gomez T., Anzola J. Comparison of thyristor-controlled reactors and voltage-source inverters for compensation of flicker caused by arc furnaces // IEEE Trans Power Deliv, 2000. 15(4):1225–1231. doi:10.1109/61.891507.
8. Gaurav S. Investigation of Auxiliary winding harmonic resonance phenomena in single-phase induction motors // Clemson University, 12-2012, All Theses. 1561.
9. Horia G.B., Virgil M, Sorin G.P., Iulian B, Constantin S.P., Pompei C.D. Harmonics Consequences on Drive Systems with Induction Motor // Appl. Sci. 2020, 10, 1528; doi:10.3390/app10041528.
10. Ilisiu D., Dinu E.-D. Modern reactive power compensation for smart electrical grids. In Proceedings of the 2019 22nd International Conference on Control Systems and Computer Science (CSCS), Bucharest, Romania, 28–30 May 2019; pp. 353–357.
11. Juan R.N. Real and Reactive Power Control of Induction Motor Drives // Louisiana State University and Agricultural and Mechanical College, 2016 | Pages: 12-30.
12. Karimjonov D.D. Study of characteristics of three-phase electromagnetic current converters for filter-compensation devices of asynchronous motor reactive power // Novateur publications. International journal of innovations in engineering research and technology [IJIERT] ISSN: 2394-3696 website: ijiert.org volume 10, issue 1, jan. -2023.
13. Karimjonov D.D., Siddikov I.X., A’zamov S.S., Uzakov R. Study on determination of an asynchronous motor’s reactive power by the current-to-voltage converter // IOP Conference Series: Earth and Environmental Science, ICECAE-2022, doi:10.1088/1755-1315/1142/1/012023.
14. Klingshirn, E.A. Polyphase induction motor performance and losses on non-sinusoidal voltage sources // IEEE Trans. – 1968. – Vol. PAS-87. – P. 624–631.
15. Makhsudov M.M., Karimjonov D.D. Electromagnetic current converters for control of reactive power sources // Scientific and technical Journal of Mechanical Engineering, ISSN 2181-1539 Andijon, 2022. № (3), 106-110 b.
16. Махсудов М. Т., Бойхонов З. У. Исследование электромагнитных преобразователей тока в напряжение //Бюллетень науки и практики. – 2018. – Т. 4. – №. 3. – С. 150-154.
17. Okkes K.F., Acikgoz H., Sekkeli M. “Advanced configuration of hybrid passive filter for reactive power and harmonic compensation” (2016). Kececioglu et al. SpringerPlus (2016) 5:1228 DOI 10.1186/s40064-016-2917-7. http://creativecommons.org/licenses/by/4.0/.
18. Ömer A.K., Ahmet G., Mehmet C. Performing reactive power compensation of three-phase induction motor by using parallel active power filter // Karaman et al., International Advanced Researches and Engineering Journal, 2020, 04(03) P: 239-248.
19. Panfilov D.I., ElGebaly A.E., Astashev M.G. Design and evaluation of control system for static VAR compensators with thyristors switched reactors // In Proceedings of the 2017 IEEE 58th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Riga, Latvia, 12–13 October 2017; pp. 1–6.
20. Pinyol R. “Harmonics: causes, effects and minimization” (2015). Salicru white papers. https://www.salicru.com/files/pagina/72/278/jn004a01_whitepaper-armonics_(1).pdf.
21. Махсудов М. Т., Анарбаев М. А., Сиддиков И. Х. Электромагнитные преобразователи тока для управления источниками реактивной мощности //Universum: технические науки. – 2019. – №. 3 (60). – С. 58-61.
22. Siddikov I. K., Abdumalikov A. A., Makhsudov M. T. Modeling and research multiphases signal transducers of power control systems //2020 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2020. – С. 1-4.

REFERENCES

1. Akagi H. Active harmonic filters // Proceedings of the IEEE. T. 93. 2005. № 12, pp. 2128-2141.
2. Alahakoon D., Yu X."Advanced analytics for harnessing the power of smart meter big data," in Intelligent Energy Systems (IWIES), 2013 IEEE International Workshop on, pp. 40-45.
3. Anthony H., Eng P. How harmonics have contributed to many power factor misconceptions // *White Paper: MIRUS-TP003-A* January 15, 2014, P: 2-8.
4. Debruyne C., Desmet J., Derammelaere S., Vandevelde L. Derating factors for direct online induction machines when supplied with voltage harmonics: A critical view. In Proceedings of the 2011 IEEE International Electric Machines & Drives Conference (IEMDC), Niagara Falls, ON, Canada, 15–18 May 2011. pp. 1048 – 1052.
5. Dixon J., Moran L., Rodriguez J., Domke R. Reactive power compensation technologies // *State-of-the-art review. Proc*. IEEE 2005 (93) pp. 2144–2164.
6. Farid K., Mouna L., Abdelaziz Kh., Mohamed B. A Comparison of Symmetrical and Asymmetrical Three-Phase H-Bridge Multilevel Inverter for DTC Induction Motor Drives // *IEEE Transactions on Energy Conversion, Institute of Electrical and Electronics Engineers,* 2011, 26 (1), pp.64-72.
7. Garcia C.A., Garcia G.P., Collantes R., Gomez T., Anzola J. Comparison of thyristor-controlled reactors and voltage-source inverters for compensation of flicker caused by arc furnaces // *IEEE Trans Power Deliv,* 2000. 15(4):1225–1231. doi:10.1109/61.891507.
8. Gaurav S. Investigation of Auxiliary winding harmonic resonance phenomena in single-phase induction motors // *Clemson University,* 12-2012, All Theses. 1561.
9. Horia G.B., Virgil M, Sorin G.P., Iulian B, Constantin S.P., Pompei C.D. Harmonics Consequences on Drive Systems with Induction Motor // Appl. Sci. 2020, 10, 1528; doi:10.3390/app10041528.
10. Ilisiu D., Dinu E.-D. Modern reactive power compensation for smart electrical grids. In Proceedings of the 2019 22nd International Conference on Control Systems and Computer Science (CSCS), Bucharest, Romania, 28–30 May 2019; pp. 353–357.
11. Juan R.N. Real and Reactive Power Control of Induction Motor Drives // Louisiana State University and Agricultural and Mechanical College, 2016 | Pages: 12-30.
12. Karimjonov D.D. Study of characteristics of three-phase electromagnetic current converters for filter-compensation devices of asynchronous motor reactive power // *Novateur publications. International journal of innovations in engineering research and technology [IJIERT]* ISSN: 2394-3696 website: ijiert.org volume 10, issue 1, jan. -2023.
13. Karimjonov D.D., Siddikov I.X., A’zamov S.S., Uzakov R. Study on determination of an asynchronous motor’s reactive power by the current-to-voltage converter // *IOP Conference Series: Earth and Environmental Science,* ICECAE-2022, doi:10.1088/1755-1315/1142/1/012023.
14. Klingshirn, E.A. Polyphase induction motor performance and losses on non-sinusoidal voltage sources // IEEE Trans. – 1968. – Vol. PAS-87. – P. 624–631.
15. Makhsudov M.M., Karimjonov D.D. Electromagnetic current converters for control of reactive power sources // *Mashinasozlik ilmiy-texnika jurnali,* ISSN 2181-1539 Andijon, 2022. № (3), 106-110 b.
16. 16. Makhsudov M. T., Boikhonov Z. U. Investigation of electromagnetic current-to-voltage converters // *Bulletin of Science and practice*. – 2018. – vol. 4. – No. 3. – pp. 150-154. (in Russ).
17. Okkes K.F., Acikgoz H., Sekkeli M. “Advanced configuration of hybrid passive filter for reactive power and harmonic compensation” (2016). Kececioglu et al. SpringerPlus (2016) 5:1228 DOI 10.1186/s40064-016-2917-7. http://creativecommons.org/licenses/by/4.0/
18. Ömer A.K., Ahmet G., Mehmet C. Performing reactive power compensation of three-phase induction motor by using parallel active power filter // *Karaman et al., International Advanced Researches and Engineering Journal*, 2020, 04(03) P: 239-248.
19. Panfilov D.I., ElGebaly A.E., Astashev M.G. Design and evaluation of control system for static VAR compensators with thyristors switched reactors // *In Proceedings of the 2017 IEEE 58th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Riga, Latvia,* 12–13 October 2017; pp. 1–6.
20. Pinyol R. “Harmonics: causes, effects and minimization” (2015). Salicru white papers. https://www.salicru.com/files/pagina/72/278/jn004a01_whitepaper-armonics_(1).pdf.
21. Makhsudov M. T., Anarbaev M. A., Siddikov I. Kh. Electromagnetic current converters for controlling reactive power sources // *Universum: technical sciences*. - 2019. - No. 3 (60). - P. 58-61. (In Russ)
22. Siddikov I. K., Abdumalikov A. A., Makhsudov M. T. Modeling and research multiphases signal transducers of power control systems // 2020 *International Conference on Information Science and Communications Technologies (ICISCT)*. – IEEE, 2020. – C. 1-4.