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BOSHQARILUVCHAN CHIQISH KUCHLANISHLI TOK O‘ZGARTKICHLARINING DINAMIK TAVSIFLARI

Boixanov Zailobiddin Urazali o‘g‘li,
Andijon mashinasozlik instituti doktoranti,
ORCID: 0000-0001-7915-4210, e-mail: zaylobiddin1992@gmail.com

Annotatsiya. *Ushbu maqolada asinxron motor reaktiv quvvatini nazorat qilish va boshqarish uchun boshqariluvchan chiqish kuchlanishli tok o‘zgartkichidan foydalanildi. Tok o‘zgartkichining ishonchliligi, sezgirligi, o‘lchash aniqlik va xatoliklarining dinamik tavsiflari Simulnik dasturidan foydalanilgan holda olindi. Tok o‘zgartkichlari, asosan, asinxron motor elektr ta’minoti tizimining normal barqaror ish rejimi davrida ishlaydi. Bu rejimda ba’zi shartli chegaralar bilan tok o‘zgartkichlarini tadqiq etishda kirish tokining minimal va maksimal qiymatlari qabul qilinadi, buning uchun aniqlik sinfi (0,1–1,2)·*I_{nom} *deb olinadi. Elektr jihozlar va tarmoqlardagi shikastlanishlar asinxron motor elektr ta’minoti tizimining halokatli ish rejimiga olib keladi. Bu holda tok o‘zgartkichlari dinamik rejimda ishlaydi. Asinxron motorda qisqa tutashuvlar elektromagnit tok o‘zgartkichlarining dinamik rejimlarda ishlashiga olib keluvchi asosiy sababdir. Elektromagnit tok o‘zgartkichlarining bunday rejimda ishlashi boshqaruv tizimi sxemalaridagi ishlash shartlaridan sezilarli farq qiladi. Agar elektromagnit tok o‘zgartkichlari o‘lchov maqsadida ishlatilsa, odatda, nominaldan oshmagan birlamchi tokda ishlashi talab etiladi. Bunda asinxron motorning boshqaruv tizimlarida qo‘llanuvchi elektromagnit tok o‘zgartkichlari nominaldan ancha katta toklarda, o‘tish rejimi sharoitlarida, masalan, qisqa tutashuv va shikastlanish hollarida o‘z funksiyalarini bajarishi shart.*

Kalit so‘zlar: *asinxron motor, boshqariluvchan chiqish kuchlanishli tok o‘zgartkichi, magnit maydon, ishchi tavsiflar, tok, kuchlanish, quvvat, tezlik va moment.*

ДИНАМИЧЕСКИЕ ХАРАКТЕРИСТИКИ УПРАВЛЯЕМЫХ ПРЕОБРАЗОВАТЕЛЕЙ ВЫХОДНОГО НАПРЯЖЕНИЯ

Боиханов Заилобиддин Уразали угли,
докторант Андижанского
машиностроительного института

Kirish

Uch fazali asinxron motor reaktiv quvvatining nosimmetrik kattaliklarini nazorat qilish va boshqarish uchun stator chulg‘amidan nosimmetrik i_1, i_2, i_3, birlamchi toklar o‘tishi natijasida hosil bo‘lgan magnit oqimlar ta’sirida tok o‘zgartkichi o‘lchov chulg‘amlari chiqishlarida $u_{чик.1}$(t), $u_{чик.2}$(t), $u_{чик.3}$(t) kuchlanishlar olinadi. Bu signal ko‘rinishidagi chiquvchi kuchlanishni quyidagicha yozib olamiz [1, 6-b.]:

$$\left(\begin{aligned} u_{чик.1}(t) &= -R_{ў.1}\cdot i_{чик.1}(t) - L_{ў.1}\frac{di_{чик.1}(t)}{dt} + w_5\frac{d\Phi_2(t)}{dt} + w_6\frac{d\Phi_3(t)}{dt}; \\ u_{чик.2}(t) &= -R_{ў.2}\cdot i_{чик.2}(t) - L_{ў.2}\frac{di_{чик.2}(t)}{dt} + w_4\frac{d\Phi_1(t)}{dt} + w_6\frac{d\Phi_3(t)}{dt}; \\ u_{чик.3}(t) &= -R_{ў.3}\cdot i_{чик.3}(t) - L_{ў.3}\frac{di_{чик.3}(t)}{dt} + w_4\frac{d\Phi_1(t)}{dt} + w_5\frac{d\Phi_2(t)}{dt}; \end{aligned} \right. \quad (1)$$

Bu yerda $R_{ў.1}$, $R_{ў.2}$, $R_{ў.3}$, $L_{ў.1}$, $R_{ў.2}$, $R_{ў.3}$ – uch fazali tok o‘zgartkichining nosimmetrik aktiv va induktiv qarshiliklari; $w_{ў.1}$, $w_{ў.2}$, $w_{ў.3}$, – o‘lchov elementi sifatidagi o‘ramlar soni.

Uch fazali asinxron motorlar kuchlanishining nosimmetriklik darajasini tavsiflovchi asosiy sifat ko‘rsatkichini teskari ketma-ketlikdagi kuchlanishning koeffitsienti orqali aniqlash mumkin:

$$k_{2U} = \frac{U_2}{U_1}, \quad (2)$$

bu yerda U_2, U_1 – mos ravishda to‘g‘ri va teskari ketma-ketliklar kuchlanishi.

Uch fazali asinxron motorlarining nosimmetrik kuchlanishi sharoitida ishlashi, qo‘shimcha ravishda, teskari ketma-ketlikdagi

Аннотация. *В этой статье описывается управляемый преобразователь выходного напряжения в ток для контроля и управления реактивной мощностью асинхронного двигателя. Динамические характеристики преобразователя тока были получены с помощью программы Simulink с учетом надежности, чувствительности, точности измерения и погрешности. Преобразователи тока в основном эксплуатируются при нормальной устойчивой работе системы питания асинхронного двигателя. В этом режиме при исследовании преобразователей тока с некоторыми условными пределами принимаются минимальное и максимальное значения входного тока, для которых устанавливается класс точности (0,1–1,2)·$I_{ном}$. Повреждение электрооборудования и сетей может привести к аварийному режиму работы системы электроснабжения асинхронного двигателя, в этом случае преобразователи тока работают в динамическом режиме. Короткие замыкания в асинхронном двигателе являются основной причиной работы электромагнитных преобразователей тока в динамических режимах. Условия работы адаптеров электромагнитного тока в таких режимах существенно отличаются от условий работы в цепях системы управления. Если для целей измерения используются адаптеры электромагнитного тока, то обычно требуется, чтобы они работали при первичном токе, не превышающем номинальный ток, и выполняли свои функции в случае повреждения.*

Ключевые слова: *асинхронный двигатель, регулируемый выходной адаптер тока, магнитное поле, рабочие характеристики, ток, напряжение, мощность, скорость и момент.*

DYNAMIC CHARACTERISTICS OF CONTROLLED OUTPUT VOLTAGE CONVERTERS

Boikhanov Zailobiddin Urazali ugli,
Doctoral Student of
Andijan Machine-Building Institute

Abstract. *This article uses a controlled output voltage-to-current converter to control the reactive power of an induction motor. The dynamic characteristics of the current converter were obtained using the Simulink program, taking into account reliability, sensitivity, measurement accuracy and error. Current converters are mainly operated during normal stable operation of the power supply system of an asynchronous motor. In this mode, when studying current transducers with certain conditional limits, the minimum and maximum values of the input*

nosimmetrik tokning tarkibiy qismlari paydo boʻlishi bilan murakkablashadi. Bu rotor va stator chulgʻamlarida ortiqcha quvvat sarflanishiga olib keladi. Bu esa chulgʻamlar qizib ketishi bilan bir qatorda ish muddati va qurilma ishlashining barqarorligiga ham sezilarli taʼsir qiladi. Uch fazali asinxron motorlardagi bunday ortiqcha sarfni qoʻshimcha quvvat yoʻqotish koeffitsienti yordamida hisoblash mumkin [2, 12-b.]:

$$K_r = \frac{\Delta P_{nes}}{\Delta P_{sim}} = \frac{3I_1^2R_1+3I_2^2R_2}{3I_1^2} = 1 + k_{2i}^2 \qquad (3)$$

Bu yerda $k_{2i} = \frac{I_2}{I_2}$ – teskari ketma-ketlikdagi tok koeffitsienti; I_1, I_2 – mos ravishda toʻgʻri ketma-ketlikdagi toklar; R_1, R_2 – mos ravishda toʻgʻri ketma-ketlikdagi qarshiliklar; ΔP_{nes} – nosimmetrik tokdagi quvvat sarfi; ΔP_{sim} – toʻgʻri ketma-ketlik oqimlari tufayli quvvat yoʻqotishlari.

Teskari kuchlanish ketma-ketligining nosimmetrik koeffitsientini quyidagicha yozishi mumkin:

$$K_{2U} = \frac{U_2}{U_1} = \frac{I_2 * Z_2}{I_1 * Z_1} \qquad (4)$$

Bu yerda Z_1, Z_2 – (3) ifodani mos ravishdagi toʻgʻri va teskari ketma-ketliklarning toʻla qarshiliklari koʻrinishida yozib olamiz.

(5) ifodada teskari ketma-ketlik oqimini ifodalaymiz:

$$K_r = 1 + (I_2|I_1)^2 \qquad (5)$$

$$I_2 = I_1\sqrt{K_r - 1}. \qquad (6)$$

Keyin k_{2U} koeffitsienti quyidagicha koʻrinadi.

Shundan k_{2U} koeffitsientini quyidagicha yozib olamiz:

$$k_{2U} = \frac{\sqrt{k_r - 1Z_2}}{Z_1}\ . \qquad (7)$$

(6) ifodadan quvvat sarfining koeffitsientini aniqlab olamiz:

$$K_r = 1 + \left(k_{2U}\frac{Z_1}{Z_2}\right)^2. \qquad (8)$$

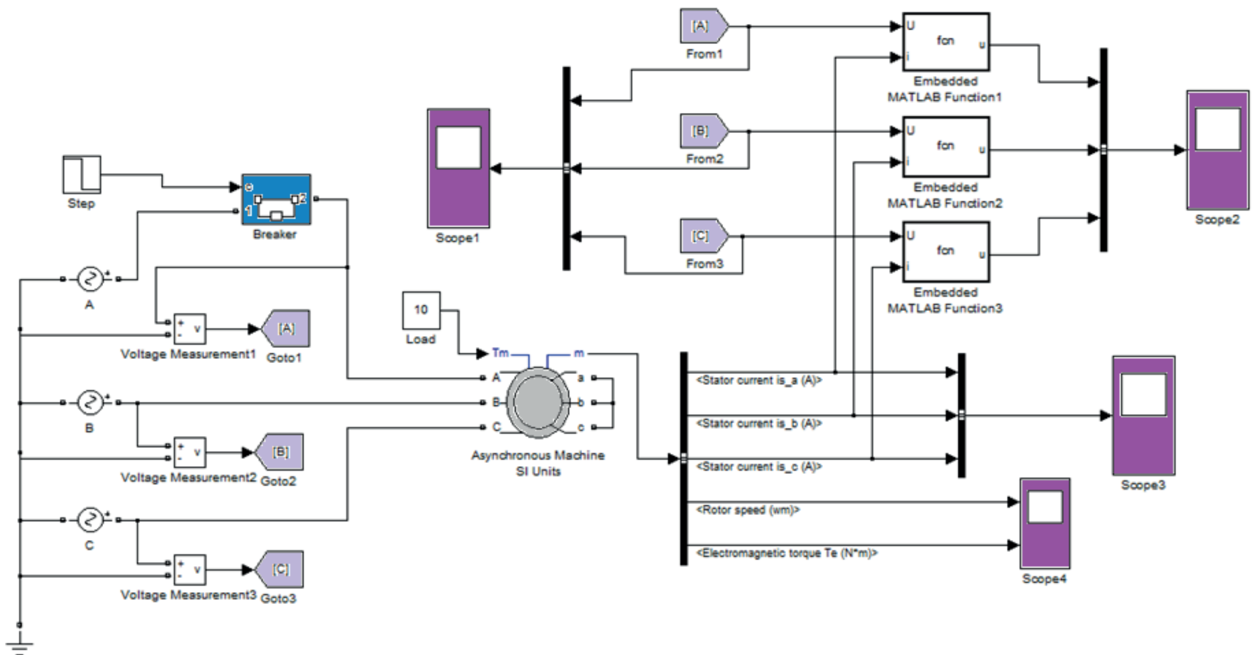
Uch fazali asinxron motor nosimmetrik kuchlanish ta’sirida quvvat iste’moli, statorda magnit (sochiluvchi) oqimlari sezilarli ravishda o‘zgardi.

Material va metodlar

Uch fazali asinxron motor nosimmetrik kuchlanish sharoitida yuzaga keladigan jarayonlarni ifodalash uchun ushbu jarayonlarning matematik modeli yaratildi. Matematik model simulnik kengaytmali matlab tizimi (Matrix Laboratory) orqali amalga oshirildi. Nosimmetrik kuchlanish sharoitida uch fazali asinxron motorning simulyatsiya modelida (1-rasm) A, B va D portlari asinxron motor stator chulg‘amining kirish qismi hisoblanadi. Simulyatsiyada Tm porti qarshilik momentini hosil qilish uchun kerak bo‘ladi.

current are accepted, for which the accuracy class (0.1–1.2)·I_{nom} is set. Damage to electrical equipment and networks can lead to emergency operation of the power supply system of an asynchronous motor, in which case the current converters operate in dynamic mode. Short circuits in an asynchronous motor are the main reason for the operation of electromagnetic current converters in dynamic modes. The operating conditions of electromagnetic current adapters in such modes differ significantly from the operating conditions in the control system circuits. If electromagnetic current adapters are used for measurement purposes, they are usually required to operate at a primary current not exceeding the rated current and must perform their functions in the event of a fault.

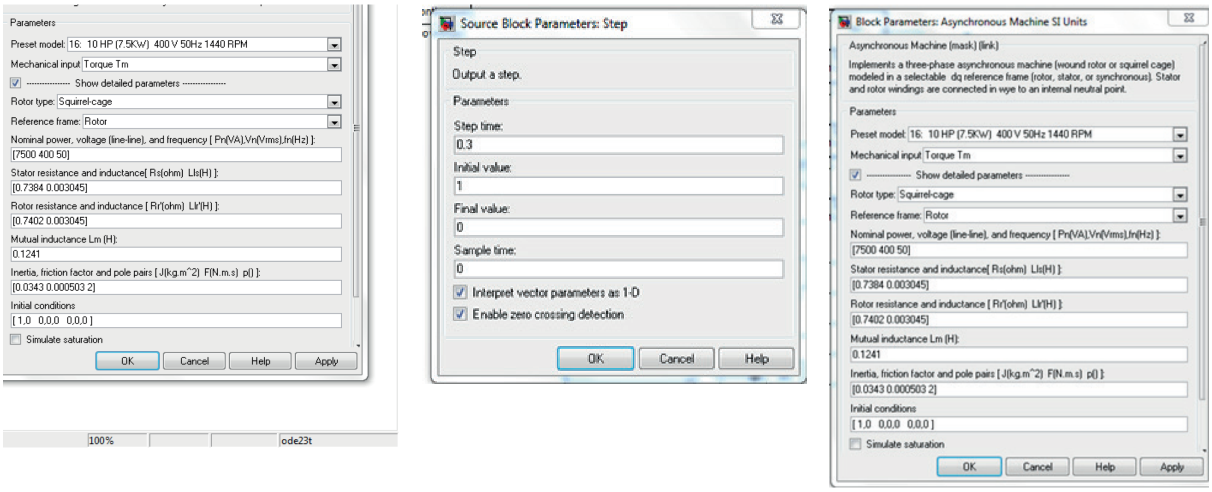
Keywords: *induction motor, variable output current adapter, magnetic field, performance, current, voltage, power, speed and torque.*



1-rasm. Uch fazali asinxron motorning nosimmetrik kuchlanish ta’sirida tokni kuchlanishga o‘zgartirishning imitatsion modeli

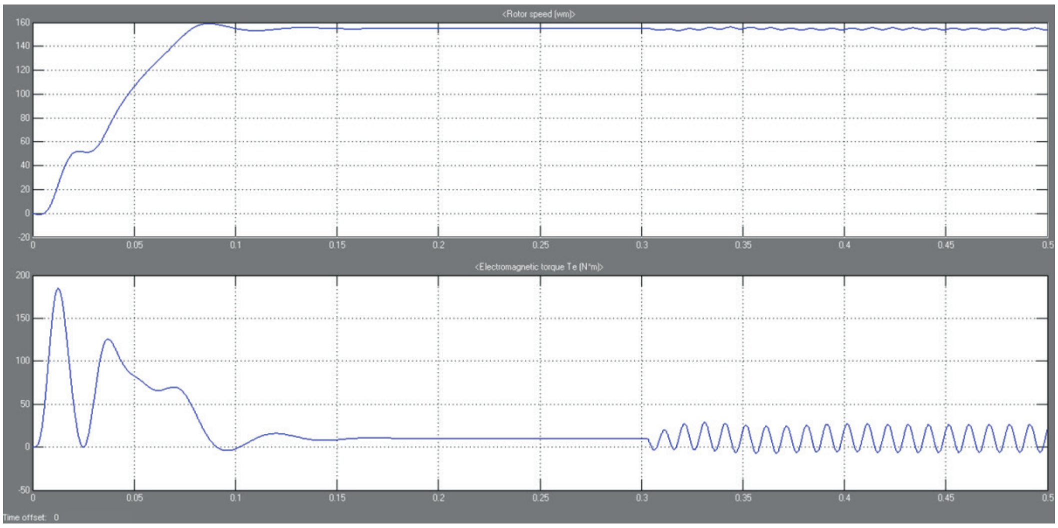
Tadqiqot natijalari

Uch fazali asinxron motor stator chulg‘amidagi tokni kuchlanishga o‘zgartirish modeli to‘rtinchi tartibli holat bilan ifodalanadi hamda ikkinchi tartibdagi dinamik xarakteristkalarni olish uchun mexanik qismi modellashtirilgan. Uch fazali asinxron motorning nominal parametrlarini quyidagicha ifodalay olamiz: nominal quvvat $P_n = 0{,}75kW$; nominal kuchlanish $U_n = 380V$; tarmoq chastotasi $f = 50Hz$; nominal aylanishlar soni n= 1500 *ay./daq.*



2-rasm. Simulyatsiya qilinadigan uch fazali asinxron motorning texnik parametrlari

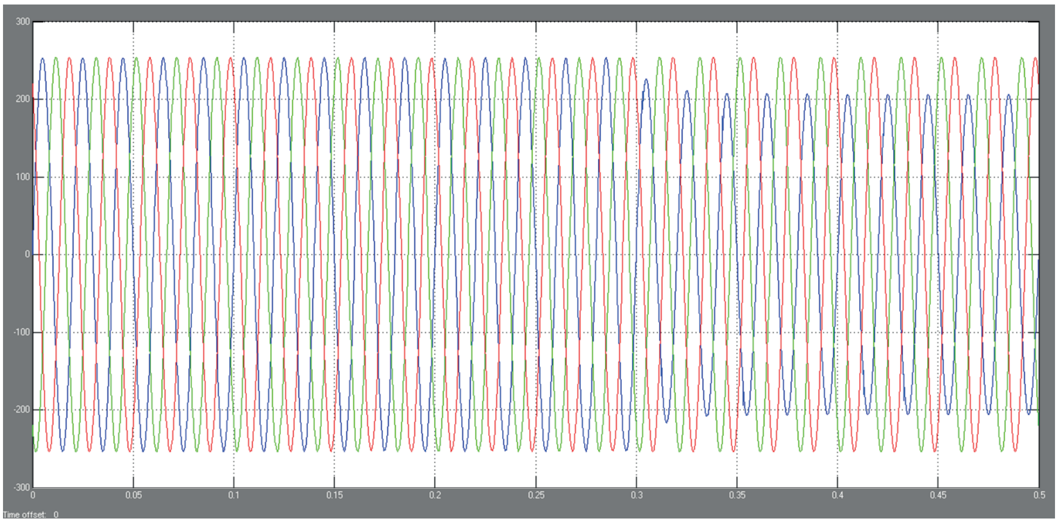
Uch fazali asinxron motor reaktiv quvvatining nosimmetrik kattaliklarini boshqariluvchan chiqish kuchlanishli tok oʻzgartkichining bir qator tajribalar orqali amalga oshirdik. Uch fazali asinxron motorning stator chulgʻamida hosil boʻlgan nosimmetrik tokni kuchlanish koʻrinishidagi chiquvchi signal orqali, uch fazali asinxron motor aylanishlar tezligining grafigi hamda elektromagnit momenti, stator chulgʻamida hosil boʻlgan uch fazali nosimmetrik sinusoidal garmonika, chiquvchi kuchlanish koʻrinishidagi signalning ushbu jarayonlarga ustma-ust tusha olishini ifodalaydigan xarakteristikalar olindi [4, 5, 7, 9, 23-32-b., 6-b.].



3-rasm. Uch fazali asinxron motor boshqariluvchan chiqish kuchlanishli tok oʻzgartkichiga boʻylama nosimmetrik kuchlanish ta'sir etganda, aylanishlar soni (n) va moment (M) grafiklari

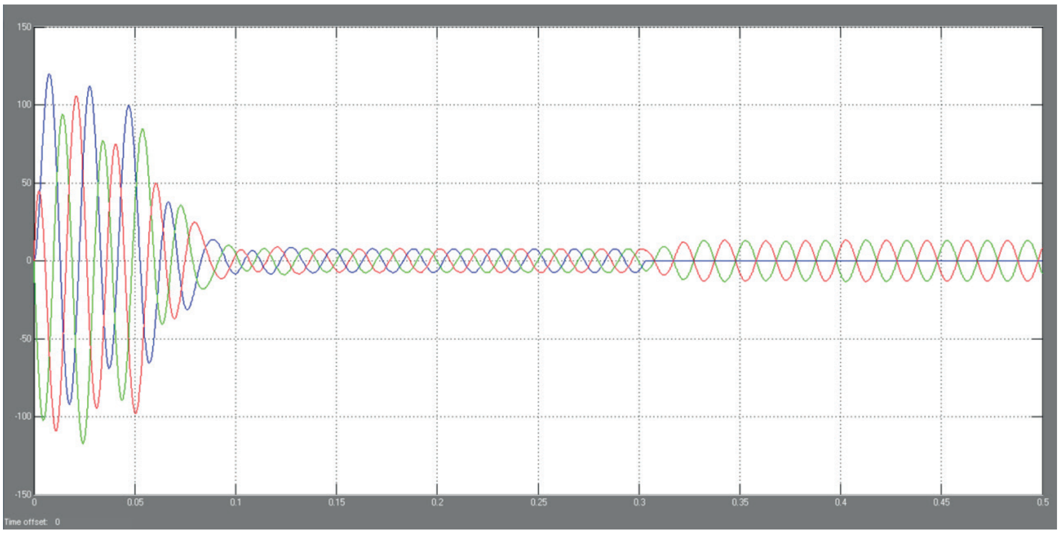
Uch fazali asinxron motor 0 ÷ 0.3 s vaqt oraligʻida oʻzining elektromagnit momentning garmonikasi (3-rasm)dan koʻrinadiki, 0,3 s vaqt oʻtgandan keyin barqaror ish rejimiga tushadi. Uch fazaning bir fazasini 0 deb qabul qilsak, qolgan fazalardagi kuchlanish statorda sochiluvchi magnit maydonni F_0 hosil qiladi, lekin asinxron motorining ish parametrlari yomonlashadi hamda nosimmetrik rejimida burchak tezligi (ω) oshishi natijasida oʻsish taxminan 1% ni tashkil etdi, rotor validagi foydali quvvat P_2 taxminan 5% ga kamaydi.

Simulnik qilinganda, uch fazali asinxron motorning nosimmetrik rejimdagi barcha faza kuchlanishlarining vaqtga nisbatan grafigini tuzamiz (4-rasm).



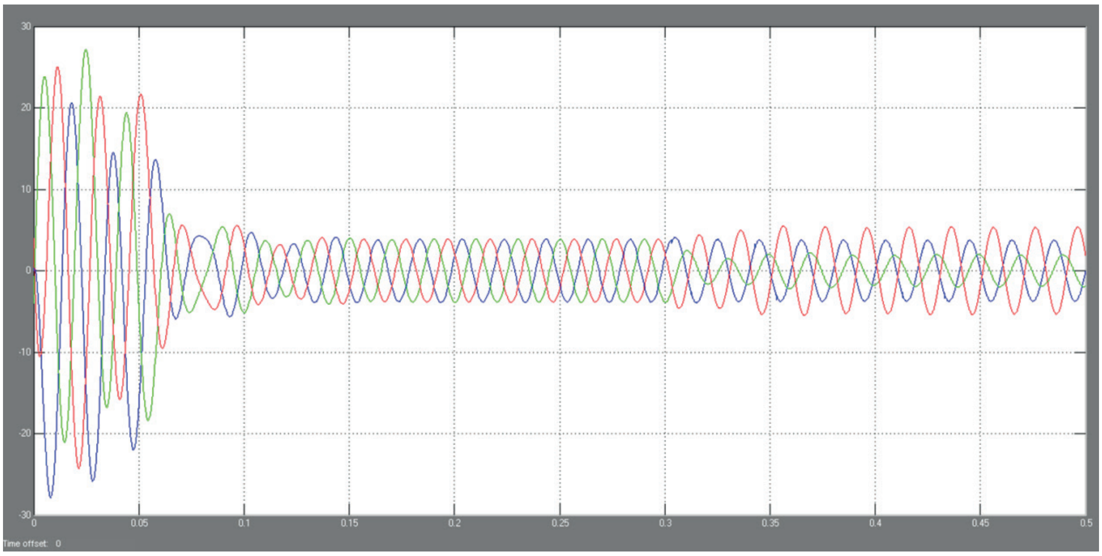
4-rasm. Uch fazali asinxron motorning bo‘ylama nosimmetrik kuchlanish ta’sirida hosil qilingan EYUKlar garmonika grafiklari

Uch fazali asinxron motorga nosimmetrik kuchlanish ta’siridan stator chulg‘amidan o‘tayotgan nosimmetrik toklar garmonikalari o‘zgarishini matlab dasturida ko‘ramiz.



5-rasm. Uch fazali asinxron motorga tarmoqdan nosimmetrik kuchlanish berilganda, stator chulg‘amidan o‘tayotgan tokning vaqtga bog‘liq grafigi

Uch fazali asinxron motorga bo‘ylama nosimmetrik kuchlanish ta’sir etganda, ishga tushirish 0-0.05 s oralig‘ida sodir bo‘lyapti. 0-0.3 s oralig‘ida motor o‘zining turg‘un holatiga erishayotganini ko‘rish mumkin. 0.3 s dan keyingi a fazada tok kuchi qiymati kamayotgani kuzatiladi. Bunda iste’mol qilinayotgan reaktiv quvvat qiymati stator paziga aniqlik bilan joylashtirilgandan so‘ng tokni kuchlanish ko‘rinishidagi signalga o‘zgartirish o‘zgartkichi yordamida nazorat qilib boshqarish imkoniyatiga erishish mumkin [13, 14, 17, 12-19-b.].



6-rasm. Stator chulg'amiga berilgan nosimmetrik kuchlanishni tokni kuchlanishga o'zgartirish o'zgartkichidan chiquvchi signal orqali tavsiflovchi grafig

Xulosalar

Tarmoqdan kelayotgan nosimmetrik kuchlanish statorda magnit maydoni hosil qiladi. Agar L1 fazada kuchlanish yo'q bo'lib qolsa, sezuvchi element L1 da kuchlanish yo'qligi haqida xabardor bo'ladi. Matlab dasturida uch fazali asinxron motorni modellashtirish natijasida nosimmetrik kuchlanish ta'siri ish sharoitlarini tahlil qilish, nosimmetriklik darajasini aniq ifodalash va uni nazorat qilish imkonini beradi.

REFERENCES

1. Loukianov A., Rivera J., Alanis A., Raygoza J. Super-twisting sensorless control of linear induction motors. *Electrical engineering, computing science and automatic control (CCE),* 2012, 9th international conference, 2012, pp. 1-5.

2. Bucci G., Meo S., Ometto A., Scarano M. The control of LIM by a generalization of standard vector techniques. *Industrial electronics, control and instrumentation*, 1994. IECON'94, 20th international conference, 1994, pp. 623-626.

3. Zhang Z., Eastham T.R., Dawson G.E. Peak thrust operation of linear induction machines from parameter identification. Industry applications conference, 1995. *Thirtieth IAS annual meeting*, IAS'95, Conference Record of the 1995 IEEE, 1995, pp. 375-379.

4. Da Silva E.F., Dos Santos C.C., Nerys J.W.L. Field oriented control of linear induction motor taking into account end-effects. *Advanced motion control*, 2004. AMC '04. The 8th IEEE international workshop, 2004, pp. 689-694.

5. Da Silva E.F., Dos Santos E.B., Machado P.C.M., De Oliveria M.A.A. Vector control for linear induction motor. *Industrial technology*, 2003. IEEE international conference, 2003, vol. 1, pp. 518-523.

6. Rathore A.K., Mahendra S.N. Direct secondary flux oriented control of linear induction motor drive. *Industrial technology*, 2006. ICIT 2006. IEEE international conference, 2006, pp. 1586-1590.

7. Motlagh S., Fazel S.S. Indirect vector control of linear induction motor considering end effect. *Power electronics and drive systems technology* (PEDSTC), 2012, 3rd, pp. 193-198.

8. Jeong-Hyoun S., Kwanghee N. A new approach to vector control for a linear induction motor considering end effects. Industry applications conference, 1999. *Thirty-fourth IAS annual meeting*. Conference record of the 1999 IEEE, 1999, vol. 4, 1999, pp. 2284-2289.

9. Makhsudov M.T., Boykhonov Z.U. Issledovaniye elektromagnitnykh preobrazovateley toka v napryazheniye [Research of electromagnetic current-to-voltage converters]. *Byulleten' nauki i praktiki – Bulletin of Science and Practice*, 2018, vol. 4, no. 3, pp. 150-154. Available at: http://www.bulletennauki.com/mahsudov/ (accessed 03.15.2018).

10. Siddikov I.Kh., Makhsudov M.T., Boikhanov Z.U. Skhema zameshcheniya i analiz raboty asinkhronnogo dvigatelya pri potreblenii reaktivnoy moshchnosti [Substitution scheme and analysis of the operation of an asynchronous motor with the consumption of reactive power]. *Glavnyy energetik – Chief Power Engineer,* 2021, no. 7.

11 Egamov D.A., Uzakov R., Boikhonov Z.U. Effektivnost' primeneniya «Perenosnogo AVR-0, 4 kV» dlya obespecheniya bespereboynogo elektrosnabzheniya potrebiteley [The effectiveness of the "Portable AVR-0, 4 kV" to ensure uninterrupted power supply to consumers]. 2019.

12. Egamov D.A., Uzakov R., Boykhonov Z.U. Sposoby obespecheniya bespereboynogo elektrosnabzheniya potrebiteley, imeyushchikh odnu sistemu shin 6-10 kV i dva nezavisimykh istochnika pitaniya 6-10 kV [Ways to ensure uninterrupted power supply to consumers with one bus system 6-10 kV and two independent power sources 6-10 kV]. *Byulleten' nauki i praktiki – Bulletin of science and practice,* 2018, vol. 4, no. 3, pp. 155-159. Available at: http://www.bulletennauki.com/egamov-uzakov/ (accessed 03.15.2018).

13. Kudrin B.I. Power supply of industrial enterprises. Moscow, Intermet Engineering, 2005, p. 672.

14. Andreev V. A. Relay protection and automation of power supply. Moscow, Graduate School, 2006, p. 639.

15. Kakuevitsky L.I., Krupitsky, A.Yu., Sakov A.D., Smirnova T.V. Reference book of the relay of protection and automatics. 2nd ed., revised. and additional. Moscow, Energy, 1968, p. 296.

16. Bubenchikov A.A., Demidova N.G., Komarov A.G., Gorbachev V.V., Bubenchikova T.V. It is possible to use alternative energy sources in the Omsk region. *Omsk Scientific Bulletin*, 2017, no. 6.

17. Gubina O.A., Malafeev A.V. An analysis of the observability of electric grids by "MES". Intellectual power systems: works of the V International Youth Forum, 2017, October 9-13. Tomsk, 2017, vol. 3, no. 3, pp. 87-90.

18. Lapin N.A., Korolev M.E. The problem of monitoring the quality of electricity. *Problems of modern science and education*, 2017, no. 1, pp. 44-46.

19. Lukutin B.V., Obukhov S.G. Mikrogidroelektrostantsiya s avtoballastnoy nagruzkoy, reguliruyemoy po chastote vykhodnogo napryazheniya [Microhydro power plant with auto-ballast load, frequency-controlled output voltage]. *Elektromekhanika – Electromechanics*, 1990, no. 6.

20. Lukutin B.V., Obukhov S.G. Osobennosti raboty mikroGES na asinkhronnyy dvigatel' soizmerimoy moshchnosti [Peculiarities of operation of a microhydroelectric power station for an asynchronous motor of commensurate power]. *Elektrotekhnika*, 1991, no. 7, pp. 36-40.

21. Konstantinov G.G., Mayorov G.S. Razrabotka i issledovaniye avtonomnogo istochnika elektroenergii na baze mikroGES i asinkhronnogo generatora s kondensatornym vozbuzhdeniyem [Development and research of an autonomous source of electricity based on micro hydroelectric power plants and an asynchronous generator with capacitor excitation]. *Vestnik Irkutskogo gosudarstvennogo tekhnicheskogo universiteta – Bulletin of the Irkutsk State Technical University*, 2018, no. 10 (141), pp. 92-116. Available at: https://cyberleninka.ru/article/n/razrabotka-i-issledovanie-avtonomnogo-istochnika-elektroenergii-na-baze-mikroges-i-asinhronnogo-generatora-s-kondensatornym (accessed 04.04.2022).

Taqrizchi:

Sadullayev N.N., t.f.d., prof., "Energetika" fakulteti dekani, Buxoro muhandislik-texnologiya instituti.