Turar-joy binosi elektr iste'molchilarini 0,38 kv tarmog'idagi kuchlanish va tok sinusoidaligini buzilishiga ta'siri

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Dolzarblik: Ushbu maqolada turar-joy binolarida impulsli ish rejimiga ega bo'lgan, tok-kuchlanish xarakteristikalari nochiziqli bo'lgan ko'plab elektr iste'molchilarni paydo bo'lishi 0,38 kV elektr tarmog'iga yuqori garmonikali toklarni generatsiya qilinishini keltirib chiqaradi va ushbu garmoniklarning katta qiymatlari tarmoq kuchlanishining shaklini yomonlashuviga olib keladi. Shuning uchun turar-joy binolari elektr iste'molchilari tomonidan generatsiya qilinadigan tok garmoniklarini va ularni 0,38 kV tarmoq kuchlanishining nosinusoidalik koeffitsiyentiga ta'sirini tadqiq etishilishi ko'rib chiqiladi..
Maqsad: 0,38 kVli elektr tarmog'iga eng katta salbiy ta'sirni impulsli elektr ta'minot bloklari bo'lgan elektr iste'molchilarni aniqlash, hamda turar-joy binolaridagi elektr iste'molchilari tomonidan generatsiya qilinadigan tok garmoniklari va ularning 0,38 kVli elektr tarmog'idagi kuchlanish nosinusoidalik koeffitsiyentiga ta'sirini tadqiq etish hisoblanadi.
Usullar: Matlab Simulink dasturida turar-joy binosi uchun 0,38 kVli tarmoq modelining imitatsion modelini ishlab chiqish, bu esa elektr taqsimlash shkafida (VRU) umumiy tok K_I va kuchlanish K_U buzilish koeffitsiyentlarini tadqiq qilish.
Natijalar: nochiziqli yuklamaning o'rnatilgan quvvati chiziqli yuklama quvvatidan oshganda, 0,38 kVli tarmoqdagi kuchlanish nosinusoidalik koeffitsiyenti GOST 13109-97 standartlarida belgilangan qiymatlardan oshish holatlarini kuzatish va bartaraf etish choralarini ko'rishda foydalaniladi.
Kalit so'zlar: elektr ta'minoti tizimi, elektr tarmog'i, elektr energiyasi sifati, kuchlanish garmonikalari, tok garmonikalari, elektromagnit mutanosiblik, elektr iste'molchi.

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Влияние электропотребителей жилых зданий на нарушение синусоидальности напряжения и тока в сети 0,38 кв

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Актуальность: В данной статье отмечается, что появление в жилых зданиях большого количества электрических потребителей с импульсным режимом работы и нелинейными вольт-амперными характеристиками приводит к генерации токов высших гармоник в электрическую сеть напряжением 0,38 кВ, что вызывает искажение формы сетевого напряжения. В связи с этим рассматривается исследование токовых гармоник, генерируемых электрическими потребителями жилых зданий, и их влияния на коэффициент несинусоидальности напряжения сети 0,38 кВ.
Цель: Определение электрических потребителей с наибольшим отрицательным воздействием на сеть 0,38 кВ, которыми являются источники питания импульсного типа, а также исследование токовых гармоник, генерируемых электрическими потребителями жилых зданий, и их влияния на коэффициент несинусоидальности напряжения в сети 0,38 кВ.
Методы: Разработка имитационной модели сети напряжением 0,38 кВ для жилого здания в среде Matlab Simulink, что позволяет исследовать коэффициенты искажения суммарного тока (КИ) и напряжения (КУ) в вводно-распределительном устройстве (ВРУ).

Результаты: Установлено, что при превышении установленной мощности нелинейной нагрузки над мощностью линейной нагрузки коэффициент несинусоидальности напряжения в сети 0,38 кВ может превышать значения, регламентированные стандартом ГОСТ 13109-97. Данные результаты могут быть использованы для выявления и предотвращения подобных ситуаций.
Ключевые слова: система электроснабжения, электрическая сеть, качество электрической энергии, гармоники напряжения, гармоники тока, электромагнитная совместимость, электрический потребитель

The influence of electrical consumers in residential buildings on the disturbance of voltage and current sinusoidality in the 0.38 kv network

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Relevance: This article highlights that the widespread use of electrical consumers with impulsive operating modes and nonlinear current-voltage characteristics in residential buildings leads to the generation of higher harmonic currents in the 0.38 kV power network, which causes distortion of the network voltage waveform. Therefore, the study focuses on current harmonics generated by residential electrical consumers and their impact on the non-sinusoidality coefficient of the 0.38 kV network voltage.
Objective: To identify electrical consumers that have the most adverse impact on the 0.38 kV power network, which are mainly impulse-type power supply units, and to investigate the current harmonics generated by residential consumers and their influence on the non-sinusoidality coefficient of the 0.38 kV network voltage.
Methods: Development of a simulation model of a 0.38 kV residential power network in Matlab Simulink, which allows for the analysis of total current distortion factor (THDI) and voltage distortion factor (THDU) in the main distribution board (MDB).
Results: It has been established that when the installed capacity of nonlinear loads exceeds that of linear loads, the voltage non-sinusoidality coefficient in the 0.38 kV network may exceed the permissible limits defined by GOST 13109-97. The obtained results can be applied to identify such cases and to develop preventive measures.
Keywords: power supply system, power network, power quality, voltage harmonics, current harmonics, electromagnetic compatibility, electrical consumer.

1. Kirish (Introduction)

O‘zbekiston Respublikasi Davlat statistika qo‘mitasining ma’lumotlariga ko‘ra, 2010 yildan 2024 yilgacha aholi tomonidan elektr energiyasining maishiy iste’moli 27,9% ga oshgan va mamlakatdagi jami elektr energiyasi iste’molining taxminan 2% ni tashkil etgan [1].

Elektr energiyasi iste’molining o‘sishi bilan birga yuklama xarakteri ham o‘zgargan. Noelektr chiziqli tok-kuchlanish xarakteristikasiga ega bo‘lgan elektr iste’molchilar (EI) soni ortib bormoqda [2, 3, 4].

Shu sababli, turar-joy binolaridagi elektr iste’molchilari tomonidan generatsiya qilinadigan tok garmoniklari va ularning 0,38 kVli elektr tarmog‘idagi kuchlanish nosinusoidalik koeffitsiyentiga ta’sirini tadqiq etish amalga oshirildi.

Yuqori garmonika toklarining ossillogramma va spektrogrammalarini o‘lchash, shuningdek, turar-joy binolaridagi elektr iste’molchilar yuklama grafiklarini olish GOST 30804.4.30-2013 (IEC 61000-4-30:2008), GOST 30804.4.7-2013 (IEC 61000-4-7:2009), GOST 30804.3.2-2013 (IEC 61000-3-2:2009) va GOST 13109-97 tavsiyalariga muvofiq amalga oshirildi. O‘lchash vositasi sifatida Circutor kompaniyasining AR-5L va AR6 tipidagi sertifikatlangan elektr energiyasi sifatini taxlil qilish imkonini beruvchi asboblar ishlatildi, ularning tashqi ko‘rinishi 1-rasmda keltirilgan.

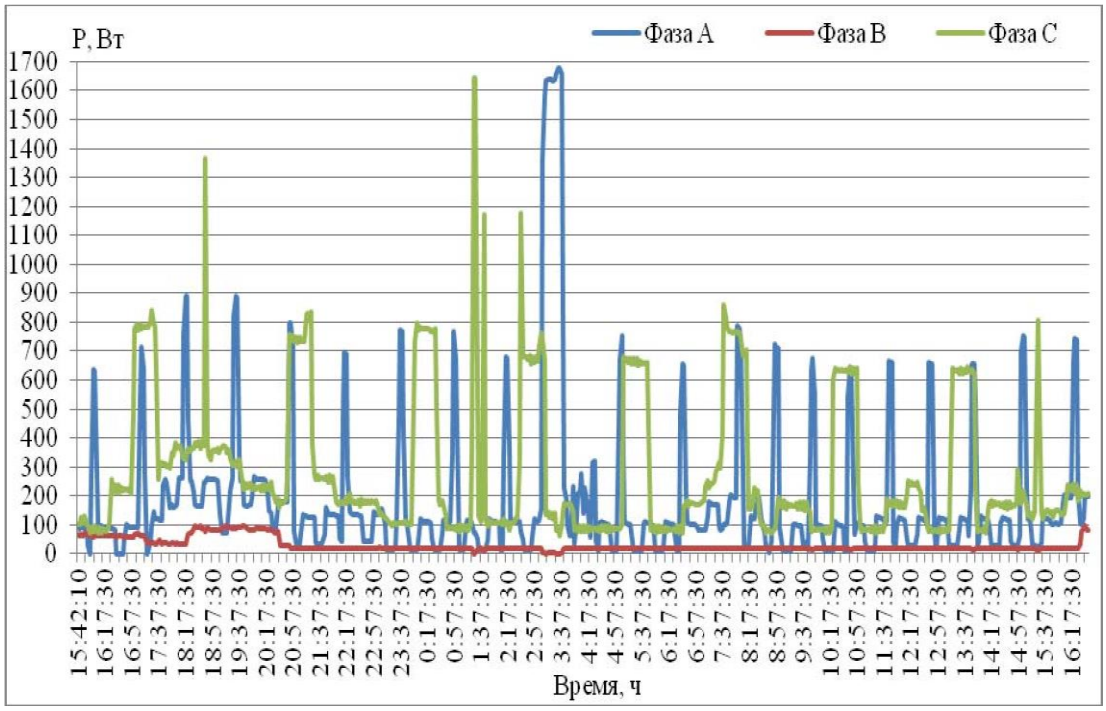
b) AR6 Circutor a) R-5L Circutor

1-rasm. Elektr energiyasi sifatini taxlil qilish imkonini beruvchi asboblarning tashqi ko‘rinishi
Fig.1. “External appearance of instruments for power quality analysis”

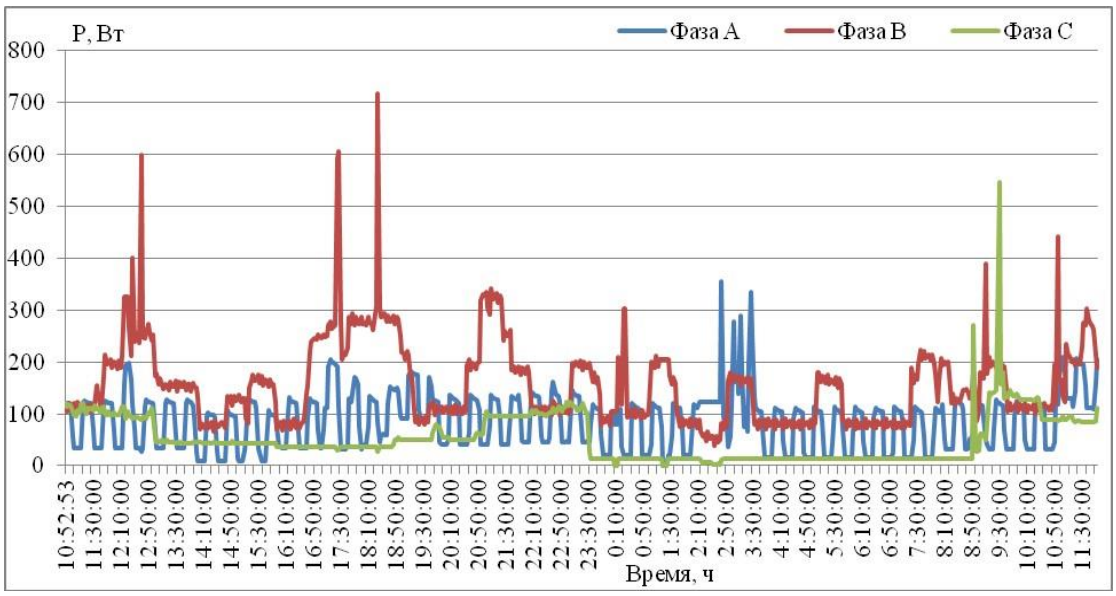
2. Materiallar va usullar (Methods and materials)

O‘lchovlar turar-joy binolarida qo‘llaniladigan turli elektr iste’molchilar uchun amalga oshirildi [5, 6]. Kunlik yuklama grafiklari Toshkent viloyati Olmaliq shahrida joylashgan turar-joy binolarining 0,38 kV li kirish taqsimlovchi qurilmalarida(KTQ) o‘lchangan bo‘lib, ular 2- va 3-rasmlarda keltirilgan.

Turar-joy binolaridagi elektr iste’molchilarning ish rejimlarini o‘rganish natijalari shuni ko‘rsatdiki, ularning aksariyati takroriy-qisqa muddatli yoki qisqa muddatli rejimda ishlaydi. Bu esa mazkur turdagi turar-joy binolari yuklama grafiklaridagi tok va quvvatlarning sakrashlari bilan izohlanadi.



2-rasm. 1-turar-joy binosining kunlik yuklama grafigi (Toshkent viloyati, Olmaliq shahri)
Fig.2. “Daily load profile of Residential Building No. 1 (Olmaliq, Tashkent Region)”



3-rasm. 2-turar-joy binosining kunlik yuklama grafigi (Toshkent viloyati, Olmaliq shahri).
Fig.3. "Daily load profile of Residential Building No. 2 (Olmaliq, Tashkent Region)"

Kunlik yuklama grafiklarining xos xususiyati – elektr energiyasini kunning turli soatlarida va mavsumlar bo'yicha nomutanosib iste'mol qilinishidadir.

Yuqorida ta'kidlanganidek, turar-joy binolarida impulsli ish rejimiga ega bo'lgan, nochiziqli tok-kuchlanish xarakteristikali elektr iste'molchilar soni ortib borishi 0,38 kVli elektr tarmog'ida yuqori garmonikali toklarning generatsiya qilinishiga sabab bo'ladi.

GOST 13109-97 tok garmonikalari qiymatlarini cheklamaydi, ammo ularning katta qiymatlari tarmoq kuchlanishi egri chizig'i shaklini yomonlashishiga olib keladi [7 – 11].

3. Natijalar (Results)

Ushbu tadqiqot ishida turar-joy binolarida qo'llaniladigan turli ishlab chiqaruvchilarning elektr iste'molchilari tomonidan generatsiya qilinadigan tok garmonikalari o'rganildi. 1-jadvalda o'rganilgan elektr iste'molchilarining parametrlari keltirilgan**.**

Turar-joy binolaridagi elektr iste'molchilarni tahlil qilish shuni ko'rsatadiki, ishlab chiqaruvchi kompaniyalar mazkur elektr iste'molchilar tomonidan generatsiya qilinadigan yuqori garmonik toklar haqida ma'lumot bermaydi. Bu esa turar-joy binolarini ta'minlaydigan 0,38 kVli elektr ta'minoti tizimlarini loyihalash va ekspluatatsiya qilishda tok va kuchlanishning yuqori garmonik tarkibini hisoblash imkonini bermaydi. 1-jadvalda o'rganilayotgan elektr iste'molchilar uchun o'lchangan umumiy garmonik tarkib koeffitsiyenti THDI natijalari keltirilgan.

1-jadval. O'rganilayotgan elektr iste'molchilar parametrlari va o'lchangan umumiy garmonik tarkib koeffitsiyenti THDI natijalari
Table 1. "Parameters of the investigated electrical consumers and the measured Total Harmonic Distortion Index (THDI) results"

№ t/r	EI nomi	Kuchlanish, V	Quvvat, Vt	cos φ, n.b.	THD_I, %
1	Kir yuvish mashina LG	220-240	2100	0,7	33,1
2	Gazli qozon Bosch	230	150	0,9	23,8
3	Televizor LG	100-240	300	0,92	34,8
4	Netbuk Sony	100-240	220	0,5	205,0
5	Noutbuk Samsung	100-240	330	0,5	194,0
6	PEVM Dell	100-240	600	0,9	128,8
7	Printer Xerox	220-240	1000	0,9	6,2

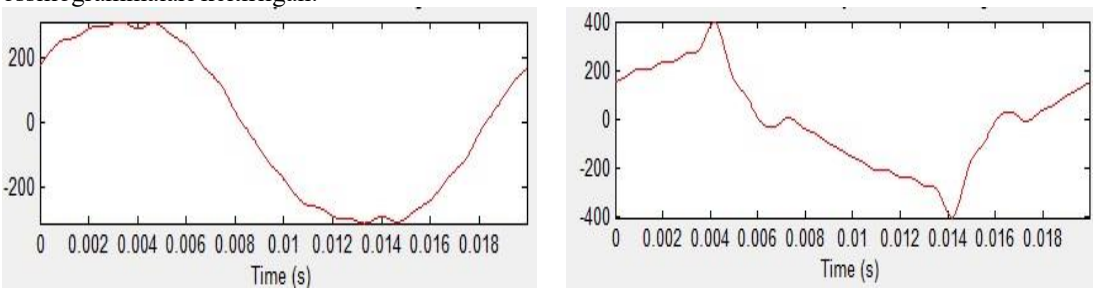
8	Mikroto‘lqinli pech Samsung	230	1150	0,98	26,7
9	Muzlatgich Siemens	220-240	90	0,98	15,8
10	Idish yuvish mashina Bosch	220-240	2000	0,98	85,8
11	Dazmol Tefal	220-240	1740	0,99	6,4
12	Xavo tozalagich Elikor	220-230	140	0,6	15,4
13	Changyutgich Samsung	230	1300	0,99	21,1
14	Boyler Thermex	230	2000	1	38,2
15	Elektr issiq pol	220-230	550	1	12,8
16	Darvozani elektr yuritmasi DoorHan	230	150	0,85	46,0
17	SDL Osram	220	9	0,9	122,1

Olingan xarakteristikalarga ko‘ra, elektr tarmog‘iga eng katta salbiy ta’sir impulsli elektr ta’minot bloklari bo‘lgan elektr iste’molchilar, ya’ni shaxsiy elektron hisoblash mashinalari (PEVM), noutbuklar va netbuklar, shuningdek, idish yuvish mashinalari va E14 hamda E27 patronli svetodiod chiroqlar tomonidan ko‘rsatiladi.

GOST 13109-97 talablariga muvofiq, o‘rganilayotgan tarmoqdagi kuchlanishning umumiy garmonik tarkib koeffitsiyenti K_U qiymatlari haftaning 95% vaqti davomida 8% dan, 100% vaqti davomida esa 12% dan oshmasligi lozim [11].

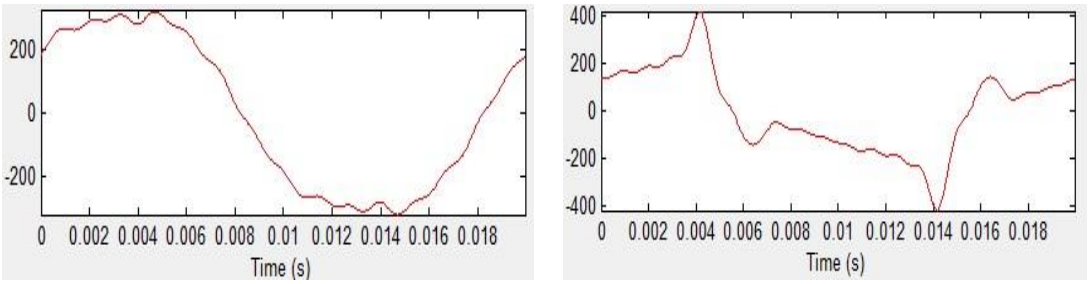
4. Muhokama (Discussion)

Nochiziqli elektr iste’molchilari tomonidan generatsiya qilinadigan yuqori garmonik toklarning kuchlanish nosinusoidalik koeffitsiyentiga ta’sirini o‘rganish uchun **Matlab Simulink** dasturida turar-joy binolari yuklama uzelining imitatsion modeli ishlab chiqildi. 4-rasmda ishlab chiqilgan imitatsion model asosida turar-joy binosi kirishidagi taqsimlash qurilmasida(KTQda) nochiziqli va chiziqli yuklama nisbatlarining turli qiymatlarida modellashtirish natijasida olingan tok va kuchlanish ossillogrammalari keltirilgan.



a) Kuchlanish va tok ossillogrammasi (Nochiziqli yuklamani chiziqli yuklamaga nisbati 50/50 bo‘lgan holat uchun)

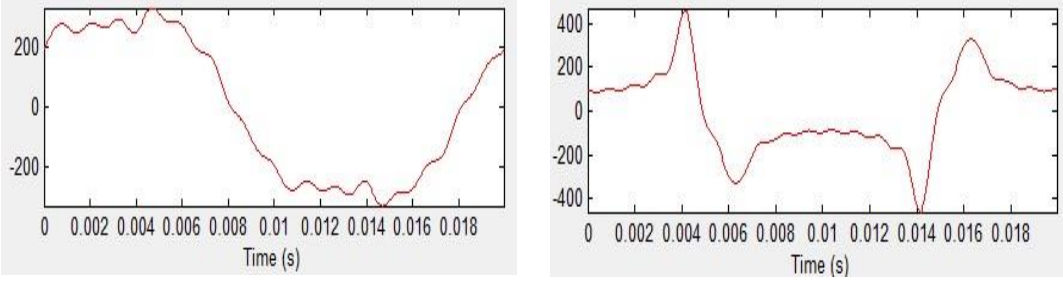
“a) Voltage and current oscillogram (nonlinear-to-linear load ratio: 50/50)”



b) Kuchlanish va tok ossillogrammasi (Nochiziqli yuklamani chiziqli yuklamaga nisbati 50/50 bo‘lgan

holat uchun)

“b) Voltage and current oscillogram (nonlinear-to-linear load ratio: 50/50)”



v) Kuchlanish va tok ossillogrammasi (Nochiziqli yuklamani chiziqli yuklamaga nisbati 50/50 bo‘lgan holat uchun)

“c) Voltage and current oscillogram (nonlinear-to-linear load ratio: 50/50)”

4-rasm. Matlab Simulink dasturida modellashtirish natijasida olingan turar-joy binolarining kirish qismidagi(VRUsidagi) tok va kuchlanish ossillogrammalari

Fig.4. “Oscillograms of current and voltage at the input (VRUs) of residential buildings obtained by MATLAB Simulink modeling”

3-jadvalda **0,38** kVli elektr tarmog‘ining imitatsion modeli asosida aniqlangan turar-joy binolari kirishidagi taqsimlash qurilmadagi **(**KTQ**)** kuchlanish va tokning umumiy garmonik tarkib koeffitsiyentlari va ularning nochiziqli yuklamani chiziqli yuklamaga nisbatiga bog‘liqligi keltirilgan**.**

3-jadval. Nochiziqli yuklamani chiziqli yuklamaga nisbatiga bog‘liqliq ravishda kuchlanish va tokning nosinusoidallik koeffitsiyentlari

Table 3. “Voltage and current distortion factors as a function of the ratio of nonlinear to linear load”

№ p/p	Nochiziqli yuklama /chiziqli yuklama nisbati	Kuchlanishning nosinusoidalik koeffitsiyenti, K_U, %	Tok nosinusoidalikning koeffitsiyenti, K_I, %
1	0/100	0	0
2	10/90	1,2	4,47
3	20/80	2,48	9,86
4	30/70	3,86	16,42
5	40/60	5,35	24,44
6	50/50	6,95	34,28
7	60/40	8,68	46,29
8	70/30	10,56	60,58
9	80/20	12,59	77,32
10	90/10	14,79	95,58
11	100/0	17,18	113,52

Eksperimental tadqiqotlar natijasida olingan natijalar(3-jadval) shuni ko‘rsatdiki, turar-joy binolarida qo‘llanilayotgan zamonaviy elektr iste’molchilar elektr tarmog‘iga yuqori garmonik tarkibli toklarni generatsiya qilish orqali kuchlanish egri chizig‘ining sinusoidaligini buzilishiga olib keladi.

5. Xulosa (Conclusion)

0,38 kVli elektr tarmoqning Matlab Simulink dasturida ishlab chiqilgan imitatsion modeli asosida, turar-joy binolari kirish qismidagi taqsimlovchi qurilmadagi(KTQ) tok K_I va kuchlanishning K_U buzilish koeffitsiyenti turli chiziqli va nochiziqli yuklama nisbatlarida tadqiq etildi. Bu esa turar-joy binolari elektr ta’minoti tizimlarining kuchlanish garmonikalarining ruxsat etilgan darajalari GOST 32144-2013 talablariga muvofiqligiga baholash imkonini beradi.

Modellashtirish natijalari shuni ko‘rsatadiki, agar nochiziqli yuklamaning o‘rnatilgan quvvati chiziqli yuklamaning quvvatidan ikki barobar ortiq bo‘lsa, u holda 0,38 kVli elektr tarmoqdagi kuchlanish nosinusoidalik koeffitsiyenti GOST 32144-2013 da belgilangan cheklangan qiymatlardan oshishi mumkin.

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