Elektr stansiyada parallel ishlayotgan sinxron va asinxron generatorning imitatsion model asosidagi holat parametrlari tahlili

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Dolzarbligi: so‘nggi yillarda dunyoning ko‘plab mamlakatlarida energiya resurslarini tejash, yangidan yangi muqobil energiya manbalarini yaratish va mavjud qayta tiklanuvchi energiya (QTE) manbalaridan oqilona foydalanish masalalariga alohida ahamiyat berilmoqda. Rivojlangan mamlakatlar bo‘yicha, «2020-yil uchun samaradorlikning muhim ko‘rsatkichlari sharhida QTE manbalarining eng katta ulushlari Shvetsiyaga - 60,1%, Finlyandiyaga - 43,8% va Latviyaga - 42,1% to‘g‘ri kelishi ma’lum qilingan. Ushbu mamlakatlardagi asosiy energiya ishlab chiqarish manbalari GES va SHES lar, shuningdek, biomassani qayta ishlash manbalari hisoblanadi». Bu borada, avtonom tizimlar quvvat manbalari tuzilishining soddaligi, texnik xizmat ko‘rsatishning qulayligi, nisbatan kichik massa (kVA/kg) va hajmga ega bo‘lishi, hamda holat parametrlarining barqarorligi kabi talablarga alohida ahamiyat berilmoqda. O‘tkazilgan tadqiqotlardan, elektr energiya manbai sifatida qisqa tutashgan rotorli asinxron generator (AG) lardan foydalanilganda boshqa turdagi mexanik o‘zgartirgichlarga qaraganda yuqori energetik ko‘rsatkichlarga egaligi, dinamik va statik xususiyatlarining ustunligi, texnik jihatdan yuqori ishonchliligi, tuzilishining oddiyligi va narxining arzonligi kabi asosiy parametrlarini inobatga olib, AG ni har qanday turdagi birlamchi dvigatellar yordamida harakatga keltiriladigan energetik tizimlardagi kabi avtonom stansiyalarda qo‘llanilishi – elektr energetikaga oid dolzarb masalalarni yechishga qaratilgan ilmiy-tadqiqot ishlarini olib borishda muhim ahamiyatga ega hisoblanadi.
Maqsad: avtonom holatida parallel ishlayotgan sinxron generator (SG) va AG ning imitatsion modeli asosidagi natijalarni tahlil qilish va asoslash.
Usullari: imitatsion model asosida elektr energetikasi tizimlarining barqarorlashgan va o‘tkinchi rejimlarini tahlil qilish usullaridan foydalanildi.
Natijalar: qisqa tutashgan rotorli AG dan iborat quvvat manbasining yuklama miqdori o‘zgargan holatlarida holat parametrlari barqarorligiga ta’sirlari tahlil qilingan. Tahlil natijalari asosida AG ni qayta tiklanuvchi energiya manbalarida foydalanish bo‘yicha tegishli takliflar kiritildi.
Kalit so'zlar: qisqa tutashgan rotorli AG, SG, o‘z-o‘zidan qo‘zg‘atishli AG, imitatsion model.

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Анализ параметров режима параллельно работающего синхронного и асинхронного генератора на электростанции на основе имитационной модели

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Актуальность: в последние годы во многих странах мира уделяется особое внимание экономии энергоресурсов, созданию новых альтернативных источников энергии и рациональному использованию существующих возобновляемых источников энергии (ВИЭ). Согласно обзору ключевых показателей эффективности за 2020 год, наибольшая доля ВИЭ приходится на Швецию – 60,1%, Финляндию – 43,8% и Латвию – 42,1%. Основными источниками производства энергии в этих странах являются гидроэлектростанции (ГЭС) и ветряные электростанции (ВЭС), а также источники переработки биомассы. В этом контексте осо-бое значение придается автономным системам, предъявляющим требования к простоте конструкции источников питания, удобству технического обслуживания, относительно малой массе (кВА/кг) и габариту, а также обеспечение стабильности режимных параметров. Исследования

показали, что при использовании асинхронных генераторов с короткозамкнутым ротором (АГ) в качестве источника электроэнергии, при сравнении с другими видами механических преобразователей, АГ обладают более высокими энергетическими показателями, превосходными динамическими и статическими характеристиками, высокой технической надежностью, простотой конструкции и низкой стоимостью. Поэтому применение АГ в автономных станциях, как и в энергетиче-ских системах, приводимых в движение любыми типами первичных двигателей, имеет важное значение для проведения научно-исследовательских работ, направленных на решение актуальных проблем электроэнергетики.
Цель: анализ и обоснование результатов на основе имитационной модели параллельно работающих синхронного генератора (СГ) и АГ в автономном режиме.
Методы: использовались методы анализа установившихся и переходных режимов систем электроэнергетики на основе имитационного моделирования.
Результаты: проанализировано влияние изменения нагрузки источника питания, состоящего из асинхронного генератора с короткозамкнутым ротором, на стабильность параметров его состояния. На основе результатов анализа внесены соответствующие предложения по использованию асинхронных генераторов в возобновляемых источниках энергии.
Ключевые слова: Асинхронный генератор с короткозамкнутым ротором, синхронный генератор, самовозбуждающийся асинхронный генератор, имитационная модель.

Analysis of the parameters of the parallel-operating synchronous and asynchronous generator at the power plant based on the simulation model

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Relevance: In recent years, many countries around the world have been paying special attention to energy resource conservation, the creation of new alternative energy sources, and the rational use of existing renewable energy sources (REMs). According to the review of key performance indicators for 2020, the largest share of renewable energy sources falls on Sweden - 60.1%, Finland - 43.8% and Latvia - 42.1%. The main sources of energy production in these countries are hydroelectric power plants (HPPs) and wind power plants (WPPs), as well as biomass processing sources. In this context, special importance is attached to autonomous systems that impose requirements for the simplicity of power source design, ease of maintenance, relatively low mass (kVA/kg), and overall dimensions, as well as ensuring the stability of operating parameters. Studies have shown that when using short-circuited rotor (AG) asynchronous generators as a power source, compared to other types of mechanical converters, AG has higher energy performance, superior dynamic and static characteristics, high technical reliability, simplicity of construction, and low cost. Therefore, the use of AG in autonomous stations, as well as in energy systems driven by any type of primary motors, is of great importance for conducting research aimed at solving pressing problems in electric power engineering.
Aim: analysis and justification of the results based on the simulation model of a parallel-operating synchronous generator (SG) and an AG in autonomous mode.
Methods: methods for analyzing the established and transient modes of electric power systems based on simulation modeling were used.
Results: The influence of power source load change on the stability of its state parameters, consisting of a short-circuited rotor asynchronous generator, was analyzed. Based on the analysis results, appropriate proposals were made for the use of asynchronous generators in renewable energy sources.
Keywords: Short-circuited rotor asynchronous generator, synchronous generator, self-exciting asynchronous generator, simulation model.

1. Kirish (Introduction)

So‘nggi 20-25-yil ichida aksariyat rivojlangan davlatlarda noan’anaviy manbalardan foydalanib elektr energiya ishlab chiqarilishiga, qayta tiklanuvchi energiya manbalaridan keng foydalanishga katta e’tibor qaratilmoqda, jumladan shamol elektr stansiyalari(SHES) va gidro elektr stansiyalar (GES) dan foydalanishni kengaytirilishi maqsadga muvofiq hisoblanadi. O‘tkazilgan nazariy va amaliy tadqiqotlardan, mazkur stansiyalarda o‘z-o‘zidan qo‘zg‘atishli, qisqa tutashgan rotorli AG lardan foydalanish boshqa turdagi generatorlardan foydalanishga qaraganda texnik va iqtisodiy, hamda xizmat ko‘rsatilishi bo‘yicha qator afzalliklarga ega ekanligi ma’lum bo‘ldi [1].

2. Usullar va natijalar (Methods and materials)

Ilm – fan taraqqiyoti davomida ilmiy tadqiqotlar o‘tkazish bo‘yicha ham qulay ixtirolar qilindi, xususan turli zamonaviy modellashtirish usullari (Matlab, PCAD, ORKAD va boshqa) dan foydalanib har qanday texnik ishlanmalarni, jumladan elektr qurilmalarni va tizimlarni modellashtirish imkoniyati yaratildi. Dastlab, MATLAB/Simulink dasturidan foydalanib, avtonom ishlash holatidagi, o‘z–o‘zidan qo‘zg‘atishli, qisqa tutashgan rotorli, uch fazali AG ning imitatsion modeli tahlil qilindi. Ma’lumki, o‘zgaruvchan tok generatorlar rotori bug‘ turbina yoki gidroturbina, shamol, ichki yonuv dvigatellari kabi birlamchi dvigatellar tomonidan hosil qilinuvchi mexanik energiya hisobiga harakatga keltiriladi. AG ning rotori harakatga kelishi bilan, stator chulg‘amida hosil bo‘luvchi EYK, rotor qoldiq magnit maydoni kuch chiziqlari stator konturlarini kesib o‘tishi natijasida paydo bo‘ladi. AG ga xar qanday elektr yuklama ulanganida, aynan EYK hisobiga uning stator chulg‘ami bo‘ylab o‘zgaruvchan tok paydo bo‘lishini keltirib chiqaradi. AG larda elektr energiya hosil bo‘lishi uchun stator magnit maydoni va rotor aylanish chastotalarning o‘zaro teng bo‘lmasligi talab etiladi. AG dagi qoldiq magnit maydoni stator chulg‘amlarida dastlab kichik qiymatdagi EYK paydo etishi, katta qiymatlardagi EYK hosil bo‘lishi uchun AG statori chulg‘amida magnit induksiyasini oshirish lozim bo‘lib, buning uchun stator chulg‘amiga uch fazali statik kondensatorlarni ulash taqozo etiladi [2].

O‘tgan davrlarda AG dan, asosan 2 ta sababga ko‘ra elektr energiya tizimiga tatbiq etilmasdan kelgan: AG ni magnitlovchi, reaktiv quvvat manbai bo‘lgan, kichik o‘lchamlardagi statik kondensator batareyalarini sanoatda ishlab chiqarilishi yo‘lga qo‘yilmaganligi va stator kuchlanishini barqarorlashtirishning murakkabligi hisoblangan.

AG ga ulangan aktiv yuklama miqdori o‘zgarishiga mos ravishda rotor aylanish chastotasining o‘zgarishi, statordagi EYK va chastota qiymatlarini kichik miqdorlarda o‘zgarishlarini keltirib chiqaradi.

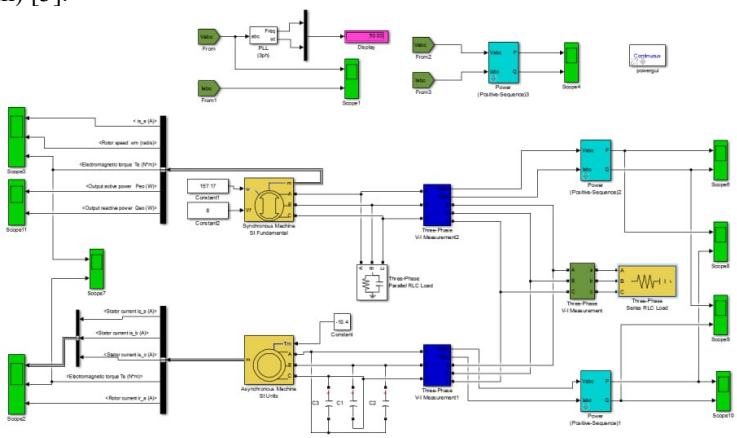
Modeldagi portlar A, B va C, AG stator chulg‘amlari chiqishlari hisoblanadi. AG valiga beriladigan mexanik quvvatga teng bo‘lgan signal uning kirish portiga uzatiladi. AG va energo tizimga tegishli parametrlar nisbiy birliklarda berilgan.

Reaktiv quvvat ishlab chiqarish uchun mo‘ljallangan C1, C2 va C3 kondensatorlar sig‘imlari o‘zaro teng bo‘lib, AG chiqishiga yulduzcha usulida ulangan.

Imitatsion model asosida o‘tkazilgan tadqiqotlar, AG ga ulangan har qanday xarakter-dagi yuklama va uning o‘zgarishlarida kondensator sig‘imlarini to‘g‘ri tanlash bilan, yoki sig‘im qiymatlarini avtomatik boshqarish yo‘li bilan AG chiqishidagi kuchlanishni o‘zgarmasdan qolishini ta’minlash mumkinligini ko‘rsatadi.

Keltirilgan model asosida qayta tiklanuvchi elektr stansiyalarda kondensator batareyasi yordamida qo‘zg‘atiluvchi AG ni avtonom elektr manbai sifatida amalda qo‘llanilishiga doir tadqiqotlar o‘tkazildi.

Avtonom holatida parallel ishlayotgan AG va SG dan iborat stansiyaga aktiv yuklama ulangan holatining imitatsion modeli asosida AG va SG chiqishidagi holat parametrlarining o‘zgarishlarini aniqlab tahlil qilindi (1-rasm) [3].



1-rasm. Parallel ishlayotgan AG va SG dan iborat stansiyaning avtonom ishlash holatida, stansiyaga aktiv yuklama ulangan xolatiga mos imitatsion modeli

Fig.1. Simulation model of a station consisting of parallel operating AG and SG in autonomous operation, corresponding to the state of active load connection to the station

SG parametrlari:

quvvati: S_{SG} =16 kVA

чиқиш кучланиши: U_H=400 V

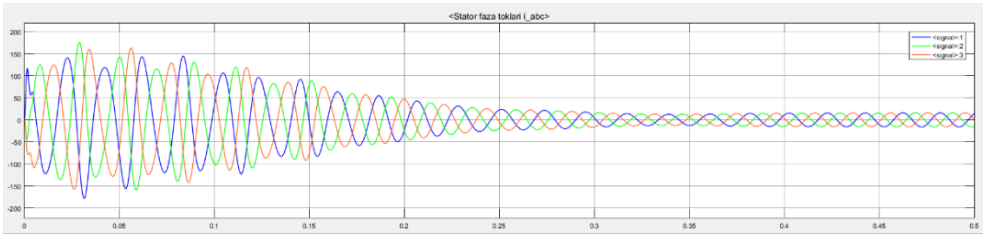
tarmoq chastotasi: f=50 Hz

Statot parametrlari:

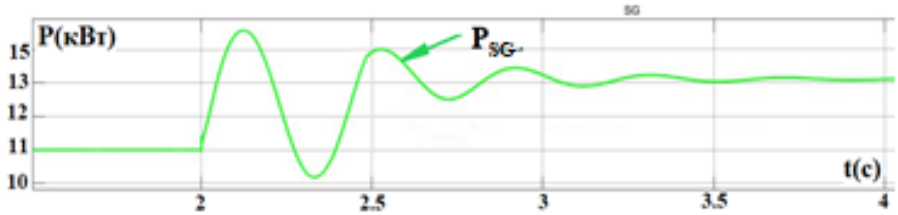
R_s = 0,645 Om

L_I = 0,002228 H
L_{md} = 0,05297 H
L_{mq} = 0,02518 H
R_f = 0,3968 Om
L_{lfd} = 0,005492 H
dempfer chulg‘ami:
R_{kd} =0,9843 Om
L_{lkd} =0,003371 H
R_{kq} = 1,545 Om
L_{lkq} = 0,004906 H
AG parametrlari:
quvvati: P_{ag} =15 kW
chiqish kuchlanishi: U_n =400 V
tarmoq chastotasi: f=50 Hz
aylanish tezligi: n_2=1460 ayl/min
Stator parametrlari:
R_s = 0,2147 Om
L_s = 0,000991 H
Rotor parametrlari:
R_r = 0,2205 Om
L_r’ = 0,000991 H
o‘zaro induktivlik: Lm=0,06419 H
inersiya momenti; J=0,102 kg·м^2
ishqalanish koeffitsiyenti; F=0,009541
juft qutblari soni: p=2
qo‘zg‘atish kondensatori sig‘imi: C=27·10^{-6} F
aktiv yuklama: P = 20000 W.

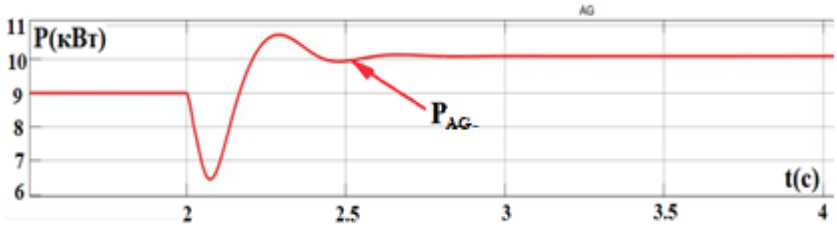
AG va SG dan iborat stansiyaga aktiv yuklama ulangan vaqtdagi holat parametrlarining vaqt bo‘yicha o‘zgarish ossillogrammalari quyidagi ko‘rinishlarda:



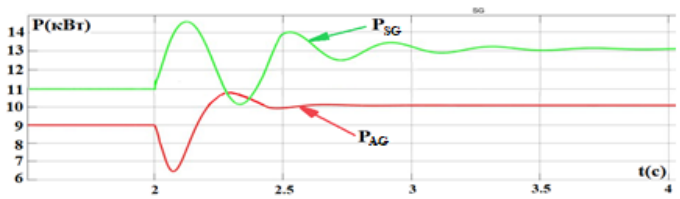
2-rasm. Stator faza toklari
Fig.2. Stator phase currents



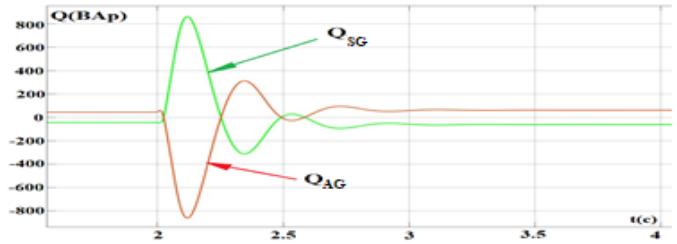
3-rasm. SG chiqishidagi aktiv quvvatining o‘zgarish ossillogrammasi
Fig3. Oscillogram of the change in active power at the output of the SG



4-rasm. AG chiqishidagi aktiv quvvatining o‘zgarish ossillogrammasi
Fig4. Oscillogram of the change in active power at the output of the AG



5-rasm. SG va AG ning chiqishidagi aktiv quvvatlarining o‘zgarish ossillogrammasi
Fig.5. Oscillogram of the change in active power at the output of SG and AG



6-rasm. SG va AG ning chiqishidagi reaktiv quvvatlarining o‘zgarish ossillogrammasi – Q_{SG}, Q_{AG}
Fig.6. Oscillogram of the change in reactive power at the output of SG and AG - Q_{SG}, Q_{AG}

SG va AG ning stansiyada parallel ishlayotgan holatining imitatsion modelida o‘tkazilgan tadqiqotlar natijalari: 2-rasm, 3-rasm, 4-rasm, 5-rasm va 6-rasmlardan, stansiyaga aktiv yuklama ulangandan kichik vaqt o‘tishi bilan yuklamalar generatorlar o‘rtasida taqsimlanguncha rotorlar harakatining o‘zgarishiga olib keldi, ya’ni SG da yuklama burchagi δ ning, AG da sirpanish S ning oshishi sodir bo‘ladi. Bunday o‘zgarishlar sinxronlovchi quvvatga, rotorlar inersiya doimiysiga yoki agregatlar kinetik energiyalariga proporsionaldir [4]. Yuklama ulanganda AG sinxronlovchi quvvati kichik qiymatlarni tashkil etganligi uchun yuklama ulangan lahzada AG ishtirok etmaganligi sababli, uning rotori harakatida chayqalishi kuzatilmasdan, yuklama dastlab to‘la SG hissasiga to‘g‘ri keladi. SG rotorining nisbiy harakat tenglamasiga muvofiq SG sinxronlovchi quvvati va rotor inersiyasining o‘zaro ta’sirida hosil bo‘lgan rotor chayqalishlari AG rotorini chayqalishiga sababchi bo‘ladi, natijada AG ham o‘zining kinetik quvvatini tizimga uzatib boshlaydi, AG dagi chayqalishlar SG ga qaraganda kechikib boshlanganligi uchun SG va AG larning quvvat tebranishlari maksimumlari 180 burchakka siljigan holatiga ega bo‘ladi, natijada chayqalishlarning qarama– qarshi fazadagi o‘zgarishini keltirib chiqaradi [5].

3. Natijalar va muhokama (Results and discussion)

SG va AG parallel ishlayotgan stansiyaga biror tashqi turtki ta’sir etganda, SG burchak xarakteristikasi $P_{sg}=(E_q \cdot U)\cdot sin\delta/X_0$ ga asosan SG rotorida chayqalish paydo bo‘ladi, natijada P_{SG} va δ_G ning tebranishi bir tomonga o‘zgarib, quvvatning oshishi bilan generator shinasidagi kuchlanishning pasayishi kuzatiladi. AG ning aktiv quvvati shinadagi kuchlanish kvadratiga proporsional bo‘lganligi uchun shinadagi pasayishi AG uzatayotgan quvvatining pasayishini keltirib chiqaradi. Keltirilgan ossillogrammalarda SG va AG dan iborat stansiyaga aktiv yuklama ulangan holatiga mos o‘tish jarayonlaridagi holat parametrlarining tebranishlari tasvirlangan bo‘lib, tebranishlar 0,2 sek davom etgan [6]. AG holat parametrlarini so‘ndirish bilan bir qatorda SG rotori va quvvati chayqalishlarini kamayishini ta’minlaydi. Shunday qilib, generator quvvatlari maksimumlari qarama – qarshi fazalarda o‘zgarganligi hisobiga holat parametrlarining o‘tish jarayonlaridagi tebranishlari asosan stansiya shinasiga yetmasdan bartaraf etilganligi uchun stansiyada parallel ishlayotgan SG va AG o‘z–o‘zidan rostlanuvchi tizim hosil qilishi ma’lum bo‘ldi [7].

AG dan iborat avtonom stansiyaning imitatsion modeli asosida yuqorida olingan natijalardan, ushbu tizimni nisbatan arzon va ishonchli 3 fazali energiya manbai sifatida foydalanish uchun tavsiya etiladi, bunday tizim chiqish kuchlanishi sifatining yaxshilanishiga, markaziy elektr ta’minotidan uzoqda joylashgan turar – joy va sanoat obyektlari elektr ta’minoti uchun va zaxira quvvat manbai sifatida ishlatilishi mumkin [8].

4. Xulosa (Conclusion)

O‘tkazilgan tadqiqotlar tahlili, qayta tiklanuvchi energiya tizimlarida an’anaviy aylanuvchi generatorlarga nisbatan qisqa tutashgan rotorli AG larning muqobil energiya manbai sifatida yuqori imkoniyatlarini namoyon etadi.

Elektr energiyasiga bo‘lgan talabning yildan yilga ortib borayotgan hozirgi sharoitlarga mos energiya bozorini hisobga olgan holda, kelgusi tadqiqotlar, qisqa tutashgan rotorli AG lardan foydalanishning uzoq muddatli iqtisodiy va ekologik afzalliklariga qaratilishi muhim ahamiyatga ega.

ADABIYOTLAR

1. I.U. Rakhmonov, K. M. Reymov, A.M. Najimova, B.Uzakov, B Seytmuratov. Analysis and calculation of optimum parameters of electric arc furnace. Journal of Physics: Conference Series 1399 (2019) 055048, 1-4. DOI: 10.1088/1742-6596/1399/5/055048.

2. Y Bobojonov, B Seytmuratov, AN Sultanov, B Fayzullaev. Calculated studies of the vibrational properties of the mode parameter of the electric power system containing asynchronous turbogenerators by their frequency characteristics. E3S Web of Conferences 289 EDP Sciences 2021. https://doi.org/10.1051/e3sconf/202128907025.

3. Allayev, K.R., Fedorenko, G.M., Postnikov, V.I., Ostapchuk, L.B. Asynchronous generators as power system's natural dampers. 43rd International Conference on Large High Voltage Electric Systems 2010, CIGRE 20102010, 9p43rd International Conference on Large High Voltage Electric Systems 2010, CIGRE 2010; Paris; France; 22 August 2010. https://doi.org/10.1051/e3sconf/202021601177.

4. Fazylov Kh.F., Allaev K.R. Analysis of the operation of an electrical system during simultaneous operation of synchronous and asynchronous generators. Power engineering New York Volume 18, Issue 3, 1980, Pages81–88. https://doi.org/10.1088/1757-899X/163/1/012033.

5. Yu.Bobozhonov, B. Seytmuratov, B. Fayzullaev, A Sultonov. Study of the influence of different designs of massive rotor of asynchronous generator on their maximum power // E3S Web of Conferences 216, 01168 (2020) RSES 2020 (Scopus). https://doi.org/10.1051/e3sconf/202021601168.

6. Yu.M. Bobozhonov, K. M. Reymov, B.T. Seytmuratov, Khakimov T.Kh. Research of the dependence of the resistance of asynchronous generators with massive rotors on their design // E3S Web of Conferences 384. 2023. PP, 01042, 1-4. https://doi.org/10.1051/e3sconf/202338401042.

7. Yu.Bobozhonov, B. Seytmuratov, B. Fayzullaev, A Sultonov, Sh. H. Husanov. Calculated studies of the vibrational properties of the mode parameter of the electric power system containing asynchronous turbogenerators by their frequency characteristics // E3S Web of Conferences 289 EDP Sciences 2021 (Scopus) https://doi.org/10.1051/e3sconf/202128907025.

8. Bobojonov Y.M., Reymov K.M., Seitmuratov B.T. Development of two-speed asynchronous electric motors for the undercarriage of mine self-propelled cars // E3S Web of Conferences 384. 2023. PP, 01044, 1-5. https://doi.org/10.1051/e3sconf/202338401044.

REFERENCES

1. I.U. Rakhmonov, K. M. Reymov, A.M. Najimova, B.Uzakov, B Seytmuratov. Analysis and calculation of optimum parameters of electric arc furnace. Journal of Physics: Conference Series 1399 (2019) 055048, 1-4. DOI: 10.1088/1742-6596/1399/5/055048.

2. Y Bobojonov, B Seytmuratov, AN Sultanov, B Fayzullaev. Calculated studies of the vibrational properties of the mode parameter of the electric power system containing asynchronous turbogenerators by their frequency characteristics. E3S Web of Conferences 289 EDP Sciences 2021. https://doi.org/10.1051/e3sconf/202128907025.

3. Allayev, K.R., Fedorenko, G.M., Postnikov, V.I., Ostapchuk, L.B. Asynchronous generators as power system's natural dampers. 43rd International Conference on Large High Voltage Electric Systems 2010, CIGRE 20102010, 9p43rd International Conference on Large High Voltage Electric Systems 2010, CIGRE 2010; Paris; France; 22 August 2010. https://doi.org/10.1051/e3sconf/202021601177.

4. Fazylov Kh.F., Allaev K.R. Analysis of the operation of an electrical system during simultaneous operation of synchronous and asynchronous generators. Power engineering New York Volume 18, Issue 3, 1980, Pages81–88. https://doi.org/10.1088/1757-899X/163/1/012033.

5. Yu.Bobozhonov, B. Seytmuratov, B. Fayzullaev, A Sultonov. Study of the influence of different designs of massive rotor of asynchronous generator on their maximum power // E3S Web of Conferences 216, 01168 (2020) RSES 2020 (Scopus). https://doi.org/10.1051/e3sconf/202021601168.

6. Yu.M. Bobozhonov, K. M. Reymov, B.T. Seytmuratov, Khakimov T.Kh. Research of the dependence of the resistance of asynchronous generators with massive rotors on their design // E3S Web of Conferences 384. 2023. PP, 01042, 1-4. https://doi.org/10.1051/e3sconf/202338401042.

7. Yu.Bobozhonov, B. Seytmuratov, B. Fayzullaev, A Sultonov, Sh. H. Husanov. Calculated studies of the vibrational properties of the mode parameter of the electric power system containing asynchronous turbogenerators by their frequency characteristics // E3S Web of Conferences 289 EDP Sciences 2021 (Scopus) https://doi.org/10.1051/e3sconf/202128907025.

8. Bobojonov Y.M., Reymov K.M., Seitmuratov B.T. Development of two-speed asynchronous electric motors for the undercarriage of mine self-propelled cars // E3S Web of Conferences 384. 2023. PP, 01044, 1-5. https://doi.org/10.1051/e3sconf/202338401044.