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TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
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Mathematical model for studying the danger zone of train approach on sections of the roads of JSC "Uzbekistan Railways"

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Abstract: The safety of train traffic depends on the reliable operation of intermediate train control systems, the basis of which is the rail circuits as a sensor of information about the location of trains. Currently, the railway networks of many countries of the world are switching to continuous rail circuits of the tonal type with potential receivers, but with all their advantages, these rail circuits have disadvantages, which are that when a train approaches the rail circuit at a certain distance, it begins to short-circuit it and the prohibitory light turns on when the traffic light passes, that is, such rail circuits have additional short-circuit zones when the train approaches and leaves the rail circuit. To eliminate this drawback, it was proposed to use current receivers that accurately record the entry of the train into the controlled rail circuit. However, in such track circuits, a situation may arise where there may be two trains at the relay end of the track circuit, then the first train may not short-circuit the receiver and the track circuit will appear falsely empty. In this article, a mathematical model has been developed and studies have been conducted for different frequencies of the tonal track circuit to determine the critical zone of convergence of two trains at the relay end of the track circuit. A solution scheme for this problem is also proposed, which completely eliminates the above-mentioned effect.

Keywords: potential path receiver, current path receiver, standard shunt sensitivity criterion, critical zone of sensitivity

AJ “O‘zbekiston temir yo‘llari” yo‘llarning uchastkalarida poyezdlar yaqinlashishning xavfli zonasini tadqiqotning matematik modeli

Aliev R.M.[1][a], Aliev M.M.[1][b], Talipova G.D.[1][c], Yuldasheva M.M.[1]

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Annotatsiya: Poyezdlar harakati xavfsizligi poyezdlar harakatini oraliq nazorat qilish tizimlarining ishonchli ishlashiga bog‘liq bo‘lib, ularning asosi poyezdlarning joylashuvi haqidagi ma’lumot datchik sifatida rels zanjirlar hisoblanadi. Hozirgi vaqtda dunyoning ko'plab davlatlarining temir yo'l tarmog'i potentsial qabul qiluvchilar bilan tonal tipidagi uzluksiz rels zanjirlariga o'tmoqda, ammo ularning ko'pgina afzalliklari bilan bu rels zanjirlarining kamchiliklari bor, ular ma'lum masofada poezdning rels zajiriga yaqinlashganda, uni qisqa tutashuvi boshlaydi va svetoforning o'tishida taqiqlovchi chiroq yonadi, ya'ni, bunday rels zanjirlar poezd yaqinlashganda va rels zanjirdan chiqib ketganda qo'shimcha qisqa tutashuvi zonalarga ega. Ushbu kamchilikni bartaraf etish uchun poezdning boshqariladigan rels zanjiriga kirishini aniq qayd etadigan tok qabul qiluvchilardan foydalanish taklif qilindi. Ammo bunday yo'l zanjirlarida shunday vaziyat yuzaga kelishi mumkinki, rels zanjirining rele uchida ikkita poyezd bo'lishi mumkin, keyin birinchi poezd qabul qilgichni qisqa tutashuv qilmasligi mumkin va rels zanjir noto'g'ri bo'sh ko'rinadi. Ushbu maqolada rels zanjirining rele uchida ikkita poezd yaqinlashishning kritik zonasini aniqlash uchun tonal rels zanjirning turli chastotalari uchun matematik model ishlab chiqilgan va tadqiqotlar olib borilgan. Ushbu muammoni hal qilish sxemasi ham taklif etiladi, bu yuqorida aytib o'tilgan ta'sirni butunlay yo'q qiladi.

Kalit so‘zlar: potentsial yo'l qabul qiluvchisi, oqim yo'l qabul qiluvchisi, standart shuntga sezgirlik mezoni, sezgirlikning tanqidiy zonasi

1. Kirish

Hozirgi vaqtda temir yo'l tarmog'ida potentsial qabul qiluvchilar bilan izolyatsiyalovchi birikmalarsiz ohangli rels zanjirlari keng qo'llaniladi [1-5]. Biroq, bunday sxemalarda izolyatsion bo'g'inlar yo'qligi sababli, poyezd rels zanjirga yaqinlashganda ham, undan chiqib ketganda ham, rels zanjirning aniq chegarasi yo'q [6-8].

Ushbu kamchilikni bartaraf etish uchun oqim qabul qilgichlari bilan tonalli rels zanjirdan foydalanish taklif etiladi, bu poezd rels zanjiriga yaqinlashganda ularning qisqa tutashuvini va svetoforning bloklanishini butunlay yo'q qiladi [9-11].

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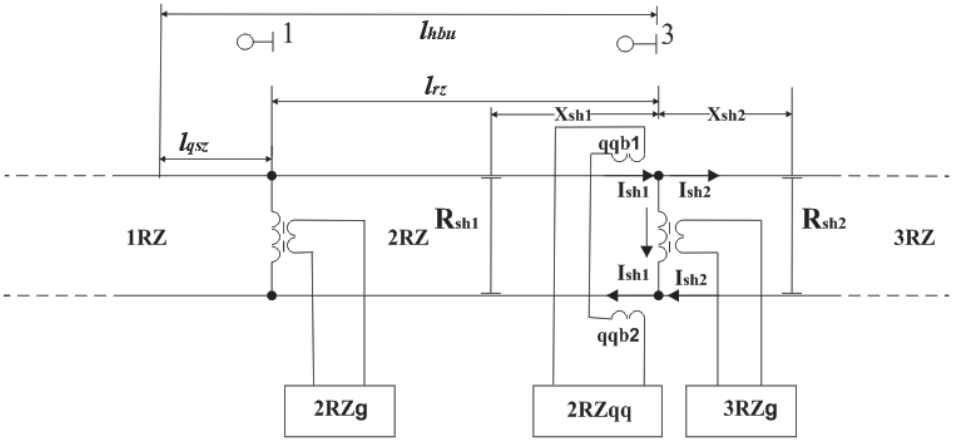
Shu bilan birga, tok yo'l qabul qilgich bilan izolyatsiyalash bo'g'inlari bo'lmagan boshqaruv datchiklarining shunt ta'siri ikkinchi poyezdning ishg'ol qilingan uchastkaga yaqinlashishiga ta'sir qiladi (1-rasm).



1 – rasm. Tok qabul qilgich yaqinida ikkita poezd borligida tok qabul qilgich bilan boshqaruv datchik sxemasi

Ushbu rasmda quyidagilar ko'rsatilgan:

1RZ,2RZ,3RZ - temir yo'l liniyasi blok uchastkalarining mos ravishda 1,2 va 3-rels zanjirlari.

Maqolada asosan ikkinchi 2RZ rels zanjir ko'rib chiqiladi, u quyidagilardan iborat:

2RZq - rels zanjirining signal tokning chastota generatori;

2RZqq - signal tokni qabul qiluvchi;

qqb_1 va qqb_2 signal tokni qabul qiluvchi bobinalar;

3RZq - uchinchi rels zanjirining signal tokning chastota generatori;

Rsh_1 - birinchi poezd shunti;

Rsh_2 - ikkinchi poezdning shunti.

Bunday vaziyatda birinchi poyezdning shunt ta'siri tok yo‘l qabul qilgichdan birinchi poyezdning xsh1 va ikkinchi poyezdning xsh2 masofasining qisqarishi, birinchi poyezdning shunt qarshiligining oshishi va ikkinchi poyezdning shunt qarshiligining kamayishi bilan kamayadi.

Ikki poezd tok yo'l qabul qilgich yaqinida joylashganida, boshqaruv datcikning shunt sezgirligi deyarli nolga teng bo'ladi.

Bunday holda, boshqaruv datchikning bandligini nazorat qilish yo'qoladi va poezdning dumi yo'l signalining qizil chirog'i bilan himoyalanmaydi, bu poezdlarning harakati uchun xavflidir. Shunday qilib, tok yo'l qabul qilgich bilan boshqaruv datchikning shunt rejimining eng yomon shartlari Rsh2 = 0 qarshiligi bilan qo'shni uchastkaning oxirida ikkinchi poezd shuntining mavjudligini o'z ichiga oladi.

Qabul qiluvchi yo'l bobinlarining xsh1 ulanish nuqtasidagi nazorat datchikning bo'limi, ikkinchi poezd ushbu bobinlarga yaqinlashganda (xsh2 = 0 va Rsh2 = 0) standart shunt sezgirligi ta'minlanmaydi, xavfli zona yoki standart shuntga befarqlik zonasi Lznsh deyiladi.

Maqolada ushbu kamchilikni rels zanjirining rele uchida – tok va potentsial qabul qiluvchilar bilan ikkita qabul qiluvchidan foydalanish orqali bartaraf etadigan usul taklif etiladi va poezd shuntiga befarqlikning tanqidiy zonasi uchun usullar taqdim etiladi.

2. Tadqiqot metodologiyasi

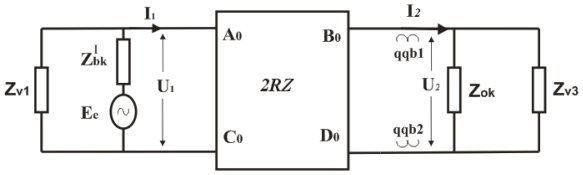
Befarqlik zonasining uzunligini hisoblash sezuvchanlik mezonining tok qabul qilgich bilan uzluksiz rels zanjirining standart shuntiga tenglamasi bilan aniqlanishi mumkin:

$$K_{nsh} = \frac{Z_{sha}}{NZ_{ath}} \geq 1, \quad (1)$$

bu erda

- Z_{sha} - qo'llaniladigan shunt bilan shunt sezgirligini aniqlash uchun qabul qilingan rels zanjir xususiyatlariga ega uzatish qarshiligi;
- Z_{ath} - poezd bo'lmaganda, rels zanjirining uzatish qarshiligi;
- $N = \frac{K_3 U_{max}}{K_B U_{min}}$ - apparat koeffitsienti;

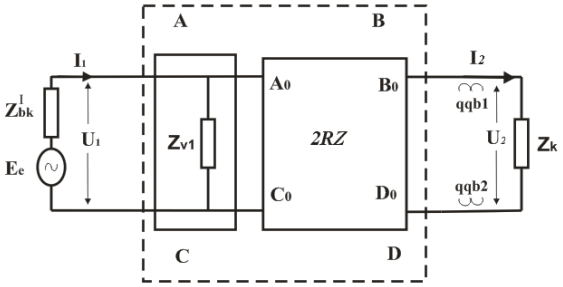
Z_{ath} tok qabul qilgichi bilan uzluksiz rels zanjirining uzatish qarshiligi 2-rasmdagi ekvivalent sxema yordamida rels zanjirida harakatlanuvchi birliklar bo'lmaganda aniqlanadi:



2 – rasm. Uzluksiz rels zanjirning harakatlanuvchi birlik bo'lmaganda o'zgartiruvchi sxemasi

Ushbu ekvivalent sxemada qo'shni rels zanjirlari 1RZ va 3RZ to'lqin qarshiliklari Zv1 va Zv3 sifatida ifodalanadi.

Me’yotiy rejimda uzatish Z_{ath} ning qarshiligini aniqlash uchun 2-rasmdagi sxemani quyidagicha ifodalaymiz: 3-rasm.



3 – rasm. O'zgartiruvchi sxemasi

Qayerda

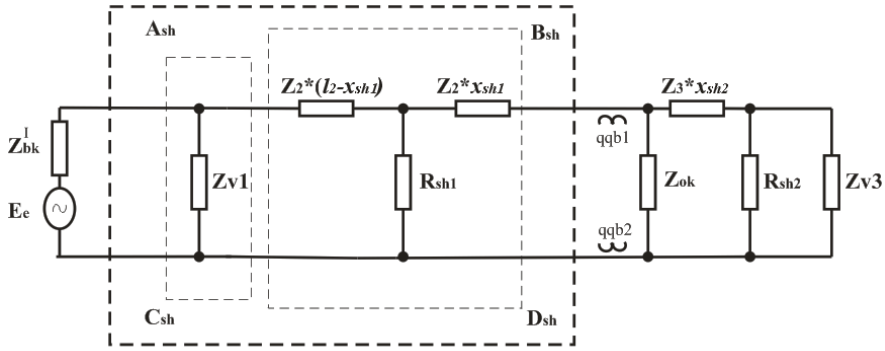
$Z_k = \frac{Z_{ok} * Z_{v3}}{Z_{ok} + Z_{v3}}$

$A_0 = ch\gamma_2 l_2;\ B_0 = Z_{v2} sh\gamma_2 l_2;\ C_0 = \frac{1}{Z_{v2}} sh\gamma_2 l_2;\ D_0 = ch\gamma_2 l_2.$

$$Z_{ath} = Z_k * A + B + Z_{bk}^l (Z_k * C + D); \quad (2)$$

$$Z_{ath} = Z_k * ch\gamma_2 l_2 + Z_{v2} sh\gamma_2 l_2 + Z_{bk}^l (Z_k * \left(\frac{ch\gamma_2 l_2}{Z_{v1}} + \frac{1}{Z_{v2}} sh\gamma_2 l_2\right) + \rightarrow$$
$$\rightarrow + \frac{Z_{v2} sh\gamma_2 l_2}{Z_{v1}} + ch\gamma_2 l_2), \quad (3)$$

Qo'yilgan shunt bilan shunt sezgirligini aniqlash uchun qabul qilingan rels zanjirning xarakteristikalari bo'lgan tok qabul qilgichli rels zanjirining uzatish qarshiligini quyidagi ekvivalent sxema yordamida aniqlash mumkin, 4-rasm.



4 – rasm. O'tish qarshiligining o'zgartiruvchi sxemasi

Qayerda

$$Z_{sha} = \left(Z_3 x_{sh2} + \frac{Z_{v3} * R_{sh2}}{Z_{v3} + R_{sh2}}\right) A_{sh} + B_{sh} + Z_{bk}^l * \rightarrow$$
$$\rightarrow \left(\left(Z_3 x_{sh2} + \frac{Z_{v3} * R_{sh2}}{Z_{v3} + R_{sh2}}\right) C_{sh} + D_{sh}\right). \quad (4)$$

$$\begin{vmatrix} A_{sh} & B_{sh} \\ C_{sh} & D_{sh} \end{vmatrix} = \begin{vmatrix} 1 & 0 \\ \frac{1}{Z_{v1}} & 1 \end{vmatrix} *$$
$$\begin{vmatrix} 1 + \frac{Z_2 * (l_2 - x_{sh1})}{R_{sh1}} & Z_2 l_2 + \frac{Z_2^2 (l_2 - x_{sh1}) * x_{sh1}}{R_{sh1}} \\ \frac{1}{R_{sh1}} & 1 + \frac{Z_2 x_{sh2}}{R_{sh1}} \end{vmatrix} \quad (5)$$

$$A_{sh} = 1 + \frac{Z_2 * (l_2 - x_{sh1})}{R_{sh1}}; \quad B_{sh} = Z_2 l_2 + \frac{Z_2^2 (l_2 - x_{sh1}) * x_{sh1}}{R_{sh1}}; \quad (6)$$

$$C_{sh} = \frac{1}{Z_{v1}} * \left(1 + \frac{Z_2 * (l_2 - x_{sh1})}{R_{sh1}}\right) + \frac{1}{R_{sh1}}; \quad (7)$$

$$D_{sh} = \frac{1}{Z_{v1}} * \left(Z_2 l_2 + \frac{Z_2^2 (l_2 - x_{sh1}) * x_{sh1}}{R_{sh1}}\right) + 1 + \frac{Z_2 x_{sh1}}{R_{sh1}}. \quad (8)$$

Ikki poyezdning kritik yaqinlashuv zonasi uchun eng yomon shartlar ikkinchi poyezd yo‘l zanjirining qabul qilish uchida $x_{sh2}=0$ va $R_{sh2}=0$ bo‘lsa, (3) tenglamani quyidagicha ifodalash mumkin:

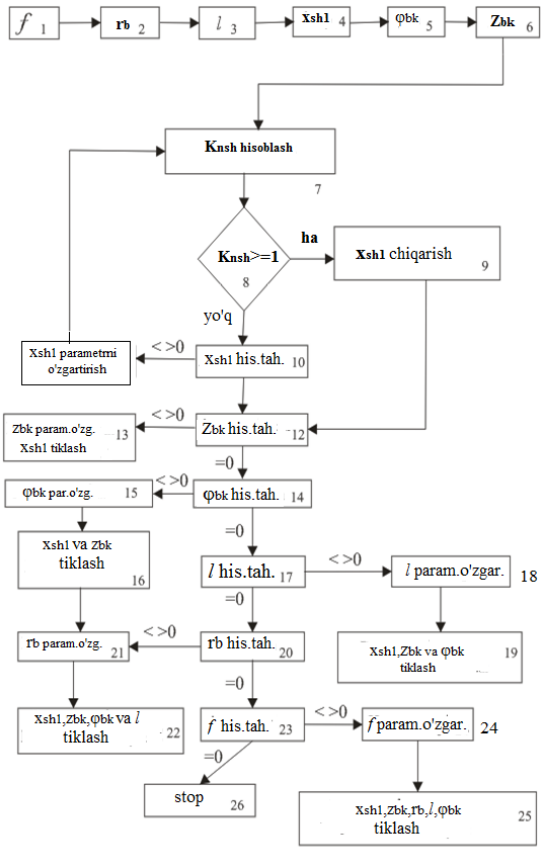
$$Z_{sha} = Z_2 l_2 + \frac{Z_2^2 (l_2 - x_{sh1}) * x_{sh1}}{R_{sh1}} + Z_{bk}^l * \left(1 + \frac{Z_2 x_{sh1}}{R_{sh1}}\right). \quad (9)$$

Ushbu o'zgarishlarni hisobga olgan holda, tok yo'l qabul qiluvchisi bilan uzluksiz yo'l zanjirining standart shuntiga sezgirlik mezoni quyidagi shaklga ega bo'ladi:

$$K_{nsh} = \frac{Z_2 l_2 + \frac{Z_2^2 (l_2 - x_{sh1}) * x_{sh1}}{R_{sh1}} + Z_{bk}^l * \left(1 + \frac{Z_2 x_{sh1}}{R_{sh1}}\right)}{N(Z_k * ch\gamma_2 l_2 + Z_{v2} sh\gamma_2 l_2 + Z_{bk}^l \left(Z_k * \left(\frac{ch\gamma_2 l_2}{Z_{v1}} + \frac{1}{Z_{v2}} sh\gamma_2 l_2\right) + \frac{Z_{v2} sh\gamma_2 l_2}{Z_{v1}} + ch\gamma_2 l_2\right))} \geq 1 \quad (10)$$

Yuqoridagi tenglamalar asosida ikkita poyezdning yaqinlashishning kritik zonasini aniqlash algoritmi va dasturi ishlab chiqildi (4-rasm) va hisoblangan grafiklari 5 - 6-rasmda ko'rsatilgan.

Ikki poezdning tok yo'l qabul qilgichi bo'ylab yaqinlashishning kritik zonasini hisoblash signal oqimi chastotalarining turli qiymatlari, balastning o'ziga xos qarshiligi, modullar va boshqaruv datchiklarining uchlaridagi qarshilik argumentlari uchun amalga oshirildi. Nazorat datchukning ikkita poyezdining kritik yaqinlashuv zonasi uzunligining optimal qiymatlarini izlash (9) tenglama yordamida normal va shunt ish rejimlarini ta'minlash sharti bilan amalga oshiriladi. Ikki poyezdning yaqinlashish kritik zonasining uzunligini aniqlashda kompyuterga quyidagi dastlabki ma'lumotlar kiritiladi: signal chastotalari f, nazorat datchik uchlaridagi Z_{bk} qarshilik moduli va argumenti, ri, l ning barcha mumkin bo'lgan qiymatlari.



5 – rasm. Danchik ishining blok-sxemasi

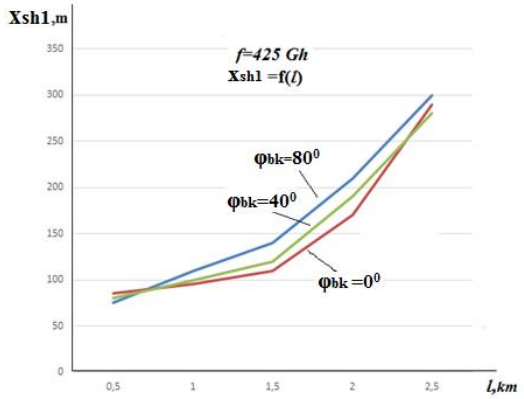
Optimal qiymatni izlash jarayonida 1÷6 operatorlari kontaktlarni hosil qiladi va ularni K_{shntd} standart shuntiga sezgirlik mezonini topishni va bu mezonni $K_{nsh} \geq 1$ ifodasi bo'yicha nazorat datchikining shuntlash bilan solishtirishni tashkil qilish uchun ularni sikl hisoblagichlariga yuboradi.

Agar sezgirlik mezoni bittadan kichik bo'lsa, u holda l_{dzshu} parametri bo'yicha sikl hisoblagichi tarkibini bittaga, x_{sh1} parametrini esa qadamining qiymatiga o'zgartiradigan 10÷11 operatorlariga o'tkaziladi. Agar sezgirlik mezoni birga teng yoki undan katta bo'lsa, boshqaruv l_{dzshu}

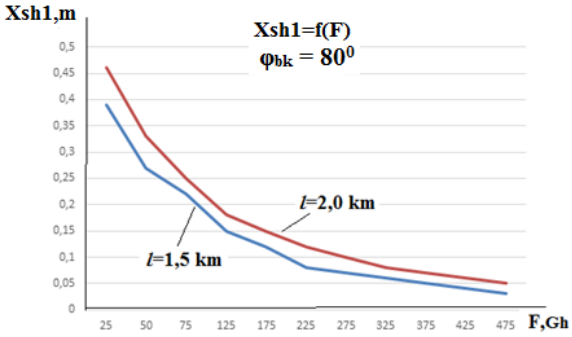
qiymatlarini chop etadi va boshqaruvni variantlarning blok diagrammasini ifodalovchi 12 ÷ 25 ga o'tkazadigan 9-operatorga o'tkaziladi. Ularning har biri ma'lum bir parametr uchun tsikl hisoblagichining tarkibini bittaga o'zgartiradi, uni nolga tahlil qiladi va agar tsikl hisoblagichining tarkibi nolga teng bo'lmasa, bu parametrni qadamining qiymatiga o'zgartiradi va keyingi parametrlarning dastlabki ma'lumotlarini tiklash uchun boshqaruvni uzatadi. Agar hisoblagichlarning tarkibi nolga teng bo'lsa, u holda boshqaruv keyingi parametr bo'yicha tsiklni tashkil qiluvchi operatorlarga o'tkaziladi. Barcha kombinatsiyalarni sinab ko'rgandan so'ng, kompyuter tugatish belgisini chop etadi va to'xtaydi.

3. Natijalar va muhokama

Yuqoridagi algoritmga muvofiq, poyezdlar yaqinlashining kritik zonasi uchun rels zanjirning qabul qiluvchi uchida dastur ishlab chiqildi va hisob-kitoblar amalga oshirildi. Hisoblash natijalari 6-7-rasmlarda keltirilgan.



6 – rasm. Signal tok chastotasi 425 Gts bo'lgan poezdlarning tok yo'l qabul qilgichga yaqinlashish kritik masofasining bog'liqligi grafiklari, Z_{bk}=0,2 ohm zanjirning uchlaridagi kirish qarshilik modullari va ularning φ_{bk} argumentlari.



7 – rasm. Signal tok chastotasi 425 Gts bo'lgan poezdlarning tok yo'l qabul qilgichga yaqinlashish kritik masofasining bog'liqligi grafiklari, zanjirning uchlaridagi kirish qarshilik modullari Z^{I}bk va Zok=0,2 ohm va argumentlar $\varphi_{bk} = 80^0$.

4. Xulosa

6-7-rasmda keltirilgan hisob-kitoblarni tahlil qilishdan shunday xulosaga kelish mumkinki, yaqinlashib kelayotgan poyezdlarning kritik masofalari keng miqyosda o‘zgarishi va ko‘pgina parametrlarga bog‘liq bo‘lishi, shuningdek, poyezdlarning tormozlanish masofasidan sezilarli darajada kichik masofaga ega bo‘lishi, bu esa favqulodda vaziyatlarga olib kelishi mumkin. Bu rels zanjirning aniq chegarasini belgilash va svetoforlarni o'rnatishni qiyinlashtiradi. Ushbu kamchilikni bartaraf etish uchun intervalli boshqaruv tizimlarida poezdlar harakati xavfsizligini ta'minlaydigan texnik echimni ishlab chiqish kerak

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