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O'ZGARMAS TOK ZANJIRLARIDA ELEKTR TOK QONUNLARINING TIBBIY QURILMALARDA AMALIY TALQINI

Annotatsiya. *Biotibbiyot qurilmalarining ko'p qismi (ECG/EEG/EMG, rezistiv datchiklar, portativ monitorlar) elektr zanjir sifatida modellashtiriladi. Maqolada o'zgarmas tok zanjirlarining tayanchi bo'lgan Ohm qonuni va Kirchhoffning tok/kuchlanish qonunlari tibbiy qurilmalarda qanday amaliy vazifani bajarishi adabiyotlar sharhi hamda uchta tipik DC-model (bemor kirish himoyasi, Wheatstone ko'prigi datchigi, batareya manbai-yuklama) asosida ko'rsatiladi. Hisoblashlar ushbu qonunlar bemor xavfsizligi (tokni cheklash), signal aniqligi (tugun/kontur balansi), va quvvat yo'qotishlarini (I^2R) baholashga bevosita xizmat qilishini yoritadi.*

Kalit so'zlar: *o'zgarmas tok; Ohm qonuni; Kirchhoff qonunlari; ekvivalent zanjir; biotibbiyot asboblari; xavfsizlik; quvvat balansi.*

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PRACTICAL INTERPRETATION OF ELECTRICAL CURRENT LAWS IN MEDICAL DEVICES FOR DIRECT-CURRENT CIRCUITS

Abstract. *A large proportion of biomedical devices (ECG/EEG/EMG systems, resistive sensors, portable monitors) can be modeled as electrical circuits. This article demonstrates how Ohm's law and Kirchhoff's current/voltage laws—the fundamental principles of direct-current (DC) circuits—serve practical*

functions in medical devices, based on a literature review and three typical DC models (patient input protection, a Wheatstone-bridge sensor, and a battery source–load system). The calculations highlight that these laws directly support patient safety (current limiting), signal accuracy (node/loop balance), and the assessment of power losses (I²R).

Keywords: *direct current; Ohm's law; Kirchhoff's laws; equivalent circuit; biomedical instruments; safety; power balance.*

1. Kirish

Biotibbiyot muhandisligida datchikdan tortib analog front-end va quvvat ta'minotigacha bo'lgan har bir bosqich elektr elementlar majmuasidir. Shu bois qurilmani ekvivalent zanjir ko'rinishida tavsiflash va DC tahlil qilish dizaynning eng tez va ishonchli tekshiruvlaridan biridir [1-4]. Ayniqsa, biopotensial o'lchovlarda bemor tanasi elektrodlar orqali zanjirning bir qismiga aylanadi; shuning uchun kichik oqimlarni cheklash va izolyatsiya talablariga amal qilish muhimdir [5,6].

Maqolaning maqsadi - Ohm (V=IR) hamda Kirchhoff (KCL/KVL) qonunlarini tibbiy qurilmalarda uchraydigan uchta holat orqali amaliy talqin qilish: (i) biopotensial kirishda himoya va oqim cheklash, (ii) rezistiv ko'prik datchigi interfeysi, (iii) portativ qurilmada manba-yuklama va quvvat yo'qotishlari.

2. Metodlar

Ish adabiyotlar sharhi va analitik modellashtirishga tayandi: biotibbiyot asbobsozligi bo'yicha manbalar [1,2], elektr zanjirlar nazariyasi darsliklari [3,4], hamda tibbiy elektr xavfsizligi standartlari [5,6] asosida tipik sxemalar soddalashtirilib DC ekvivalent modellar tuzildi.

Har bir modelda tok va kuchlanishlar Ohm qonuni bilan, tugun va kontur balanslari esa Kirchhoff qonunlari bilan yozildi. Quvvat bahosi $P=VI=I^2R=V^2/R$ orqali elementlar bo'yicha yo'qotishlar hisoblandi va dizayn mazmuni (xavfsizlik, aniqlik, samaradorlik) bilan bog'landi.

3. Natijalar

3.1. Biopotensial kirishda tokni cheklash (bemor himoyasi).

ECG/EEG kirishlarida ketma-ket cheklovchi rezistorlar (R_{lim}) va izolyatsiya zanjirlari bemor tomonga oqishi mumkin bo'lgan tokni V/R munosabatiga ko'ra kamaytiradi [1,5]. Ilustrativ misol: nosozlikda elektrod liniyasida 5 V paydo bo'lib, R_{lim}=1,0 MΩ bo'lsa, $I \approx 5/1,0 \cdot 10^6$=5 µA. Bu yondashuv standartlarda ko'zda tutilgan xavfsizlik talablariga mos dizayn tanlashga yordam beradi (aniq limitlar qurilma sinfi va rejimiga bog'liq) [5,6].

3.2. Rezistiv datchik ko'prigida (Wheatstone bridge) tugun balansini talqin qilish.

Rezistiv datchiklar ko'pincha Wheatstone ko'prigida ulanadi; muvozanatda chiqish $V_{out} \approx 0$ bo'ladi [2]. $R_1=R_2=R_3=R_4$=350 Ω, V_s=5 V bo'lsa, har tarmoq toki $I_{arm}=V_s/(R_1+R_2)$=5/700≈7,14 mA. Agar R_1 kichik ΔR ga o'zgarsa, KCL va KVL tugun kuchlanishlarining tengligi buzilishini ko'rsatadi va Vout differensial signal sifatida paydo bo'ladi. Amalda bu signal instrumental kuchaytirgich bilan kuchaytirilib, ADC ga uzatiladi [1,2,7].

3.3. Portativ qurilmada manba-yuklama: ichki qarshilik va quvvat yo'qotishi.

Batareya ichki qarshiligi r_{int} bo'lgani uchun yuklama toki ortganda chiqish kuchlanishi KVL bo'yicha pasayadi, yo'qotish esa I^2R bilan baholanadi [3]. Misol: U_0=3,7 V, r_{int}=0,15 Ω, I=0,50 A. U_{load}=3,7-0,50·0,15=3,625 V; P_{loss}=0,50^2·0,15=0,0375 W; $P_{load} \approx$3,625·0,50=1,8125 W. Impulsli yuklamalar (simsiz uzatish, motor/nasos) bu effektni kuchaytirishi mumkin, shuning uchun quvvat zanjiri tahlili analog front-end barqarorligi bilan bevosita bog'liq [7,8].

4. Muhokama

Ko'rilgan misollar Ohm va Kirchhoff qonunlari biotibbiyot dizaynida quyidagi amaliy qarorlarni asoslashini ko'rsatadi:

• Xavfsizlik: R_lim va izolyatsiya elementlari orqali tokni yuqori bahoda cheklash (V/R) va xavfli holatlarda oqim yo'lini nazorat qilish [5,6].

• Aniqlik: elektrod ofsetlari va impedans nomutanosibligi tugun/kontur balansini buzib differensial xatoga aylanishi; DRL, lead-off va front-end yechimlari zanjir modeli bilan loyihalanadi [7-10].

• Samaradorlik: ichki qarshilik va kontaktlardagi I^2R yo'qotishlar batareya ishlash vaqti, harorat va o'lchov barqarorligiga ta'sir qiladi [1,3].

5. Xulosa (Conclusion)

Ohm va Kirchhoff qonunlari tibbiy qurilmalarda bemor xavfsizligini ta'minlash, kichik signallarni ishonchli olish va quvvat yo'qotishlarini baholash uchun asosiy analitik poydevordir. DC tahlil dizaynning dastlabki bosqichida tezkor tekshiruv bo'lib, keyingi AC/noise va standart talablariga mos chuqur modellashtirish uchun yo'l ochadi.

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