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QUYOSH QURILMALARI MONITORINGIDA AXBOROT OLISH TIZIMINING DISKRETLASH CHASTOTASI VA ATsO‘ RAZRYADLIGINI ASOSLASH

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Annotatsiya. Tezida quyosh qurilmalari monitoring tizimining Pt100 harorat kanali uchun diskretlash chastotasi va analog-raqamli o‘zgartirgich (ATsO‘) razryadligini tanlash metodikasi taklif etilgan. Datchikning inersion xarakteristikasi asosida spektr ustma-ustligi xatosini 40 dB gacha bostirish uchun 4 Hz diskretlash yetarli ekani ko‘rsatilgan. 16 razryadli kuchaytirgichli ATsO‘ 0,006 K harorat ajrata olishini ta‘minlashi asoslangan.

Kalit so‘zlar: diskretlash chastotasi, ATsO‘, kvantlash, Pt100, o‘rtachalash, quyosh qurilmalari monitoringi.

Kirish

Quyosh qurilmalari monitoring tizimlarida ma‘lumot yozish oralig‘i va o‘lchash kanallari aniqligi xalqaro standartlar bilan me‘yorlanadi [1, 2]. Fotoelektrik stansiyalar monitoringi bo‘yicha sharhda datchiklar, ma‘lumot yig‘uvchi qurilmalar va ularning parametrlarini tanlash monitoring sifatining asosiy omili sifatida ko‘rsatilgan [3]. Arzon harorat o‘lchash tizimlarida ATsO‘ va diskretlash parametrlari ko‘pincha mavjud mikrokontroller imkoniyatlaridan kelib chiqib, metrologik asoslashsiz tanlanadi [4, 5].

Diskretlash chastotasi past tanlansa, signal spektrining yuqori chastotali tashkil etuvchilari past chastotalarga o‘tib, spektr ustma-ustligi (aliasing) xatosini keltirib chiqaradi [6, 7]. Diskretlash chastotasi haddan tashqari yuqori tanlansa, ma‘lumotlar hajmi, aloqa kanaliga yuklama va energiya iste‘moli asossiz ortadi [3, 8]. ATsO‘ razryadligi yetarli bo‘lmasa, kvantlash xatosi datchikning o‘z aniqligidan ham katta bo‘lib qolishi mumkin [12, 13].

Tezisning maqsadi Pt100 asosidagi harorat kanali uchun diskretlash chastotasi va ATsO‘ razryadligini miqdoriy asoslash metodikasini ishlab chiqishdan iborat [2, 9, 11].

Usullar

Gilzaga o‘rnatilgan harorat datchigi birinchi tartibli inersion bo‘g‘in sifatida qaraladi va uning amplituda-chastota xarakteristikasi quyidagicha yoziladi [9]:

$$|H(f)| = \frac{1}{\sqrt{1 + (f/f_c)^2}}, \quad f_c = \frac{1}{2\pi \tau_s}, \quad (1)$$

bu yerda $|H(f)|$ – datchik amplituda-chastota xarakteristikasining moduli; f – signal chastotasi, Hz; f_c – datchikning kesish chastotasi, Hz; $\tau_s = 8$ s – gilzadagi datchikning vaqt doimiysi [9, 10].

Talab etilgan so‘nish darajasiga erishiladigan chastota (1) dan topiladi, diskretlash chastotasi esa Kotelnikov–Nykvist–Shannon sharti bo‘yicha tanlanadi [6, 7]:

$$f_{\max} = f_c \sqrt{10^{L/10} - 1}, \quad f_s \geq 2f_{\max}, \quad (2)$$

bu yerda $f_{\max}$ – so‘nish L qiymatga yetadigan chastota, Hz; L – talab etilgan so‘nish darajasi, dB; f_s – diskretlash chastotasi, Hz [7, 8].

Kvantlash qadamining harorat ekvivalenti va kvantlash shovqini kanal sezgirliqi orqali aniqlanadi [12, 13]:

$$\Delta T_q = \frac{U_{\text{ref}}}{G_{\text{PGA}} 2^N I_0 R_0 \alpha}, \quad \sigma_{T,q} = \frac{\Delta T_q}{\sqrt{12}}, \quad (3)$$

bu yerda ΔT_q – bitta kvantlash qadamiga mos harorat, K; U_{ref} – ATsO‘ tayanch kuchlanishi, V; G_{PGA} – dasturlanuvchi kuchaytirgich koefitsiyenti; N – ATsO‘ razryadlar soni; $I_0 = 1$ mA – qo‘zg‘atuvchi tok; $R_0 = 100 \Omega$ – datchikning 0 °C dagi nominal qarshiligi; $\alpha = 0,00385 \text{ K}^{-1}$ – qarshilikning o‘rtacha harorat koefitsiyenti; $\sigma_{T,q}$ – kvantlash shovqinining harorat ekvivalenti, K [11, 13].

Real ATsO‘ning amaliy aniqligi nominal razryadlar soni bilan emas, balki samarali razryadlar soni bilan baholanadi [12]:

$$\text{ENOB} = \frac{\text{SINAD} - 1,76}{6,02}, \quad (4)$$

bu yerda ENOB – samarali razryadlar soni, bit; SINAD – signalning shovqin va buzilishlar yig‘indisiga nisbati, dB [12, 13].

Ortiqcha diskretlash va keyingi o‘rtachalashda tasodifiy shovqin quyidagicha kamayadi [8, 13]:

$$\sigma_N = \frac{\sigma}{\sqrt{N_a}}, \quad \Delta \text{SNR} = 10 \lg N_a, \quad (5)$$

bu yerda σ_N – o‘rtachalangan qiymat shovqinining o‘rtacha kvadratik og‘ishi, K; $\sigma = 0,10 \text{ K}$ – bitta o‘lchov shovqinining o‘rtacha kvadratik og‘ishi; N_a – o‘rtachalangan namunalar soni; ΔSNR – signal/shovqin nisbatining ortishi, dB [8, 13].

Bir sutkada hosil bo‘ladigan xom ma’lumotlar hajmi quyidagicha baholanadi [3, 16]:

$$V = n_{\text{ch}} b f_s t_d, \quad (6)$$

bu yerda V – sutkalik ma’lumotlar hajmi, bayt; $n_{\text{ch}} = 4$ – o‘lchash kanallari soni; $b = 4$ – bitta qiymatning hajmi (32 bitli suzuvchi nuqtali son), bayt; f_s – diskretlash chastotasi, Hz; $t_d = 86\,400 \text{ s}$ – sutka davomiyligi [3, 16].

Natijalar

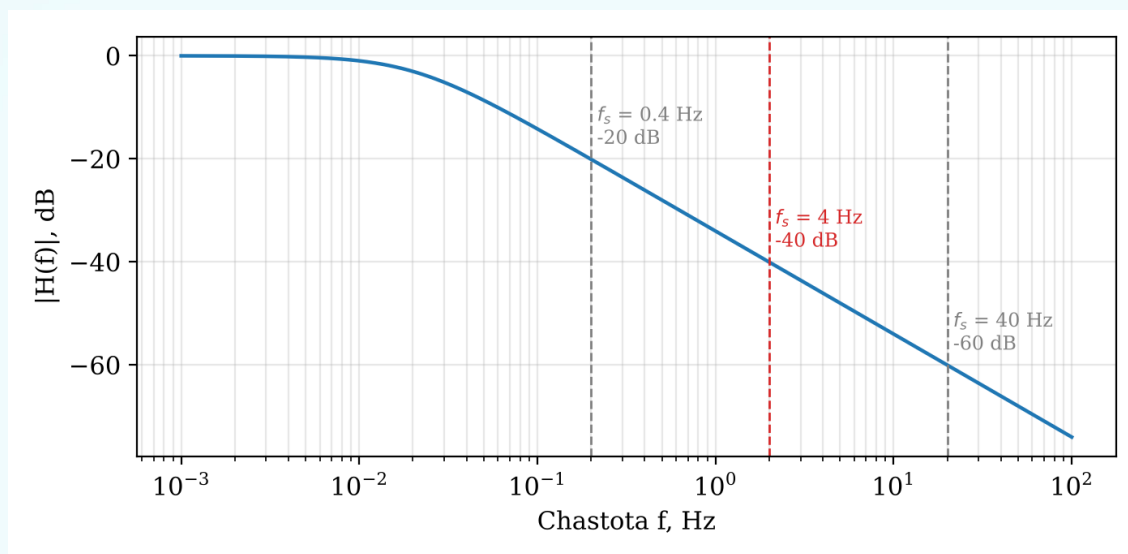
$\tau_s = 8 \text{ s}$ bo‘lganda (1) formula bo‘yicha datchikning kesish chastotasi $f_c = 0,020 \text{ Hz}$ ni tashkil etadi [9]. So‘nish 20, 40 va 60 dB bo‘lishi uchun (2) formula bo‘yicha minimal diskretlash chastotasi mos ravishda 0,40, 3,98 va 39,8 Hz ga teng bo‘ladi [7]. Turli diskretlash chastotalarida Naykvist chastotasidagi so‘nish va ma’lumotlar hajmi 1-jadvalda keltirilgan [6, 7].

1-jadval. Diskretlash chastotasining so‘nish va ma’lumotlar hajmiga ta’siri

$f_s, \text{ Hz}$	$f_s/2$ dagi so‘nish, dB	Sutkalik hajm, MB
0,4	-20	0,55

f_s , Hz	$f_s/2$ dagi so'nish, dB	Sutkalik hajm, MB
1	-28	1,38
4	-40	5,53
10	-48	13,82
40	-60	55,30

Datchikning amplituda-chastota xarakteristikasi va tanlangan diskretlash chastotalariga mos Naykvist chegaralari 1-rasmda ko'rsatilgan [8, 9].



1-rasm. Pt100 datchigining amplituda-chastota xarakteristikasi va Naykvist chastotalari Kanal sezgirligi $S = I_0 R_0 \alpha = 0,385 \text{ mV/K}$ bo'lganda turli ATsO' konfiguratsiyalari uchun (3) formula natijalari 2-jadvalda keltirilgan [11, 12].

2-jadval. ATsO' konfiguratsiyasining harorat ajrata olishiga ta'siri

ATsO' konfiguratsiyasi	q , μV	ΔT_q , K	$\sigma_{T,q}$, K
12 bit, $U_{\text{ref}} = 3,3 \text{ V}$, $G_{\text{PGA}} = 1$	805,7	2,093	0,604
16 bit, $U_{\text{ref}} = 2,5 \text{ V}$, $G_{\text{PGA}} = 1$	38,1	0,099	0,029
16 bit, $U_{\text{ref}} = 2,5 \text{ V}$, $G_{\text{PGA}} = 16$	2,38	0,0062	0,0018
24 bit, $U_{\text{ref}} = 2,5 \text{ V}$, $G_{\text{PGA}} = 16$	0,0093	0,00002	0,000007

Mikrokontrollarning ichki 12 razryadli ATsO'si Pt100 bilan bevosita ishlatilganda 2 K dan katta kvantlash qadamini beradi [12]. Bu qiymat A sinf datchikning 60 °C dagi $\pm 0,27 \text{ °C}$ ruxsat chegarasidan qariyb 8 marta katta [11]. 16 razryadli ATsO' va $G_{\text{PGA}} = 16$ kombinatsiyasi kvantlash shovqinini datchik shovqinidan ikki tartibga kichik qiladi [12, 13].

24 razryadli sigma-delta ATsO'larning nominal ajrata olishi juda yuqori bo'lsa-da, ularning amaliy aniqligi samarali razryadlar soni bilan cheklanadi [12]. (4) formula bo'yicha SINAD 86, 98 va 110 dB bo'lganda ENOB mos ravishda 14,0, 16,0 va 18,0 bitni tashkil etadi [12, 13]. Demak, 24 razryadli ATsO' tanlanganda ham hisob-kitoblarda 16–18 samarali razryad qabul qilinishi maqsadga muvofiq [13].

(5) formula bo'yicha 4 Hz chastotada olingan namunalarni 1 s davomida o'rtachalash ($N_a = 4$) shovqinni 0,10 K dan 0,05 K gacha kamaytiradi va signal/shovqin nisbatini 6 dB ga oshiradi [8, 13]. $N_a = 40$ bo'lganda bu qiymatlar mos ravishda 0,016 K va 16 dB ni tashkil etadi [8]. Bunda serverga yoziladigan ma'lumotlar hajmi 1 s yozish oralig'ida sutkasiga 1,38 MB ni tashkil etib, IoT aloqa kanallari uchun maqbul darajada qoladi [5, 16].

Muhokama

Olingan natijalar shuni ko'rsatadiki, harorat kanalida spektr ustma-ustligining asosiy cheklovchi omili datchikning issiqlik inersiyasi hisoblanadi [9, 10]. Shu sababli harorat kanallari uchun alohida analog antialiasing filtri talab etilmaydi, chunki datchikning o'zi past chastotali filtr vazifasini bajaradi [8, 9]. Biroq elektr tarmog'idan keladigan 50 Hz xalaqitni bostirish uchun sigma-delta ATsO'ning raqamli filtridan foydalanish tavsiya etiladi [10, 13].

Piranometr kanalida signal dinamikasi tezroq bo'lib, bulut o'tishlarida nurlanish bir necha soniya ichida keskin o'zgaradi [14, 15]. ISO 9060 tasnifida piranometrlarning javob vaqti alohida me'yorlangan parametr sifatida keltirilgan va u diskretlash chastotasini tanlashda hisobga olinishi kerak [14]. IEC 61724-1 standartida ham yuqori aniqlik sinfidagi monitoring tizimlari uchun qisqa diskretlash oralig'i va keyingi o'rtachalash talab etilgan [1].

Taklif etilgan «4 Hz diskretlash + 1 s o'rtachalash» strategiyasi ortiqcha diskretlashning shovqinni kamaytirish afzalligini ma'lumotlar hajmining maqbulligi bilan birlashtiradi [1, 8]. Arduino asosidagi IoT monitoring tizimida ham shunga o'xshash lokal o'rtachalash va serverga kamroq chastotada uzatish yondashuvi qo'llanilgan [5]. Arzon harorat o'lchash tizimlari bo'yicha tadqiqot ham ATsO' va signal sharhlash sxemasining to'g'ri tanlanishi umumiy aniqlikni belgilashini ko'rsatgan [4].

Xulosa

1. Gilzadagi Pt100 datchigi uchun ($\tau_s = 8$ s) 40 dB so'nishni ta'minlovchi minimal diskretlash chastotasi 4 Hz ni tashkil etadi [7, 9].
2. Pt100 kanali uchun kamida 16 razryadli, dasturlanuvchi kuchaytirgichli ATsO' tanlash zarur, chunki mikrokontrollerning ichki 12 razryadli ATsO'si 2 K dan katta qadam beradi [11, 12].
3. 4 Hz diskretlash va 1 s o'rtachalash shovqinni ikki barobar kamaytiradi hamda sutkalik ma'lumotlar hajmini 1,38 MB darajasida saqlaydi [1, 8].
4. Taklif etilgan metodika quyosh qurilmalari monitoring tizimlarini loyihalashda o'lchash kanallari parametrlarini metrologik asoslash uchun qo'llanilishi mumkin [2, 3].

Adabiyotlar

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