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CONFERENCE ON INTERNATIONAL SCIENTIFIC DEVELOPMENTS: INSIGHTS INTO MODERN SCIENCE AND INNOVATIVE PRACTICES

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PAST INERSIYALI ENERGIYA TIZIMLARIDA GIBRID SHAMOL-QUYOSH ELEKTR STANSIYALARINING CHASTOTA BARQARORLIGIGA TA’SIRINI BAHOLASH

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Qayta tiklanuvchi energiya manbalarining elektr energiyasi ishlab chiqarishdagi ulushi ortishi energiya tizimlarining dinamik xususiyatlarini o‘zgartiradi. An’anaviy elektr stansiyalaridagi sinxron generatorlarning aylanuvchi massalari kinetik energiya hisobiga quvvat muvozanati buzilganda chastotaning keskin o‘zgarishini sekinlashtiradi. Invertor orqali ulanadigan shamol va quyosh stansiyalarida bunday tabiiy inersiya javobi odatda bevosita mavjud emas. Shu sababli ular sinxron generatsiyani almashtirgan sharoitda tizimning umumiy inersiyasi kamayishi mumkin. Past inersiyada chastota dinamikasi tezlashadi va rostlash tizimlariga qo‘yiladigan talablar oshadi [1].

Gibrid shamol-quyosh stansiyalarida ikki energiya manbasini birlashtirish ishlab chiqarishning vaqt bo‘yicha o‘zgaruvchanligini ayrim sharoitlarda kamaytirishi mumkin. Biroq ishlab chiqarishning tekislanishi chastota barqarorligini avtomatik ravishda ta’minlamaydi. Buning uchun stansiyaning quvvat zaxirasi, invertor imkoniyatlari va chastota o‘zgarishiga javob berish tezligini alohida baholash zarur.

Tadqiqotning maqsadi — gibrid shamol-quyosh elektr stansiyalarining past inersiyali tizim chastotasiga ta’sirini baholash mezonlarini aniqlash va chastotani qo‘llab-quvvatlash imkoniyatlarini nazariy asoslash.

Chastota dinamikasining matematik modeli Tizim chastotasining dastlabki o‘zgarishini baholashda quyidagi soddalashtirilgan modeldan foydalanish mumkin:

$$\frac{2H_{eq}S_b}{f_0}\frac{d\Delta f}{dt} = \Delta P_g - \Delta P_L + \Delta P_{hyb} - D_f\Delta f$$

Bu yerda H_{eq} - tizimning bazaviy quvvatga keltirilgan ekvivalent inersiya doimiysi, s; S_b - bazaviy quvvat, MW; f₀ — nominal chastota, Hz; Δf = f − f₀ — chastota og‘ishi, Hz; ΔP_g - an’anaviy generatsiya quvvatining o‘zgarishi, MW; ΔP_L- yuklama quvvatining o‘zgarishi, MW; ΔP_{hyb} - gibrid stansiyaning qo‘shimcha boshqariladigan quvvati, MW; D_f - yuklamaning chastotaga bog‘liq so‘nish koeffitsiyenti, MW/Hz.

Model tizim chastotasini yagona umumlashtirilgan qiymat sifatida ifodalaydi. U dastlabki baholash uchun qulay, ammo tarmoqning hududiy tebranishlari va invertorlarning barcha ichki dinamikasini qamrab olmaydi.

Gibrid stansiyaning umumiy faol quvvati:

$$P_{\text{hyb}} = P_{\text{w}} + P_{\text{pv}} + P_{\text{es}}$$

Bunda P_{w}-shamol, P_{pv}-quyosh generatsiyasi quvvati; P_{es} esa energiya saqlash qurilmasining quvvati bo‘lib, razryad vaqtida musbat, zaryad vaqtida manfiy qiymat oladi. Saqlash qurilmasi mavjud bo‘lmasa, P_{es} = 0.

Chastotani qo‘llab quvvatlash usullari Chastota pasayganda gibrid stansiya faol quvvatni oshirish orqali quvvat tanqisligini kamaytirishi mumkin. Quyosh stansiyasining yuqoriga rostlash imkoniyati oldindan ajratilgan quvvat zaxirasi yoki energiya saqlash qurilmasiga bog‘liq. Maksimal mavjud quvvatda ishlayotgan quyosh stansiyasi zaxirasiz uzoq muddatli qo‘shimcha quvvat bera olmaydi. Maxsus boshqariladigan quyosh stansiyalarining birlamchi chastota rostlashda qatnashishi amaliy sinovlarda namoyish etilgan [2].

Nazariy boshqaruv qonuni quyidagicha yozilishi mumkin:

$$\Delta P_{hyb} = -K_f\Delta f - K_r\frac{d\Delta f}{dt}$$

Bu yerda K_f chastota ogʻishiga javob beruvchi koeffitsiyent, $K_r$esa chastota oʻzgarish tezligiga javob beruvchi koeffitsiyentdir. Birinchi had chastota pasayganda qoʻshimcha quvvat talab qiladi; ikkinchi had virtual inersiya javobini ifodalaydi.

Amalda ushbu talab mavjud quvvat va energiya zaxirasi bilan cheklanadi. Shuningdek, chastotani oʻlchashdagi kechikish, signalni filtrlash, invertor toki va shamol turbinasining aylanish tezligi chegaralari hisobga olinishi kerak.

Baholash mezonlari Gibrid stansiyaning chastota barqarorligiga ta’sirini quyidagi mezonlar orqali baholash taklif etiladi:

Mezon	Baholash mazmuni
Chastotaning oʻzgarish tezligi RoCoF	Buzilishdan keyin chastota qanchalik tez oʻzgarishini koʻrsatadi
Minimal chastota f_{min}	Quvvat tanqisligida chastotaning eng past qiymatini bildiradi
Tiklanish vaqti	Chastotaning belgilangan diapazonga qaytish vaqtini koʻrsatadi
Qoldiq chastota ogʻishi	Oʻtkinchi jarayondan keyingi chastota farqini ifodalaydi
Qoʻshimcha quvvat va energiya sarfi	Chastotani qoʻllab-quvvatlash uchun zarur resurslarni aniqlaydi

Taqqoslash bir xil yuklama, quvvat buzilishi va boshlangʻich ish rejimida oʻtkazilishi lozim. Bunda chastota rostlashsiz gibrid stansiya, quvvat zaxirasiga ega stansiya va energiya saqlash bilan jihozlangan stansiya rejimlarini solishtirish mumkin.

Natija va tahlil -Quyidagi natijalar shartli parametrlar asosidagi analitik hisoblash bo‘lib, real stansiya tajribasi yoki kompyuter simulyatsiyasi natijasi hisoblanmaydi. Nominal chastota f_0 = 50 Hz, bazaviy quvvat $\boldsymbol{S_b}$= 1000 MW va to‘satdan yuzaga kelgan quvvat tanqisligi 100 MW deb olinadi. Buzilishning dastlabki lahzasida rostlash javobi va yuklamaning chastotaga bog‘liq ta’siri e’tiborga olinmasa:

$$\frac{df}{dt} = -\frac{f_0 \cdot 100}{2H_{eq}S_b}$$

Hisoblash natijalari quyidagicha:

Ko‘rsatkich	1-holat	2-holat
Ekvivalent inersiya doimiysi, s	5	2
Quvvat tanqisligi, MW	100	100
Dastlabki df/dt, Hz/s	−0,50	−1,25

Natijadan ko‘rinadiki, bir xil quvvat tanqisligida inersiya doimiysining 5 sekunddan 2 sekundga kamayishi chastotaning dastlabki pasayish tezligi modulini 2,5 baravar oshiradi. Bu rostlash qurilmalarining tezkor javob berishiga bo‘lgan ehtiyojni kuchaytiradi.

Ikkinchi holatda gibrid stansiya 40 MW qo‘shimcha quvvat berganidan keyin qolgan tanqislik 60 MW bo‘ladi. Boshqa ta’sirlar hisobga olinmagan shu soddalashtirilgan modelda:

$$\frac{df}{dt} = -\frac{50 \cdot 60}{2 \cdot 2 \cdot 1000} = -0{,}75\ Hz/s$$

Demak, qo‘shimcha quvvat to‘liq berilgan paytdagi pasayish tezligi moduli 1,25 Hz/s dan 0,75 Hz/s gacha, ya’ni 40 foizga kamayadi. Agar boshqaruv javobi kechiksa, bu yordam buzilishning dastlabki lahzasidagi RoCoF qiymatini o‘zgartirmaydi.

Mazkur hisoblashdan minimal chastota va tiklanish vaqtini bevosita aniqlab bo‘lmaydi. Ularni baholash uchun generator rostlagichlari, invertor javobi, yuklama xususiyatlari va energiya zaxirasini qamrab oluvchi dinamik model zarur.

Nazariy tahlil shuni ko‘rsatadiki, gibrid stansiyaning chastotaga ta’siri faqat uning o‘rnatilgan quvvatiga bog‘liq emas. Sinxron generatsiyaning qancha qismi almashtirilgani, faol quvvat zaxirasi, boshqaruv kechikishi va qo‘shimcha quvvatni berish davomiyligi ham hal qiluvchi ahamiyatga ega.

Xulosa

Past inersiyali energiya tizimlarida quvvat muvozanatining buzilishi chastotaning tez o‘zgarishiga olib keladi. Gibrid shamol-quyosh elektr stansiyalarining chastota barqarorligiga ta’sirini baholashda inersiya kamayishi va stansiyaning boshqariladigan quvvat bilan yordam berish imkoniyatlarini birgalikda hisobga olish zarur.

Quvvat zaxirasi, energiya saqlash qurilmasi va muvofiqlashtirilgan boshqaruv mavjud bo‘lganda gibrid stansiya chastota pasayishini sekinlashtirish imkoniyatiga ega. Keyingi tadqiqotlarda ushbu imkoniyatni turli generatsiya ulushlari va buzilish ssenariylari uchun dinamik modellashtirish orqali tekshirish maqsadga muvofiq.

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