Frequency Stabilization Measures For the Expansion of Renewable Energy in Korea

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Power System Planning Department

Yong-gu Ha

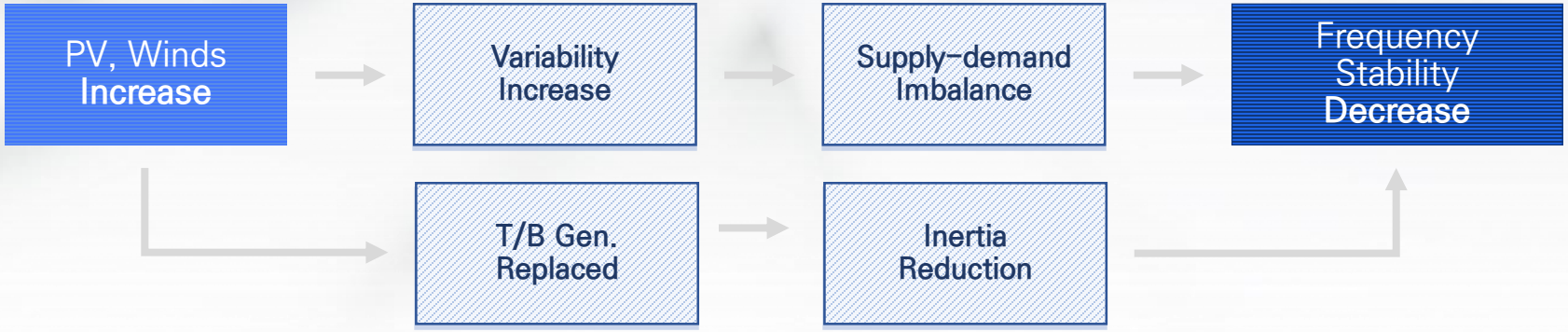
Global Energy & Solution Leader

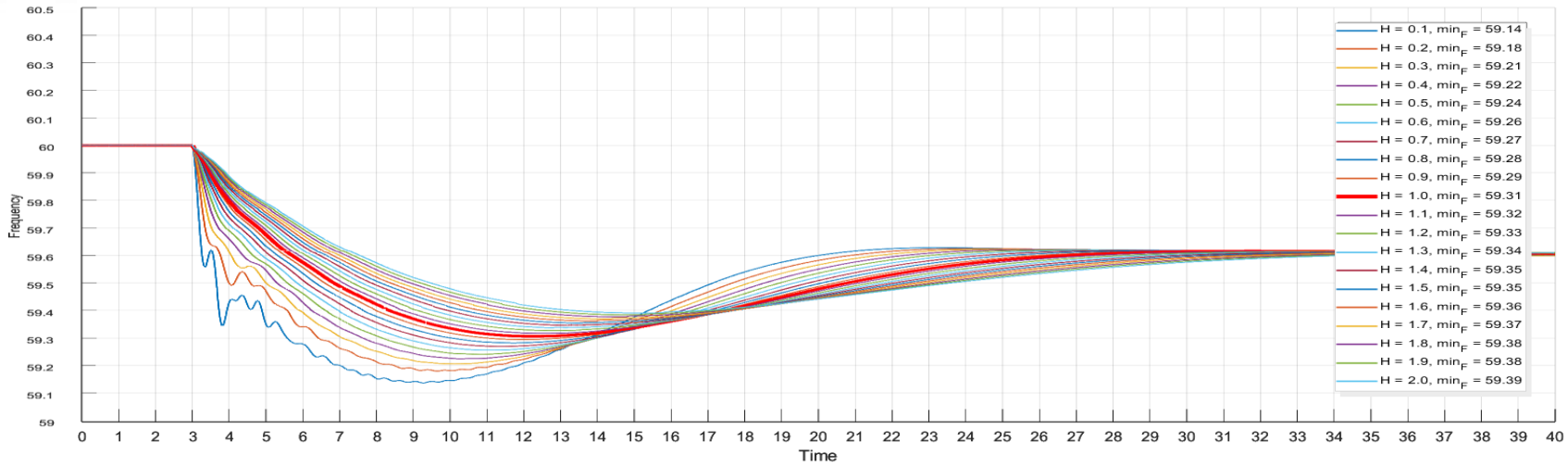
Contents

Frequency Stability with RE

Challenges of future power system

- The frequency stability decreases as the renewable energy increases.





Frequency Stability with RE

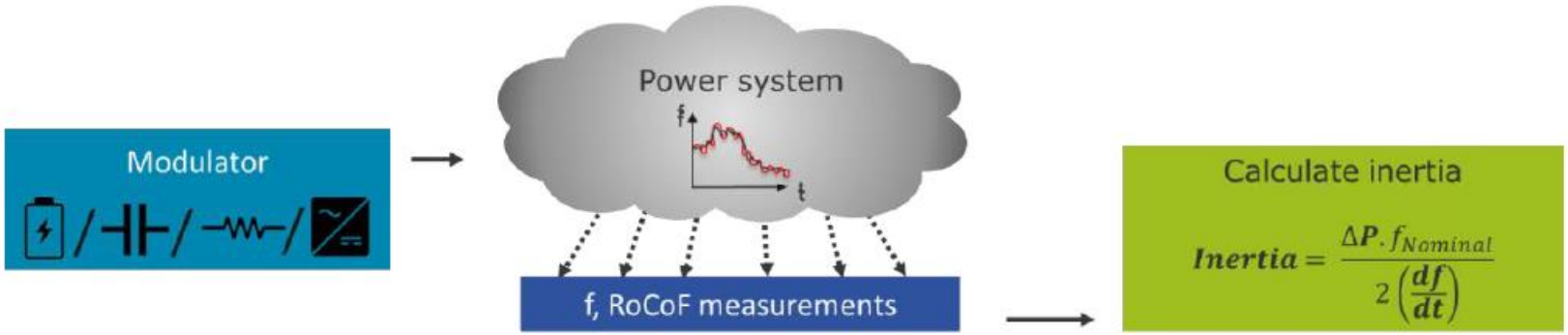
- Preparing a plan in terms of facility, policy and system to stabilize the frequency

Facility(ESS for FS)

Policy(Load Shedding)

System(Monitoring)

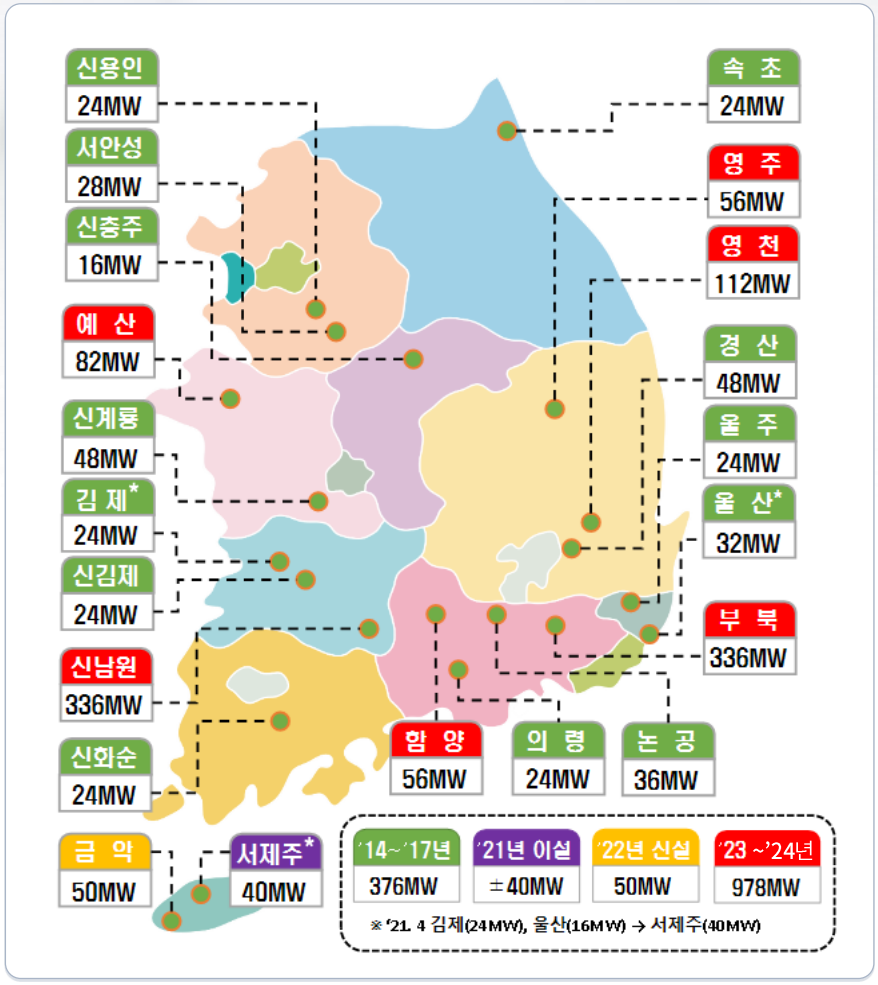
Frequency Stability



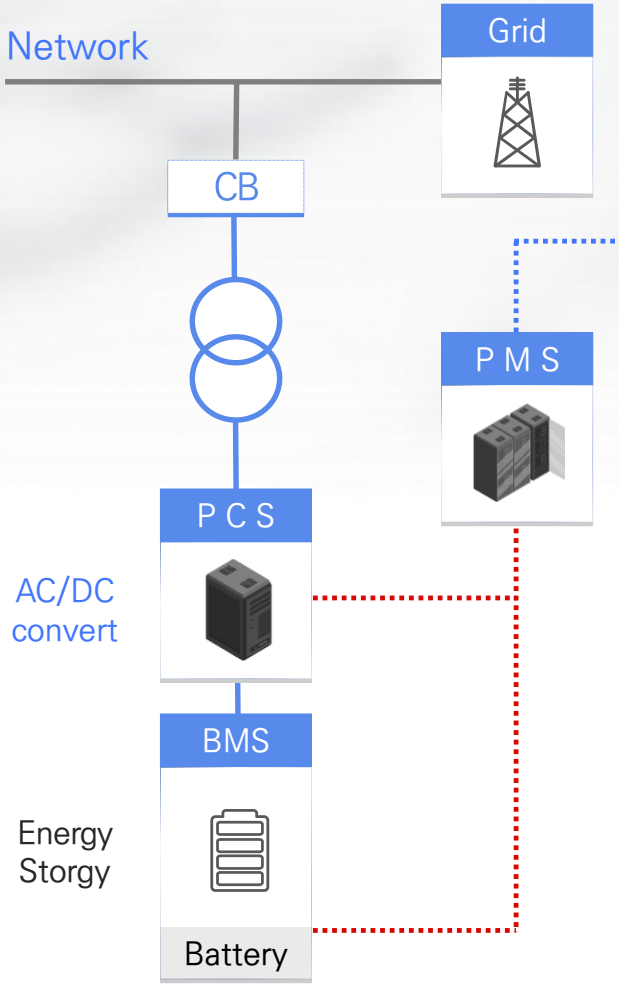
Facility Reinforcement – ESS for FS

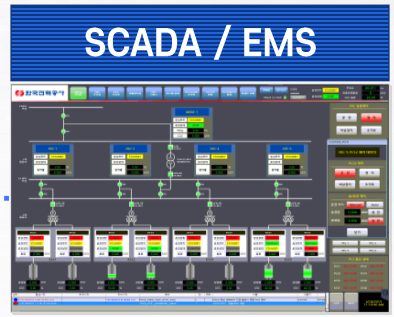
Status of ESS for FS

Year	Capacity (MW)	Substation (No.)
2014	52	2
2015	184	7
2016	140	4
2022	50	1
'23~'24	978	6
Total	1,404	20



The configuration of ESS





PMS (Power Management System)

The Part of managing ESS including PCS and BMS

PCS (Power Conditioning System)

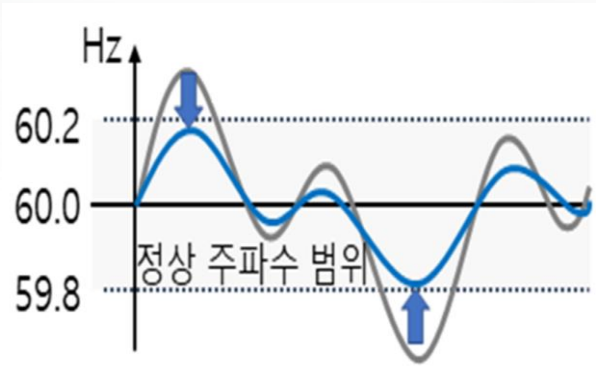
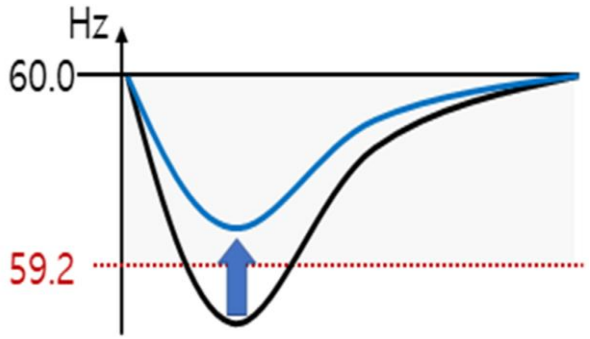
The Part that charges or discharges power to the battery by converting DC to AC according to the PMS command

BMS (Battery Management System)

Battery monitoring, protection, control, etc.

01 ESS for Frequency Stability

ESS Classification

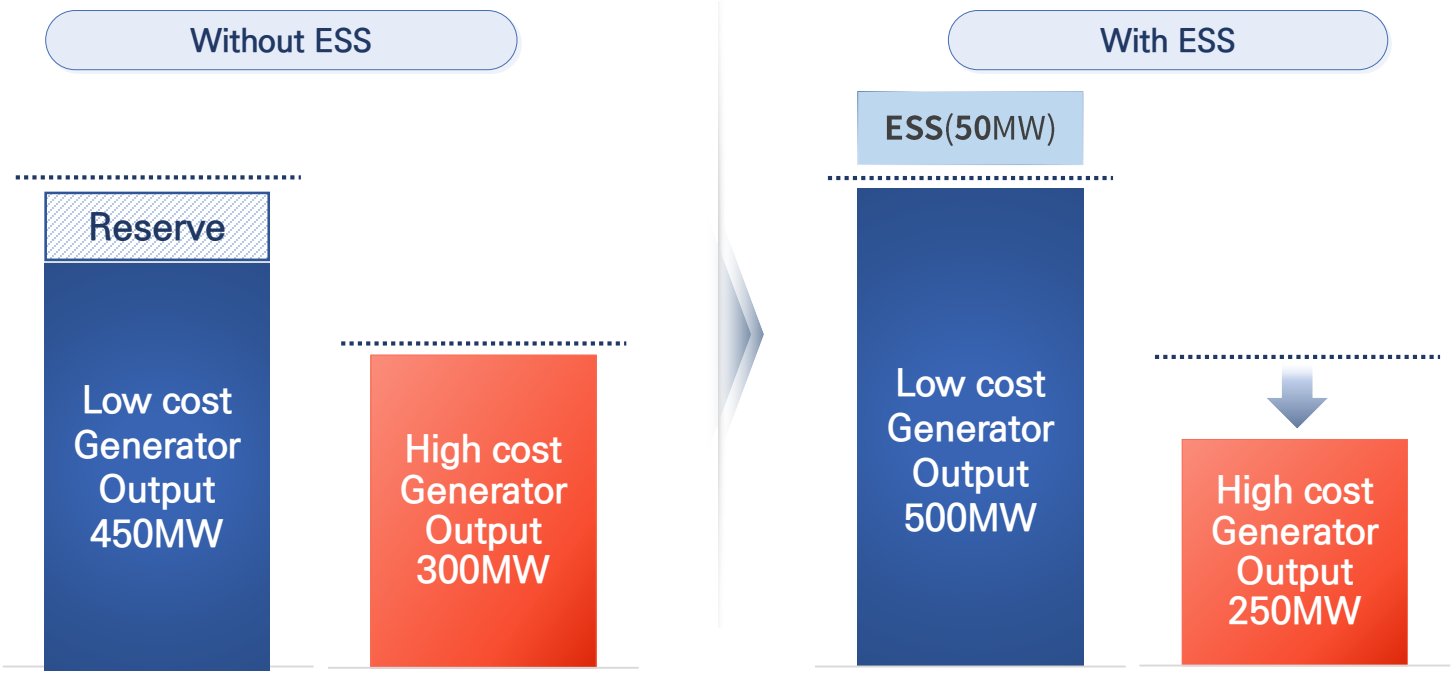
① Frequency Regulation – ESS		② Frequency Stability – ESS
Regulate 60±0.2Hz in steady state	**Purpose**	Maintain above 59.2Hz in contingency
	**Outline**	
Adjust supply and demand through charging and discharging	**Operation**	Full discharge output at 59.7Hz or less

① FR-ESS(Frequency Regulation-ESS)

Replace G/F portion of generators by controlling ESS

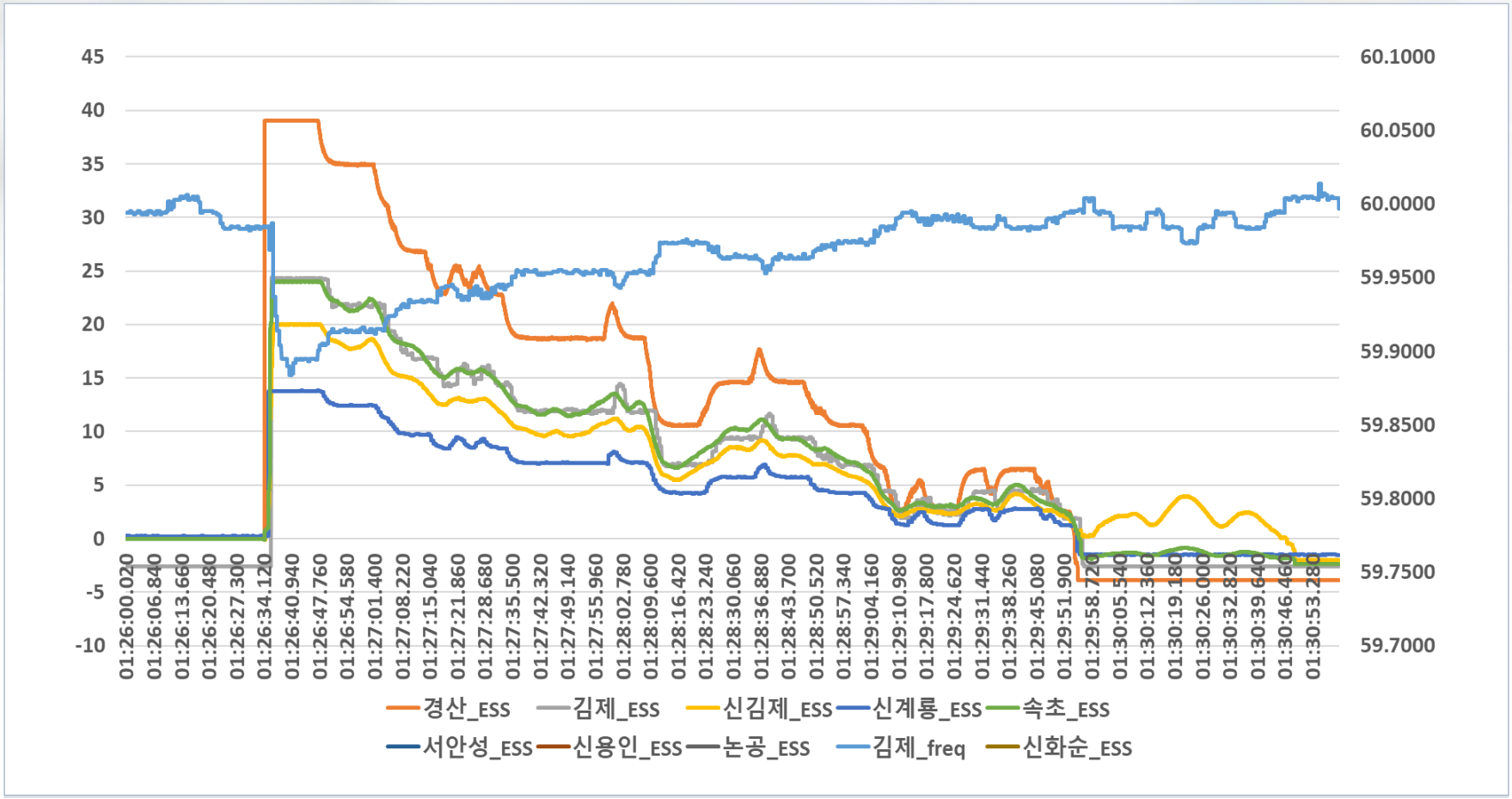
Substitution for G/F reserve of low cost generators

✓ Example : Economic Dispatch with ESS

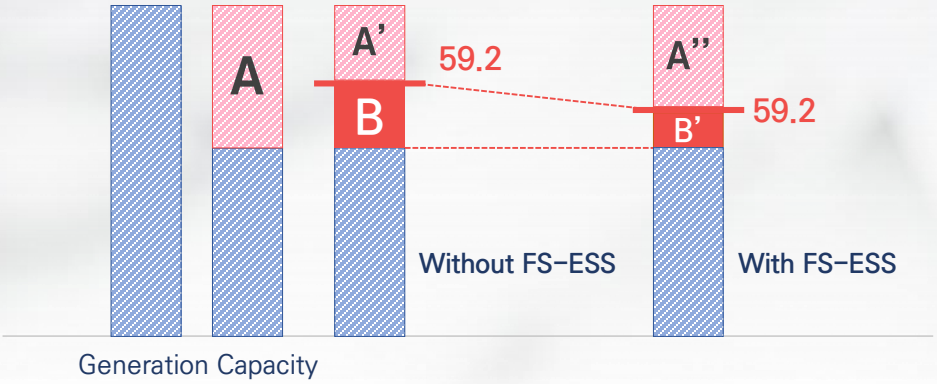


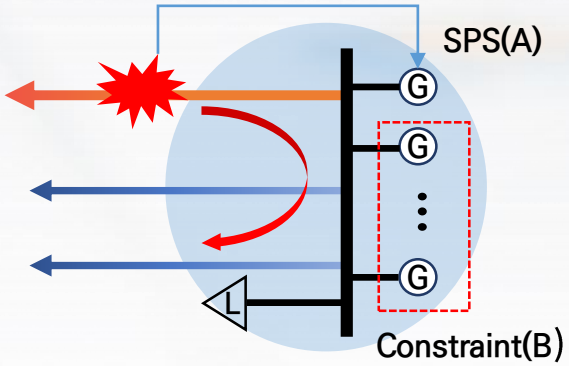
FR-ESS Performance

ESS Performance in Korea



② FS-ESS(Frequency Stability-ESS)





A	Generator capacity tripped for transient stability in contingency
A'	Generator capacity tripped for transient and frequency stability in contingency
B	Congestion for frequency stability in contingency
A"	Generator capacity tripped for transient and frequency stability in contingency with FS-ESS
B'	Congestion for frequency stability in contingency with FS-ESS

- ✓ Utilize fast response of ESS → Increase effective inertia
- ✓ Control of ESS(Discharge) in case of generator trips → Minimize frequency drop
- ✓ Keep the frequency above 59.2Hz → Prevent wide-scale power outage by UFR(59Hz)
- ✓ Improve the lowest point of frequency by using fast responsive characteristics of ESS

Policy Introduction – Participatory Load Shedding

New Policy

- Participatory Load Shedding is to automatically and urgently cut off customer loads contracted with KEPCO in case of frequency drop due to power system failure.

Customer

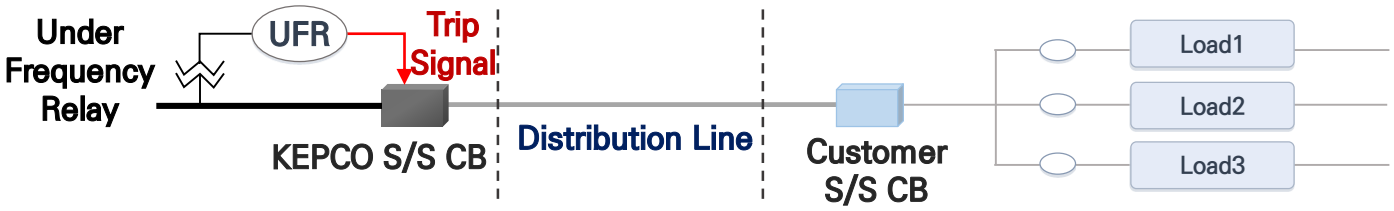
- Large-capacity customers who wish to participate using dedicated lines of 22.9kV or higher

Process

1. Generators Trip	2. Frequency ↓	3. CB Trip	4. Load Shedding
Generator stop due to grid failure	Under 59.55Hz	Customer's CB Trip by UFR	Cut off customer loads Contracted with KEPCO

8. Pay Back	7. Check Load	6. Power re-supply	5. Recovery
Pay back (within 1month)	Before and after load comparison	Resumption of load supply	Upper 59.8Hz

System

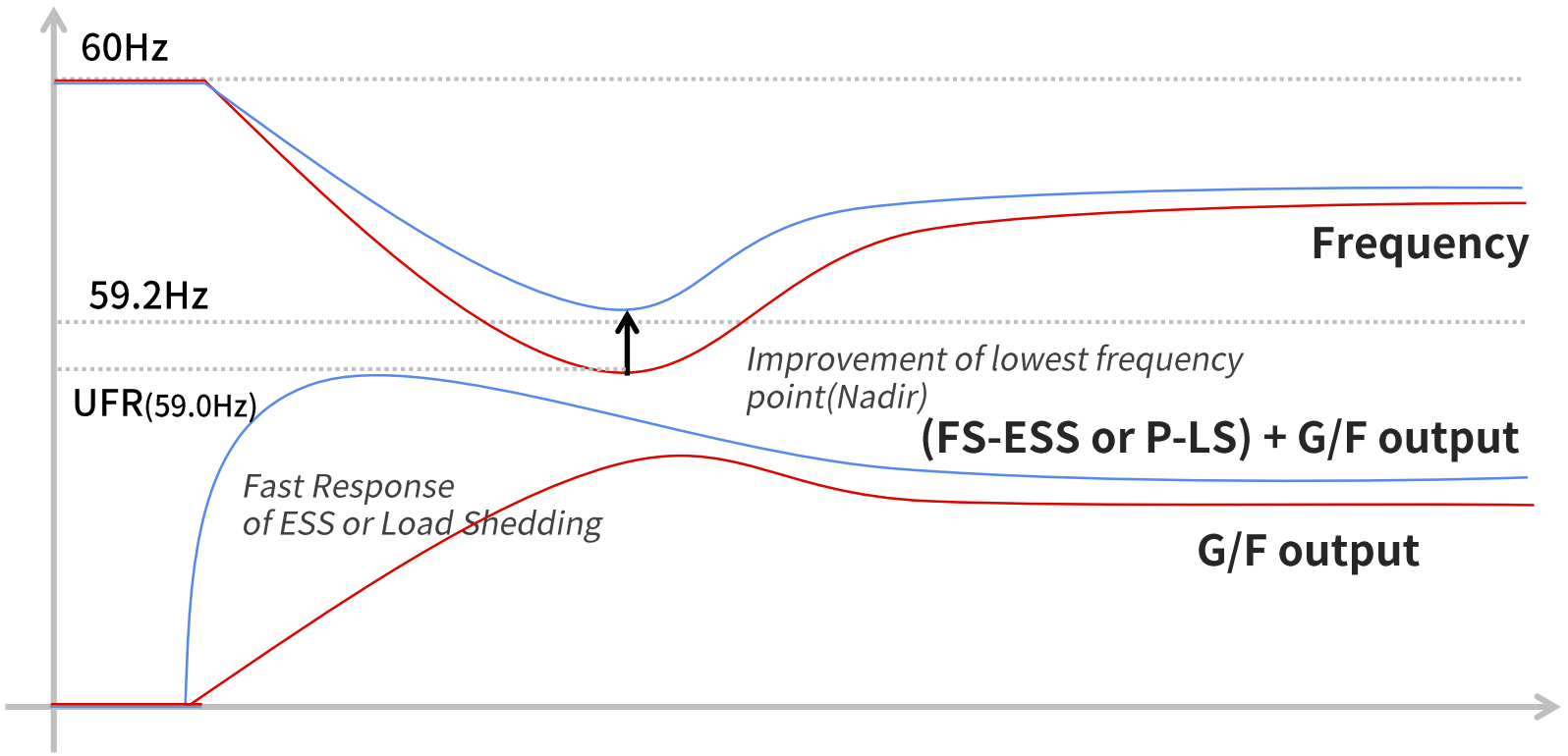


Participatory Load Shedding

- KEPCO received The Management Grand Award in 2024.

FS-ESS and Participatory Load Shedding Performance

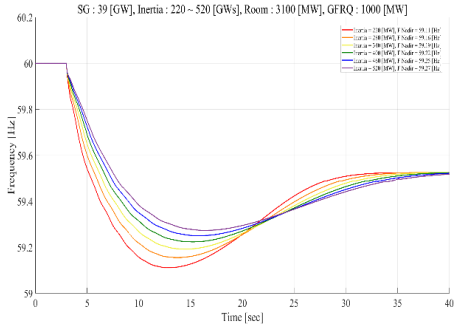
Frequency Trend with FS-ESS and Participatory Load Shedding

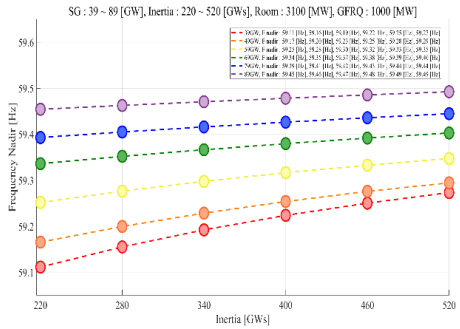


System Development – Frequency Stability Evaluation System

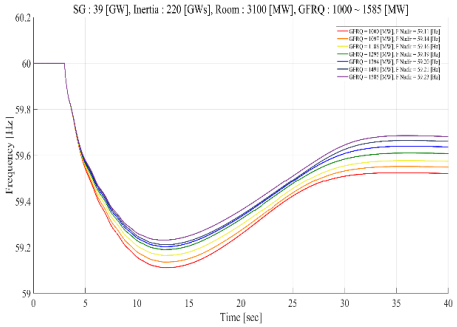
The frequency nadir has a linear correlation with inertia, reserve and load.

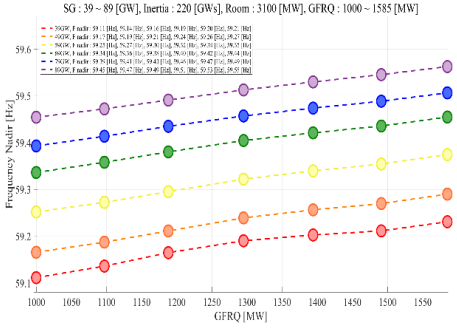
Inertia



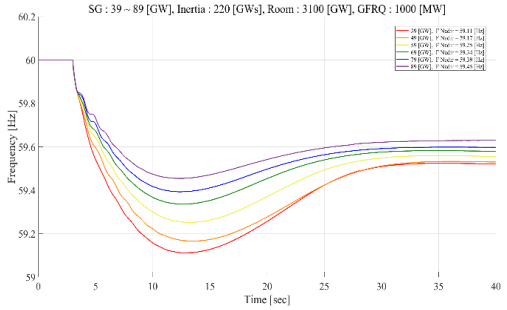


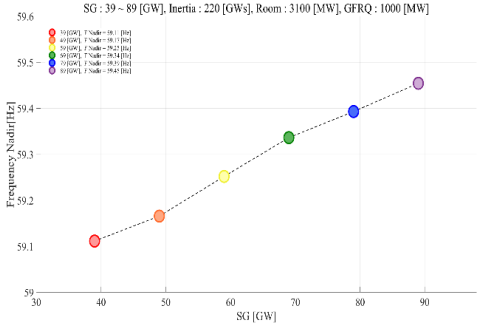
Reserve



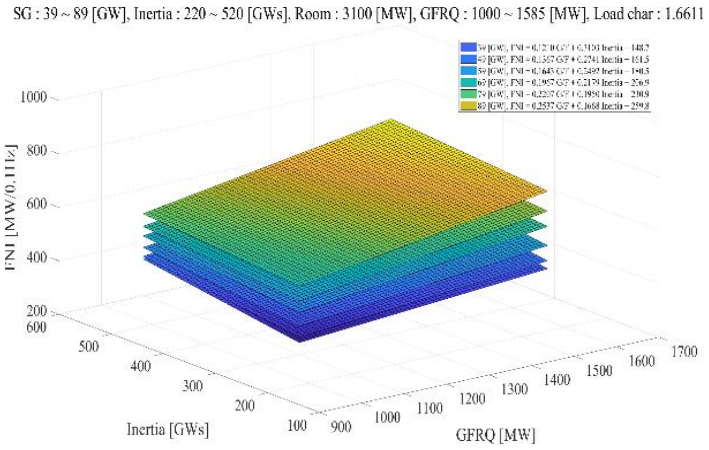


Load





Predicting Frequency Nadir By using FNI(Frequency Nadir Index)



39 [GW], FNI = 0.1121 G/F + 0.3103 Inertia + 158.3
49 [GW], FNI = 0.1267 G/F + 0.2741 Inertia + 172.2
59 [GW], FNI = 0.1524 G/F + 0.2492 Inertia + 193.1
69 [GW], FNI = 0.1782 G/F + 0.2225 Inertia + 217.3
79 [GW], FNI = 0.2010 G/F + 0.1983 Inertia + 243.7
89 [GW], FNI = 0.2274 G/F + 0.1742 Inertia + 264.1

- FNI[MW/0.1Hz] is INDEX, which represents the amount of change in the generator that affects the frequency nadir fluctuation of 0.1Hz

✓ $FNI = A \cdot (1 + S_1 \Delta P) \cdot GF + B \cdot (1 + S_2 \Delta P) \cdot I + C \cdot (1 + S_3 \Delta P)$

* A, B, C, S1, S2, S3 are parameters of sensitivity with inertia, reserve and load.

✓ $f_{Nadir} = 60 - \Delta f = 60 - \frac{Amount\ of\ Gen.\ Tripped}{FNI \times 10}\ [Hz]$

The method of Frequency Stability Evaluation

SPECIAL SECTION ON IEEE POWER & ENERGY SOCIETY SECTION

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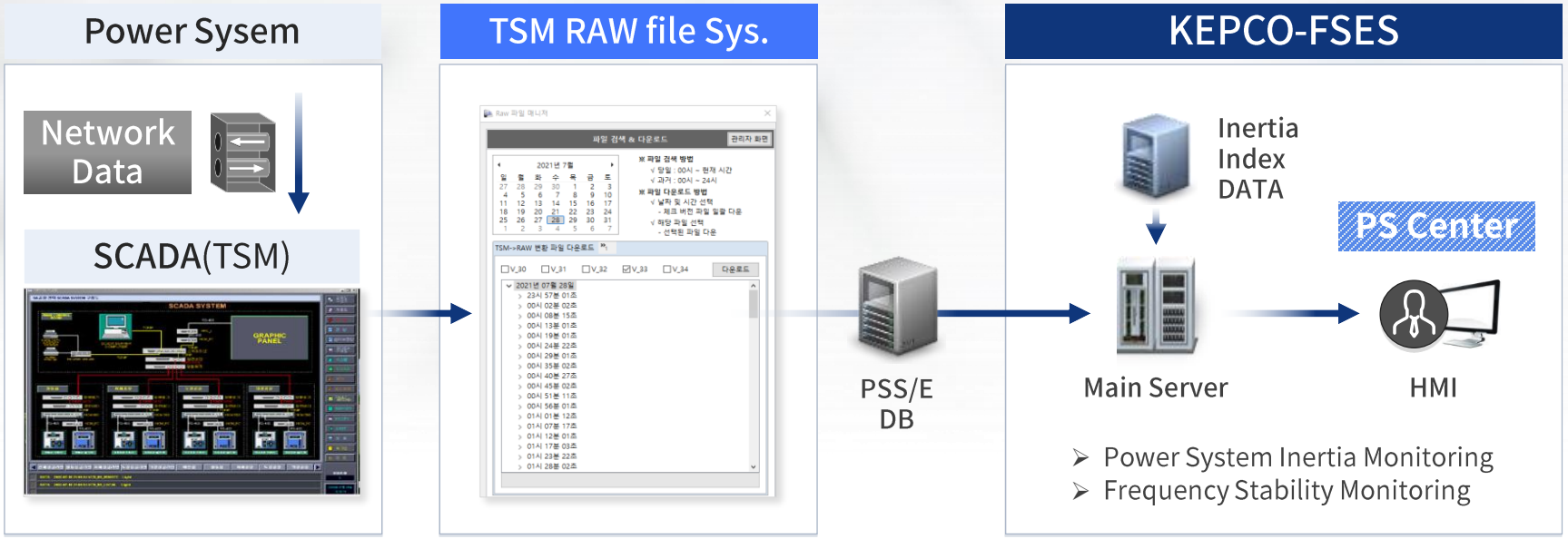
RESEARCH ARTICLE

Frequency Stability Evaluation Based on Conservative Piecewise-Linearized Frequency Nadir Model in South Korea

YONGBEOM SON[1,2], (Graduate Student Member, IEEE),
MINHYEOK CHANG[1], (Graduate Student Member, IEEE),
CHIWON SEO[1], (Student Member, IEEE), SUNGWOO KANG[1], (Member, IEEE),
YONGGU HA[2], (Member, IEEE), JONGAN KIM[2], (Member, IEEE),
MYUNGHWAN CHOI[2], (Member, IEEE), MINHAN YOON[3], (Member, IEEE),
AND GILSOO JANG[2], (Senior Member, IEEE)

KEPCO-FSES Configuration



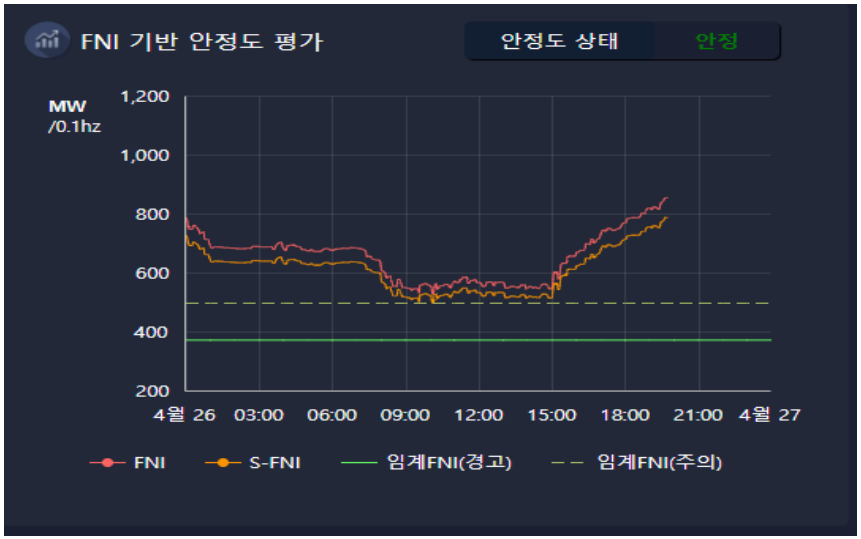
Step1	Receiving network data(PSS/E DB) regularly from SCADA
Step2	Calculating power system inertia and critical inertia
Step3	Evaluating frequency stability by comparing above data
Step4	Printing the evaluation results and related information

Online Frequency Stability Evaluation System HMI

✓ **Data :** Inertia, Reserve, Net Load, Frequency Stability and etc.

FNI	857.7 MW/0.1Hz	최대 : 857.7	Net 부하	51,942.7 MW	최대 : 52,352.8
	S-FNI 790.3 MW/0.1Hz	19 : 39 : 21		전체 부하 54,442.8 MW	00 : 01 : 56
		최소 : 531.2			최소 : 31,486.5
		10 : 07 : 24			12 : 43 : 34
계통관성	418.4 GW·s	최대 : 418.4	발전기 ROOM	11,671.2 MW	최대 : 16,716.8
		19 : 33 : 53			15 : 58 : 11
		최소 : 307.0			최소 : 6,760.8
		12 : 37 : 43			01 : 10 : 31
1차 예비력	2,477.7 MW	최대 : 2,477.7	임계관성	149.2 GW·s	최대 : 188.8
	G/F 2,243.8 MW	19 : 39 : 21			10 : 07 : 24
	ESS 233.9 MW	최소 : 1,472.8			최소 : 149.2
		10 : 07 : 24			19 : 39 : 21

3 GW 탈락 시 주파수	59.65	Hz
59.2 Hz 기준 탈락량	6,861.7	MW
계통안정화 ESS	866.0 (600.0)	MW
고객참여 부하차단	700.0 (400.0)	MW
계통 정수	1,425.6	MW/0.1Hz
발전기 정수	1,244.2	MW/0.1Hz
부하 정수	181.5	MW/0.1Hz
CB Ratio	1.7	



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Thank you for Your attention

Power System Interconnection Team

bestha@kepco.co.kr