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System Operation and Control

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Quantifying the impact of Synchronous Inertial Response and Fast Frequency Response to Frequency Stability for High Share of Renewables in HVDC Interconnected Jeju System

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Summary

- Renewable penetration increasing, leading to **more frequent curtailment of renewables in Jeju Island**.
- The **following options are considered to secure the frequency stability** of Jeju Island.
  - an **energy storage system (ESS)** for a fast frequency response
  - a **flywheel-connected synchronous condenser** to increase the synchronous inertial response.
- In this study, the **response characteristics of the resources were analyzed** through a PSS®E
  - confirmed that the control interference was resolved by **improving the operation mode of the ESS.**
  - determined **specification of S.C.(Srate & Inertia constant)** **to reduce reliability must-run synchronous generators** obeying the frequency stability guideline
- The observation about frequency response resources presented in this paper can be used to,
  - To review the **resources that are more efficient when planning the resources for a system**
  - To design a **proper deployment of frequency response resources** to ensure frequency stability

Motivation

- Brief configuration of the Jeju power system
  - Off peak/Peak load : 0.5 GW/ 1 GW
  - **two HVDC interconnections** with total capacity of 0.7GW
  - **'Reliability must-run generator'(RMR) constraint** for low demand condition
- Carbon-Free island Jeju plan (CFI 2030 plan)
  - Increase the **capacity of renewable energy to 4,085MW**(850MW in 2022)
  - Supply **100% of electricity demand by renewable energies**

→ **"Inertia & Strength" problems** arise on power system

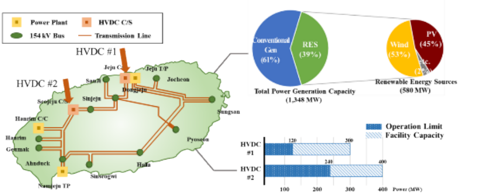


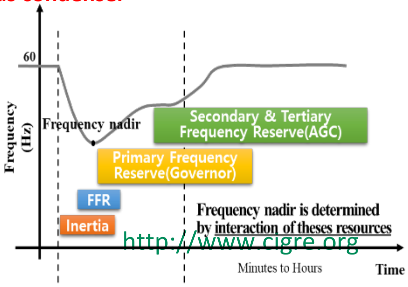
Figure 1. Configuration of the Jeju system's power generation resources

	Year					
	2015	2016	2017	2018	2019	2020
Ren. capacity (MW)	287	381	402	452	580	723
Number of events	3	6	14	15	46	77
Amount (MWh)	152	252	1,300	1,366	9,223	19,449

Table 1. Renewable curtailment in the Jeju power system

Objects of investigation

- To increase capacity of **RES, reducing RMR constraint in low demand condition** being considered.
- To prepare, two options are considered : **ESS & Synchronous condenser**
  - **Energy Storing System(ESS)**
    - Frequency response by control characteristics
    - Currently **40MW installed** in Jeju powers system(additional 50MW to be constructed)
  - **Flywheel connected synchronous condenser**
    - Frequency response by natural properties
    - **studies are being conducted on** the efficiency of capacity(Srate) and inertial constant



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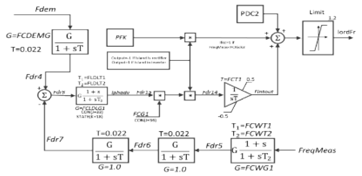
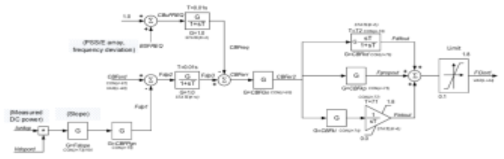
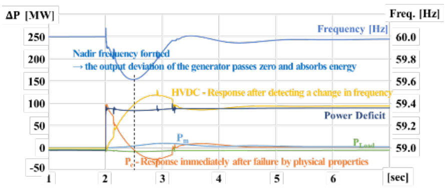
Method

- In this study, **the response characteristics of the resources were analyzed through** PSS®E simulations
- **User Defined Models (UDM)** reflecting the characteristics of **Jeju HVDC were used.**



- **#1 HVDC** has frequency control logic with **'frequency kick'** : reached **59.8, 59.6, 59.4 Hz** , shoot the output **as much as 6.25%** of the total capacity, which is **18.75MW for each**
- **#2 HVDC has PID frequency control logic**
- The response of the HVDC **after a contingency failure is confirmed with PSSE simulation**

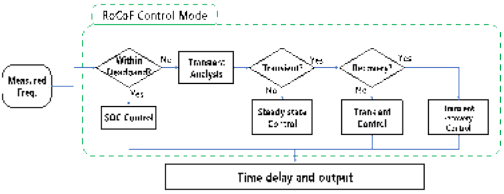




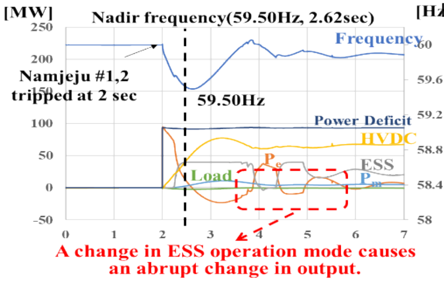
Experimental setup & test results (1) - ESS

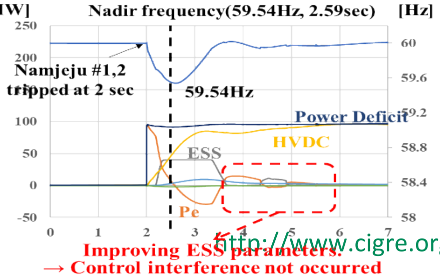
- ESS can be one option **to securing frequency stability instead of synchronous generator**
- **User Defined Models (UDM)** reflecting the characteristics of **Jeju ESS were used**

  - The **details of Jeju ESS** is as follows :
    - Dead band : 59.964Hz to 60.036Hz
    - Outside of the dead band, the steady-state control controls the frequency **with the droop of 0.28%**.
    - In transient recovery mode, the ESS continues to produce the output **with the droop of 0.16%.**



- The ESS' frequency control scheme **should consider interaction with other resources**
  - **HVDC outputs proportionally** to the decreasing frequency via droop control
  - whereas the **ESS outputs rapidly after leaving the dead band**, depending on the control mode.
- Interaction of **ESS and HVDC diminish recovery of frequency**
- **Sudden change in freq. occurs at 2.25 s** owing to power change of ESS depending its operation mode
  : **By improving ESS parameters, control interference not occurred**





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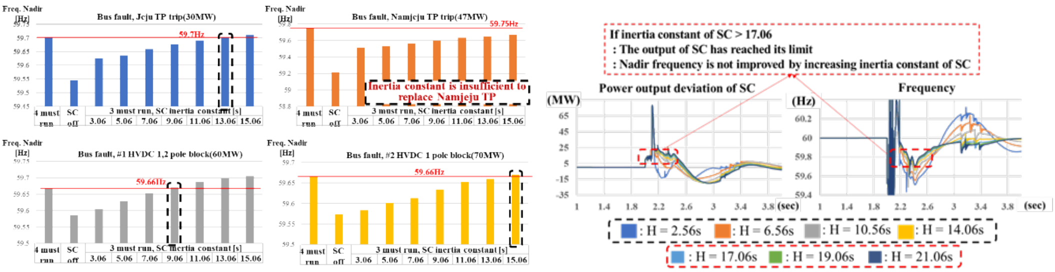
Experimental setup & test results (2) - Fly wheel connected S.C.

- The flywheel connected synchronous condenser **can reinforce inertia & strength**
- As an **inertial resource, it <u>reduces RoCoF, increasing the time</u> for other resources to act**
- The frequency improvement by **S.C. varies depending on its capacity and inertial constant**
- The red in below figure indicate the nadir frequency with the 4 of the must-run generators



Discussion

- As observed in simulation results, even if the **artificial and natural response resources** have the same size in the power unit, **<u>the contributions of each resource to the nadir frequency are different</u>.**
  : **Considering the characteristics of each resource** is essential to secure frequency stability.
- **Important observation** : S.C. is not an all-powerful solution for securing frequency stability
  - in the case of Namjeju TP #1 trip after the bus fault, the frequency nadir **did not reach the frequency nadir of the 4 must run case even if the inertia constant of the S.C. increases**
  - Furthermore, when the inertia constant of the synchronous condenser was larger than 17s, the inertial energy by the synchronous condenser **after the contingency did not increase significantly.**

Conclusion

- The response characteristics of the resources were analyzed and simulations are conducted to securing frequency stability of Jeju power system through a PSS®E
- **Two options are considered :**
  - **ESS** : The frequency can be increased very quickly according to its control scheme.
    However, **interaction with other resources can dimmish frequency stability unintentionally**
  - **S.C.** : The flywheel connected synchronous condenser can reinforce inertia & strength
    However, it **is not an all-powerful solution for securing frequency stability**
- The **<u>observation about frequency response resources presented in this paper</u>** can be used to,
  - To review **the resources that are more efficient when planning the resources** for a system
  - To design **a proper deployment of frequency response resources to ensure frequency stability**