Research on the Frequency Stability Improvement of multiple DERs under the New Grid Code Requirements in Korea

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I。 Abstract

As the penetration level of the renewable DERs escalates, concerns about the power grid stability also grow high. As for a countermeasure against stability threats, many countries are adding new or upgraded requirements into their grid code in order for new incoming DERs to be supportive in grid stability. Currently, Korea is one of the countries with urgent problems cause by the large number of renewables and is updating the grid code.

In this paper, new Korean grid code is briefly introduced with focus on the frequency stability. And the study compares the frequency stability of the traditional droop control in the grid code with the virtual inertia control of Grid Forming Converters. And the test and demonstration site for the grid stability improvement is introduced.

II 。Introduction

■ Grid problems from the high renewable penetration in Korea

- Curtailments problem in Jeju Island
  - Rapid increase of Renewables-WT(295MW), PV(545MW) (in Apr. 2022) for 500~800 MW loads (seasonally different)
  - Over-production of renewables under the condition of min. output of HVDC & reliability must-run (RMR) Units causes the curtailments.
  - WT curtailments are happening since 2015
- Frequency stability problem by PV inverter trip
  - Under frequency protection requirement (old grid code) : Hz < (57.5~59.8), disconnection time (0.16~300s) adjustable
  - Frequency drop from the single generator failure caused many PVs to trip.

WT Curtailments \ Year	2017	2018	2019	2020
Number [count]	14	15	46	77
Energy [GWh]	1.3	1.4	9.2	19.5
Proportion [%]	0.24	0.25	1.66	3.24

Fig.1 WT curtaiilment events in Jeju Island

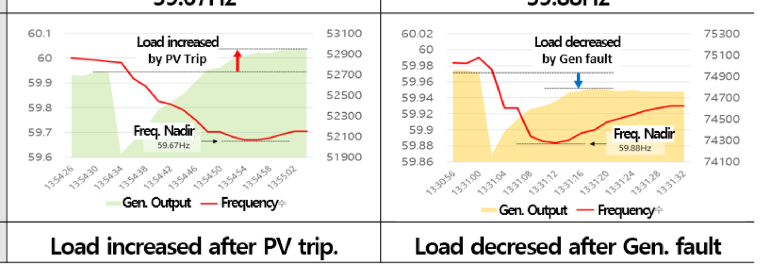
Date/Time	13:54:34 28.Mar.2020(Sat)	13:31:02 23.Dec.2019(Mon)
Output(pre-Fault)	805MW	805MW
PV Trip	○ (about 450MW)	X
Frequency Nadir	59.67Hz	59.88Hz
Frequency and Load		
Etc.	Load increased after PV trip.	Load decresed after Gen. fault

Fig. 2 Single generator fault (Shin Boryung #1) cases comparision

■ Grid codes/standards in Korea

- Structure of grid-code of Korea [1]
  - Electricity Business Law (MOTIE)
  - Regulations on using electrical equipment for transmission & distribution (KEPCO)
  - DER Smart Inverter Standards (KSGA)
    - KSGA-025-15-1 Grid Support functions for PV Smart Inverter-Pt1 Distribution system
    - KSGA-025-15-2 Grid Support functions for PV Smart Inverter-Pt2 Transmission system
    - KSGA-025-9-4 Grid Interconnection Requirements - Information Model and Interface Test Methods between Smart Inverter and Supervisory Unit.
- Major updates
  - Smart Inverter Functions for distribution(14)/Transmission(10)
  - Interoperability, Information Models for Smart Inverters

■ Motivation of the study

- To find out the frequency stability of multiple converter based DERs
- To know what is the effect/performance of the frequency support function in current grid-code.
- Virtual inertia control of grid forming converters is compared with the traditional droop control.

III。Frequency Stability Improvement Technology

■ Frequency droop (Frequency-Watt function) in Grid code

- decreases the active power according to the increased frequency
- regulate the frequency deviation caused by DER over-production

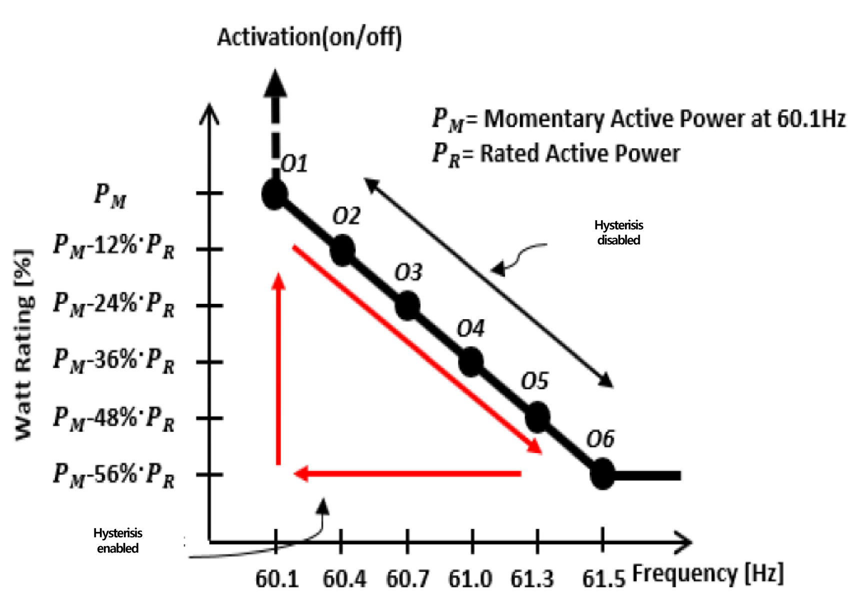


표 15 – 주파수-유효전력 제어 기능(Frequency/Watt) 데이터 (SunSpec Modbus 모델 = 711)

MB 주소	타입	배율 계수	RO/RW	이름	설명	기본값	비고	송전 요구사항
40838	enum16		RW	Ena	FreqDroop 제어 활성화 DISABLED 0 ENABLED 1 ENABLED with Hysteresis 2	1		작동
40850	uint32	Db_SF	RW	DbOf	고 주파수 데드밴드	100	[Hz]	36
40852	uint32	Db_SF	RW	DbUf	저 주파수 데드밴드	0	[Hz]	0
40854	uint16	K_SF	RW	KOf	고 주파수 변동율	417		300
40855	uint16	K_SF	RW	KUf	저 주파수 변동율	0		0
40858	int16		RW	PMin	최소 유효전력	44	[%]	37

Fig.3 Frequency droop curve and Information model

■ Virtual Inertia Control of Grid-Forming Converter [2][3]

- In the study, Interconnection reliability is focused on the freq stability.
- When fault occur, inertia-less DER system may have freq. instability
- Swing equation of synchronous generator simulates the virtual inertia
- Inertia moment(J) determines the property of resist change in motion
- Damping coefficient (D) determines the decay of oscillation.
- Virtual inertia algorithm was programmed in DC/AC (Inverter) for ESS and DC/DC converter for PV.

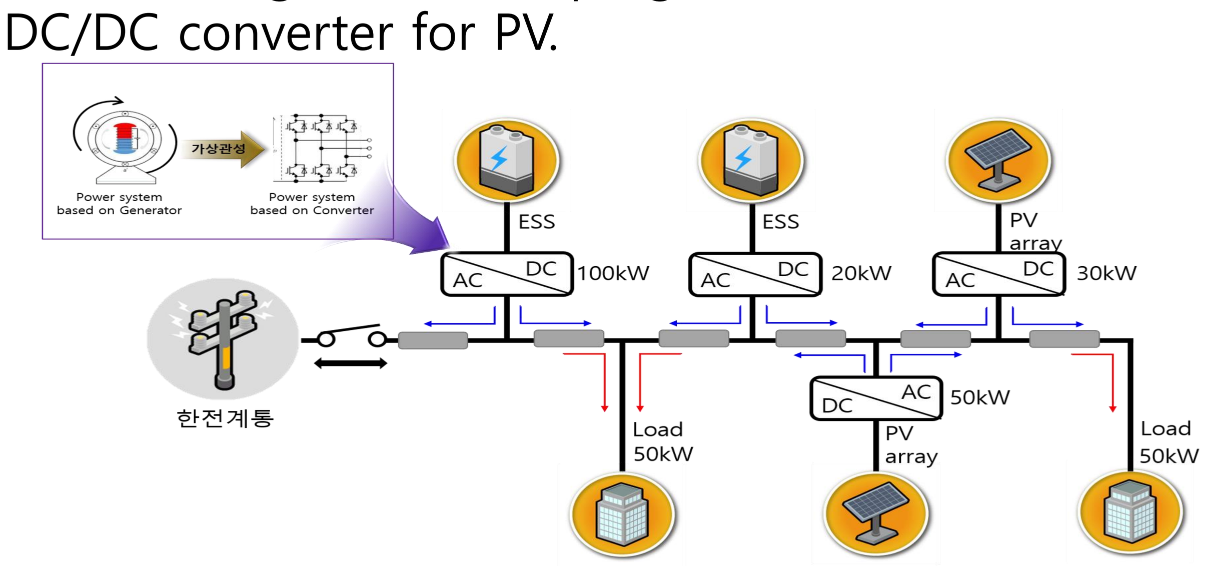


Fig. 4 Frequency Stability Simulation Test Setup

■ Simulation test conditions / Results

- Load change case (150kW loading/unloading)
  - Droop control : Freq Nadir at 59.6, Max at 60.24
  - Virtual Inertia control : Freq Nadir at 59.81, Max at 60.07
- Fault(3PhaseGround, 0.1s) case (PV 50kW at 20s)
  - Droop control : Freq Nadir at 57.6, Max at 60.79
  - Virtual Inertia control : Freq Nadir at 59.74, Max at 60.11

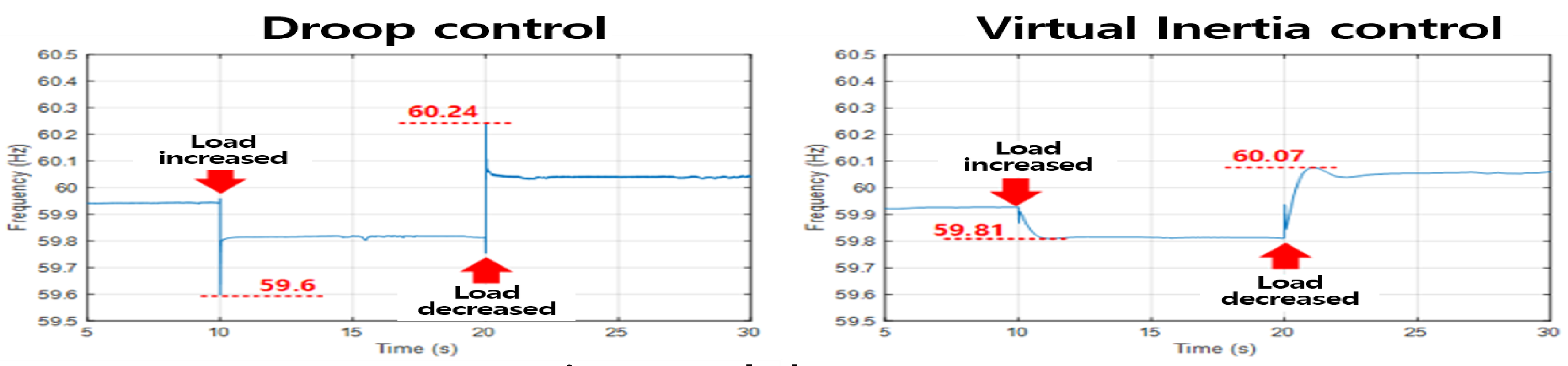


Fig. 5 Load change case

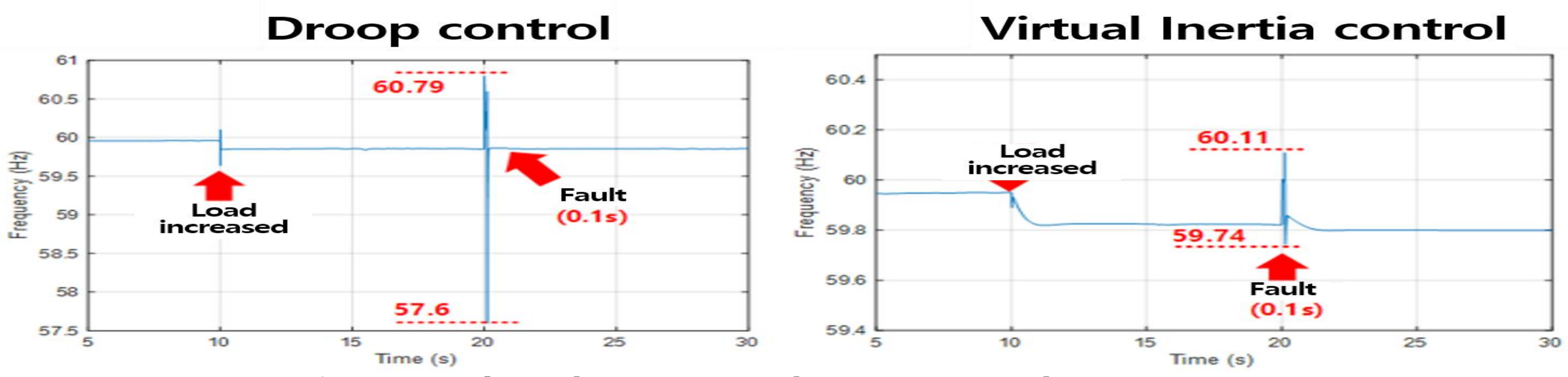


Fig. 6 Fault(3PhaseGround) case(PV 50kW at 20s)

IV。DER Reliability Test & Demonstration Site

- Reliability Test & Demonstration site is designed to provide a functional/performance evaluation of devices and algorithm in long term demonstration.
- The site consists of various simulators (Grid/PV/ESS/Load/Distribution lines), OLTC etc. that are managed by coordinated operation system.

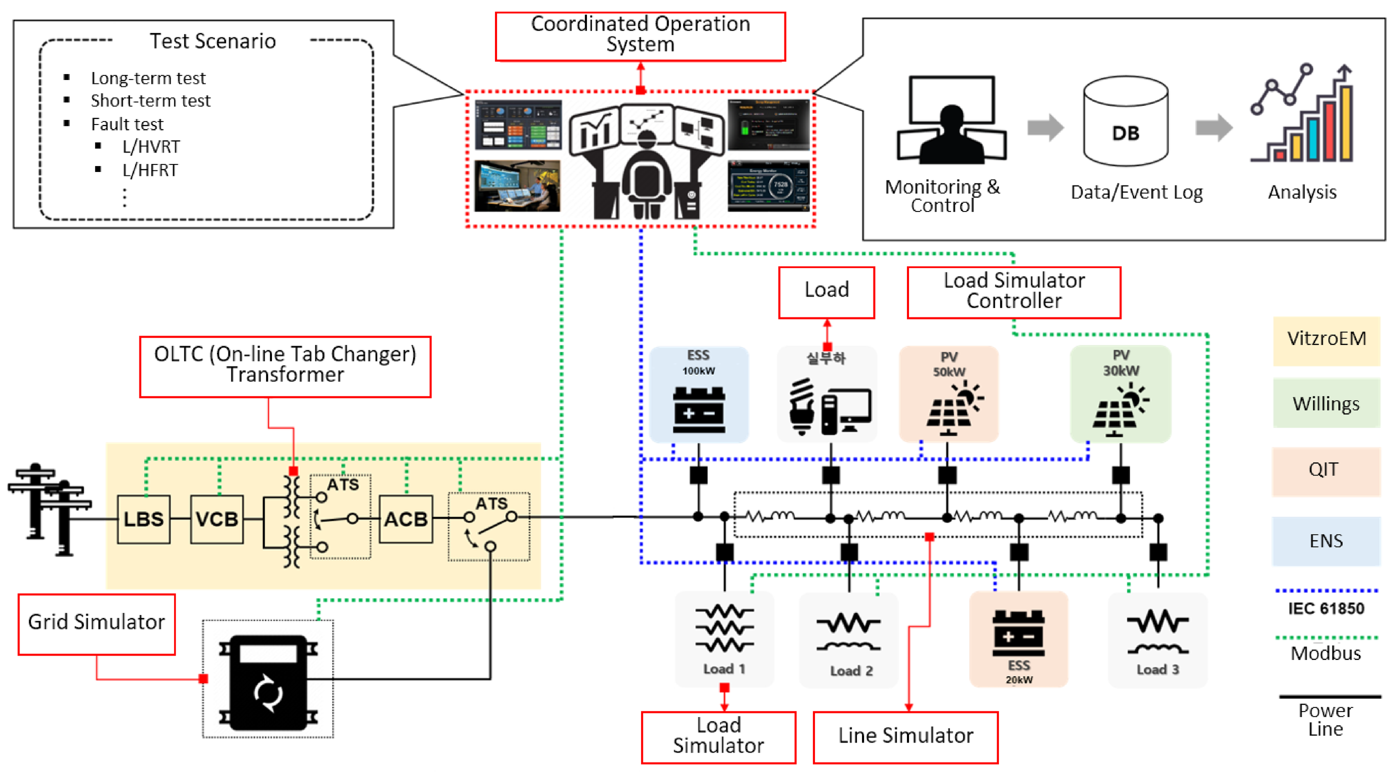


Fig. 7 Reliability Test & Demonstration Site Configuration

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V 。References

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[2] H. Yoo, K. Kim, J, Jeon. (2020). "Dynamics Analysis of DER with Virtual Inertia". Proc. of KIEE, 69(5), 664-670.

[3] C. Zhang, X. Dou, Z. Zhang, G. Lou, F. Yang, and G. Li, "Inertia-Enhanced Distributed Voltage and Frequency Control of Low-Inertia Microgrids," IEEE Trans. on Power Systems.

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