Performance Evaluation of Adaptive DER Volt-Var Functions for Voltage Stability in Microgrids

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INTERNATIONAL Microgrid SYMPOSIUMS

ISGAN INTERNATIONAL SMART GRID ACTION NETWORK

KERI KOREA ELECTROTECHNOLOGY RESEARCH INSTITUTE

I。 Abstract

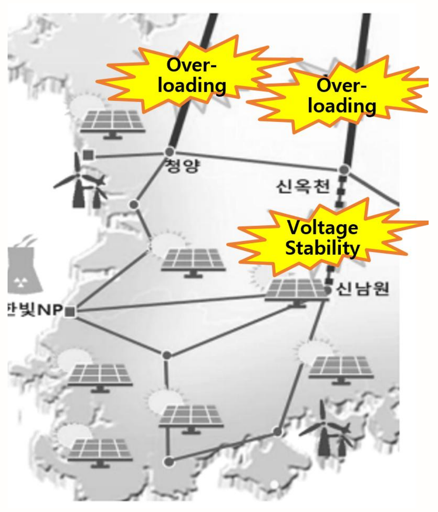
The increasing penetration of inverter-based distributed energy resources (DERs) poses significant challenges to voltage stability in microgrids, particularly under weak grid conditions. While grid-forming technologies have been emphasized for resilient microgrid operation, grid-supporting DERs equipped with smart inverters remain essential for stable voltage regulation by providing voltage supportive functions such as Volt-Var and Volt-Watt control.

This study evaluates the voltage stabilization performance of multiple DER smart inverters in a microgrid environment, validated through hardware-in-the-loop (HIL) simulations and long-term field demonstrations at KERI's microgrid test site.

II 。 Introduction

■ Grid problems from the high renewable penetration in Korea

- Curtailments problem in Jeju Island
  - Over-production of renewables under the condition of min. output of HVDC & reliability must-run (RMR) Units causes the curtailments.
  - WT/PV curtailments are happening since 2015
- Worsening Issues Due to Regional Concentration of Renewables
  - Renewable energies are concentrated in the Honam (South-East) region.
  - Only two TLs to the metropolitan(North) area have the overloading and voltage stability issues.



Curtailments	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
WT [Counts]	3	6	14	15	46	77	64	104	117	51
PV [Counts]	-	-	-	-	-	-	4	28	64	32
Total [Counts]	3	6	14	15	46	77	68	132	181	83

Fig.1 WT/PV curtailment events in Jeju Island

Fig.2 Transmission lines Congestion and Voltage Stability Problem of Korean main land.

■ Motivation of the study

- Construction of new transmission lines to resolve the regional concentration of renewable energy takes a long time.
- Slow construction of TLs delays further expansion of renewables.
- As DERs connected to the distribution network increase, a proper management of the distribution network is essential.
- Recent blackout in Spain caused by a series of generation trips and cascading voltage rise show the importance of voltage management.

III。 Voltage Stability Enhancement Techniques

■ Volt-Var supportive function

- Absorb/Inject Reactive power according to increased/decreased Volt..
- Evaluation of the voltage stabilization capability through turning each PCS's Volt-Var (VV) function On/Off or adaptive VV curve.

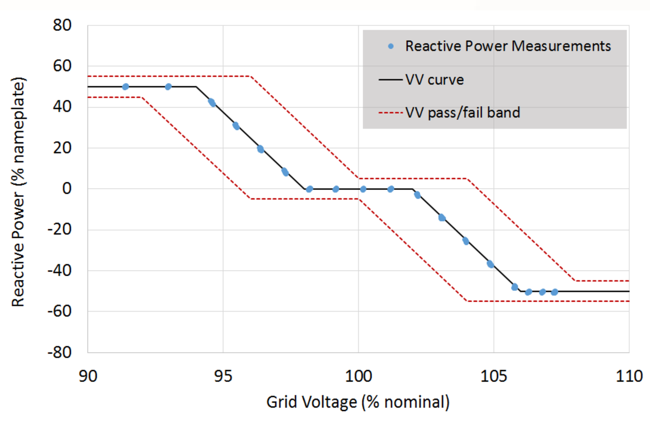


Fig.3 Fixed Volt-Var curve (grid-code)

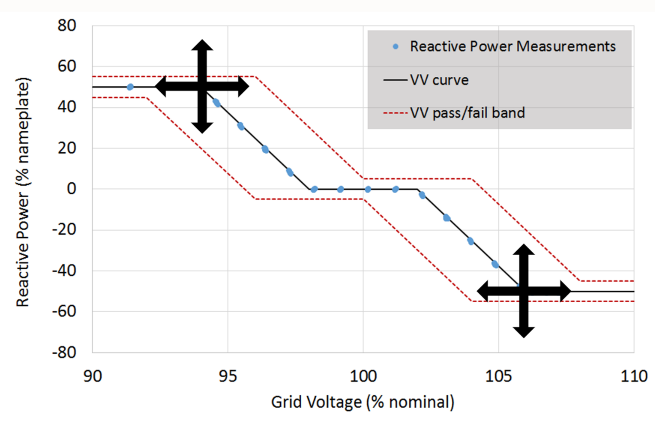


Fig.4 Adaptive Volt-Var curve

■ Continuous Operation Demonstration (Voltage Stability test)

- Is to verify the grid-support performance of the developed PCS prototype under real environmental conditions.
- A multi-day operation test was conducted on PV/ESS/load units using the same daily power profile, with Volt-Var (VV) control alternately turned on and off each day.

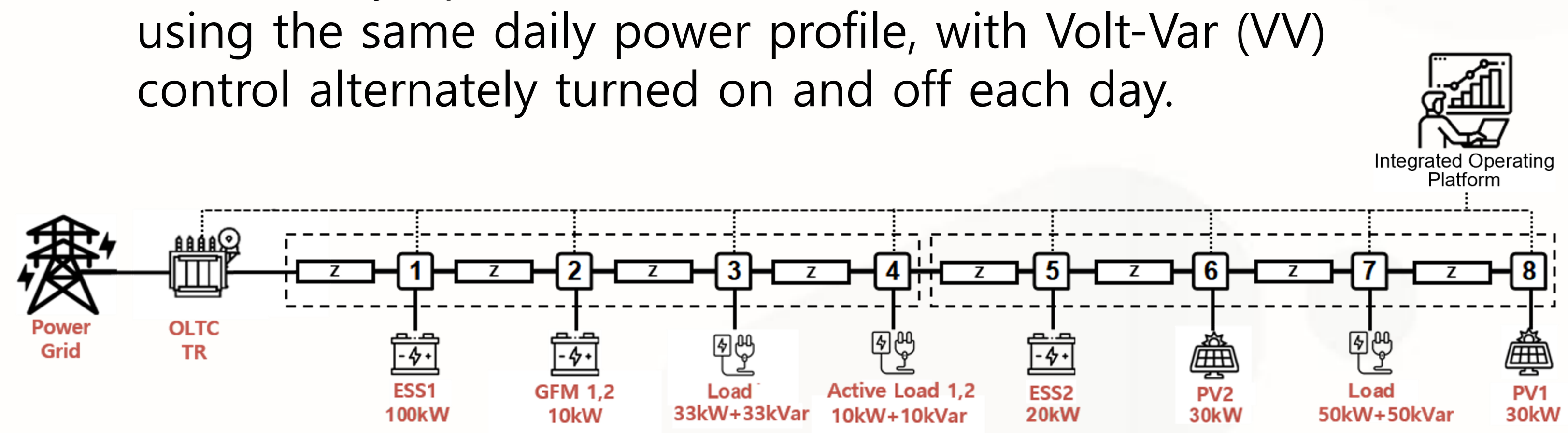


Fig.5 Configuration(PCSs & Loads position) of the Voltage Stability Test Demo

Acknowledgements

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IV。 DER PCS Reliability Test & Demonstration

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

Fig. 6 KERI Demonstration Site, Integrated Operation Platform (SCADA)

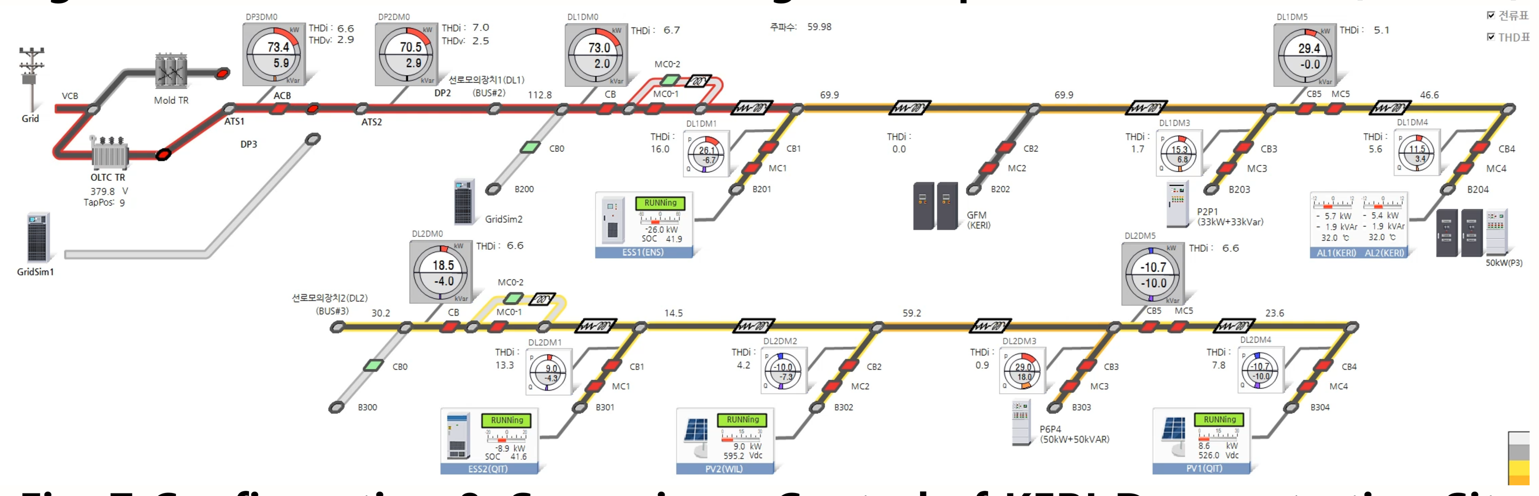

Fig. 7 Configuration & Supervisory Control of KERI Demonstration Site

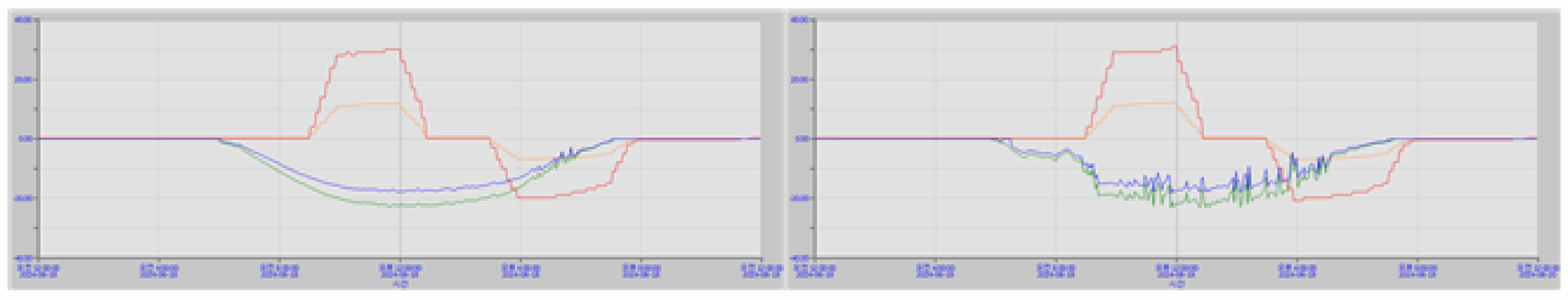

Fig. 8 PV & ESS Active Power Output (L:VV Off / R:VV On)

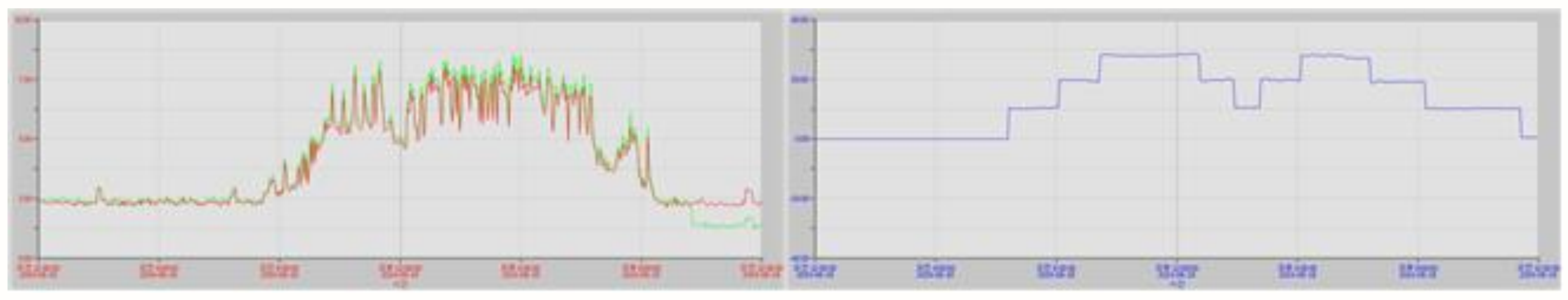

Fig. 9 Daily Load Profile (L:Active Load / R:Passive Load Sim.)

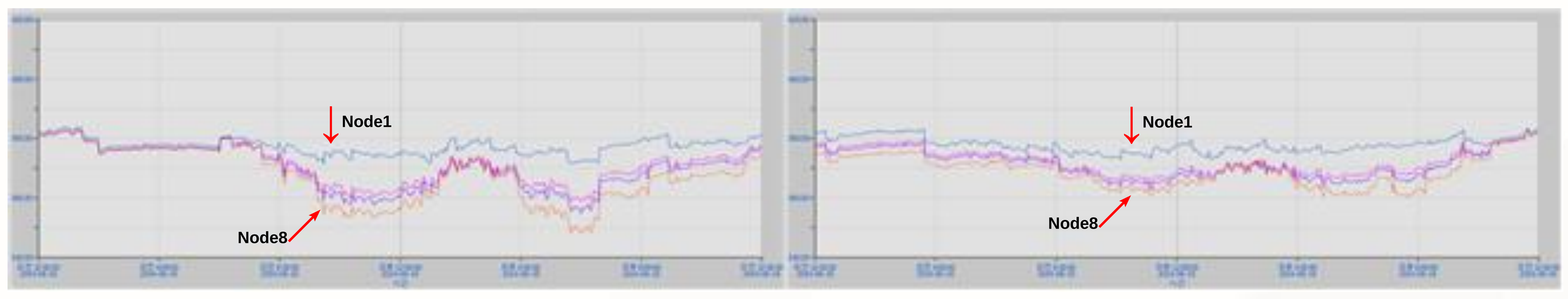

Fig. 10 Daily Nodal Voltage Profile (L:VV Off / R:VV On)

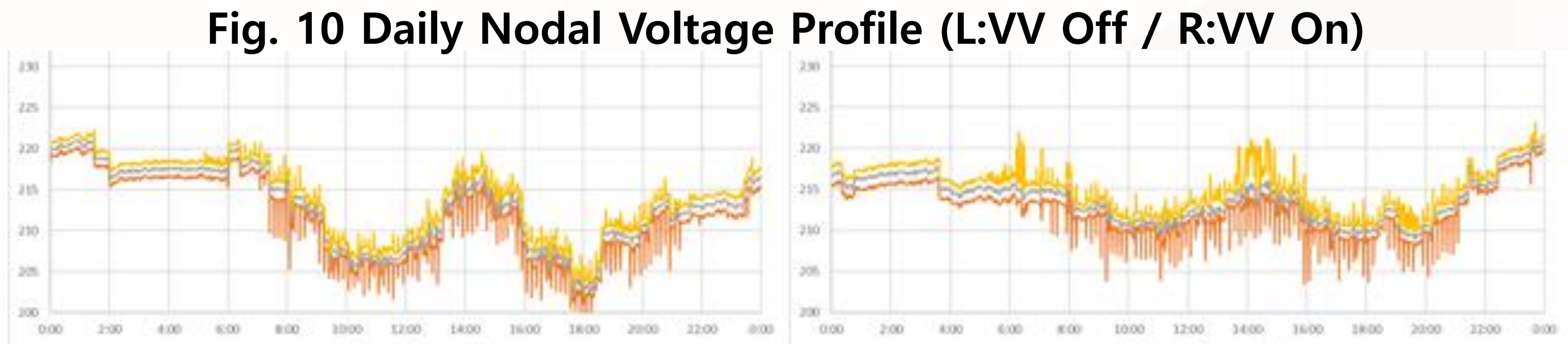

Fig. 11 Node6(PV2) Voltage (Max/Avg/Min of a Min.) (L:VV Off / R:VV On)

Fig. 12 Comparison of Voltage Histograms (L:VV Off / R:VV On)

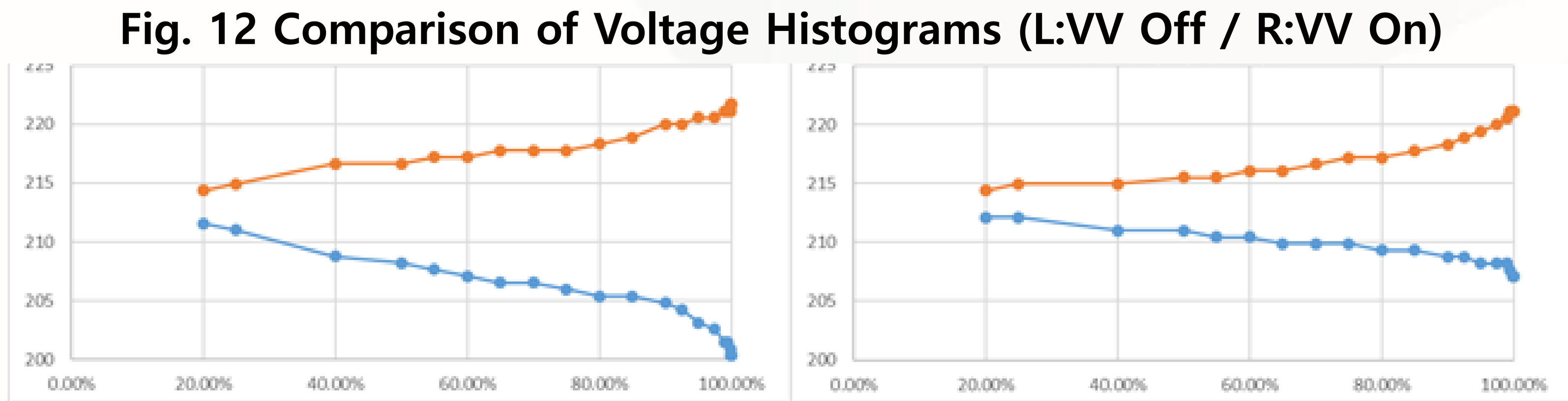

Fig. 13 Comparison of Cumulative Distribution Functions (CDFs) of Voltages

V 。 Conclusion

- Volt-Var function effectively narrowed the overall **voltage distribution**, reducing both **over and under-voltage occurrences** across nodes.
- Histogram and CDF comparison show Volt-Var control improved **voltage uniformity** and **feeder-level stability** under same daily conditions.