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Experimental Analysis of Distribution Network Voltage Regulation Using Smart Inverters

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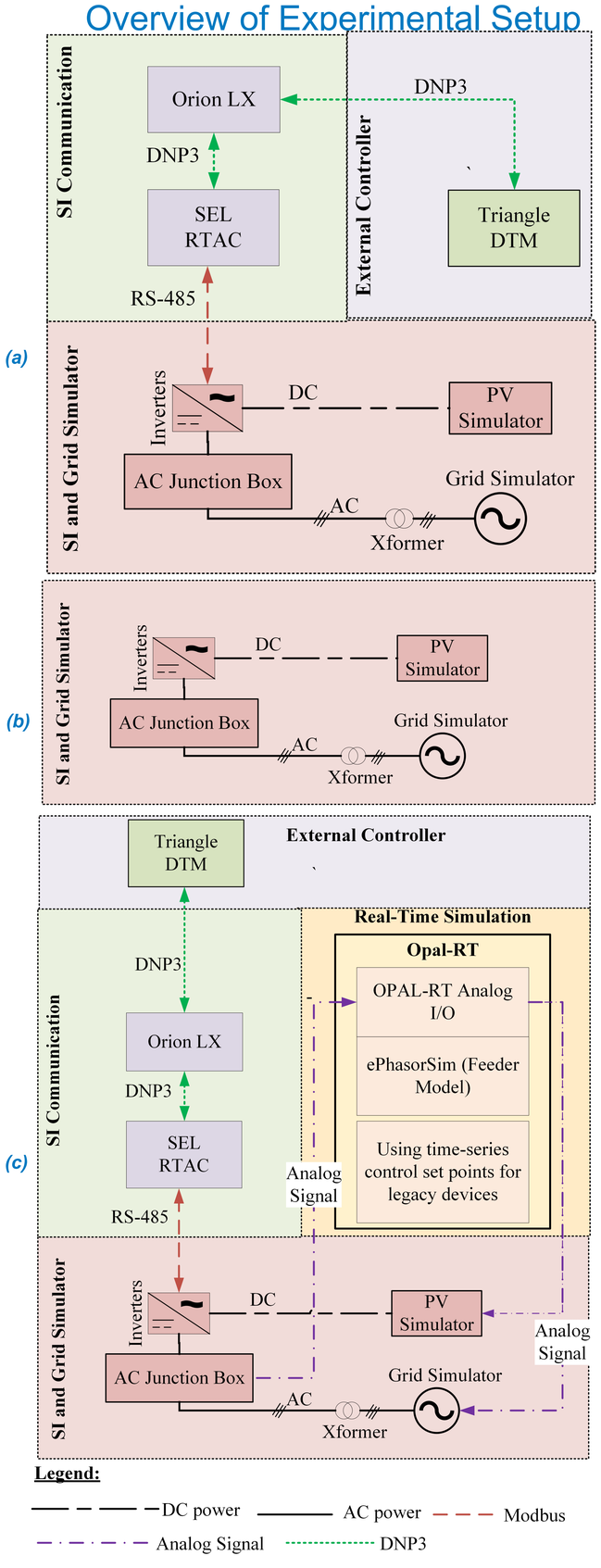
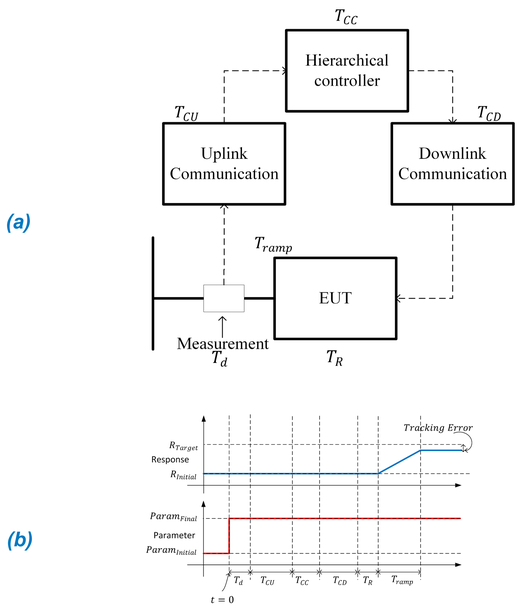
Abstract

In this presentation, we discuss the potential of smart inverters (SIs) to provide grid services, focusing on their ability to regulate voltage in distribution networks. The paper presents an experimental study comparing two control methods for SI reactive power regulation: autonomous control and remote dispatch, highlighting important differences in response characteristics and emphasizing the need to consider these factors when planning for voltage regulation using SIs in distribution networks.

Overview of Experimental Setup



Experimental setup to evaluate the performance of grid services from smart inverters: a) autonomous SI control, b) remote dispatch method, and c) scenario analysis using real-time network model

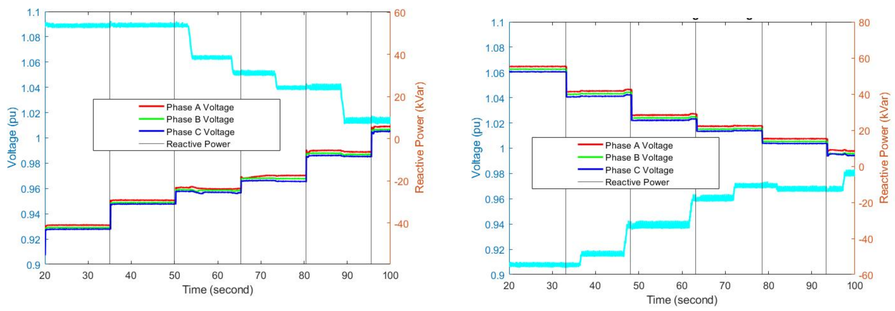


Grid services from inverter: a) generic connection and signal flow diagram for the SIs, b) typical response from SIs.

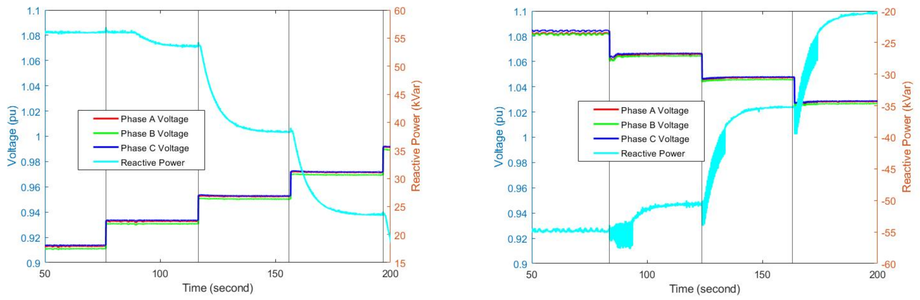
Experimental Results

Case #	Description	Test Step	Objective
1	Remote dispatch method: Open-loop DTM to inverter Q command*	Send Q1=0kVar and Q2=55kVar** from DTM to inverter Send Q1=55kVar and Q2=0kVar** from DTM to inverter	1. Determine the ramping time (Tramp).
2	Remote dispatch method: Closed-loop DTM to inverter Q command* (volt-var in DTM)	Change AC PCC voltage from high to low and low to high.	1. Test the interoperability performance between the DTM and the inverters using the applied communication method. 2. Characterize the inverter response in remote dispatch method. 3. Identify any stability and/or unknown issue for inverter control from an external controller.
3	Autonomous SI control: volt-var in inverter	Change AC PCC voltage from high to low and low to high.	1. Characterize the volt-var function in autonomous SI control.

Characterization Test Matrix



Performance of the inverter in remote dispatch method with volt-var hosted in the DTM: a) voltage changes from low to high in steps; b) voltage changes from high to low in steps.

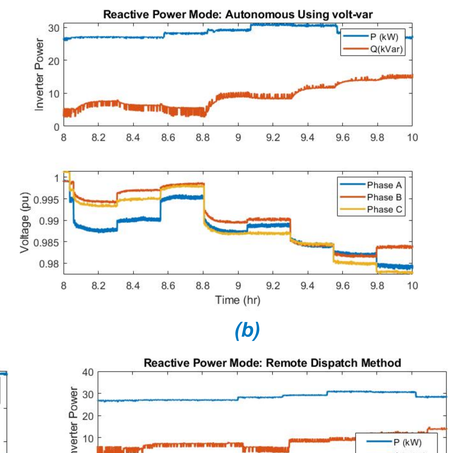


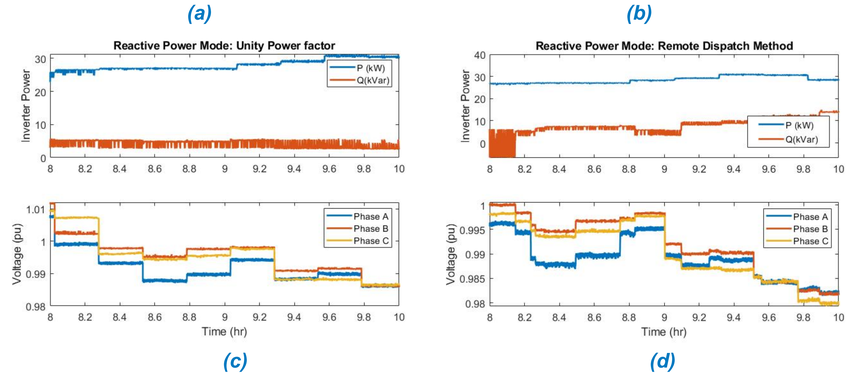
Test result to characterize the inverter volt-var response in autonomous SI control: a) voltage changes from low to high; b) voltage changes from high to low.

Characterization Parameter	Statistical Parameter	Remote Dispatch	Autonomous Control
T_L [1] Unit: second	Mean	11.74	0.77
	Std. deviation	4.78	0.31
	Maximum	20.16	1.20
	Minimum	2.80	0.20
Positive ramp rate [2] Unit: %/second	Mean	10.87	0.45
	Std. deviation	3.68	0.13
	Maximum	16.26	0.58
	Minimum	6.37	0.15
Negative ramp rate [3] Unit: %/second	Mean	-10.02	-0.49
	Std. deviation	2.96	0.01
	Maximum	-4.50	-0.47
	Minimum	-14.05	-0.51

Quantitative Comparison of remote dispatch method to autonomous SI control Response

Scenario	Reactive Power Mode	Control Model
1	Unity pf	autonomous SI control
2	VVar	autonomous SI control
3	External signal	remote dispatch method





PHIL test result to evaluate the applicability of remote dispatch method and autonomous SI control: a) Scenarios tested Using PHIL Setup, b) Scenario 1, c) Scenario 2, d) Scenario 3.

Conclusion

- ***The experimental study successfully demonstrated and validated the communication setup from a remote controller to a smart inverter (SI) using intermediate communication gateways.***
- ***The study demonstrated that the smart inverter (SI) successfully received external control signals for remote dispatch of reactive power set points, with response times varying from 2 to 20.16 seconds. The remote dispatch method also exhibited faster ramp rates, ranging from 6.3%/second to 16.26%/second (positive) and -4.5%/second to 14.05%/second (negative), while the autonomous SI control mode, including inverter embedded control response, showed slower average ramp rates of 0.45%/second (positive) and -0.49%/second (negative).***
- ***Delays in communication and response times may pose concerns for voltage control, suggesting potential benefits of utilizing a hybrid communication architecture that combines remote control and dispatch with the ability to receive inverter measurements for updating remote settings from a centralized controller.***

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Support for the work was also provided by Utilidata, Inc., under CRD-20-16909. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

The 2023 IEEE 50th Photovoltaic Specialists Conference (PVSC)
San Juan, Puerto Rico
June 11-16, 2023
NREL/PO-5D00-86559