Development of a Practical Secondary Control for Hardware Microgrids

S. Chakraborty, J. Wang, S. Ganguly, and B. Kroposki

National Renewable Energy Laboratory,

{soham.chakraborty, jing.wang, subhankar.ganguly, benjamin.kroposki}@nrel.gov

IEEE ENERGY CONVERSION CONGRESS & EXPO PHOENIX, ARIZONA, USA • OCT. 20-24

Paper ID: 1442

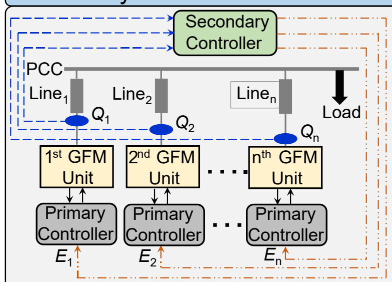
Motivations

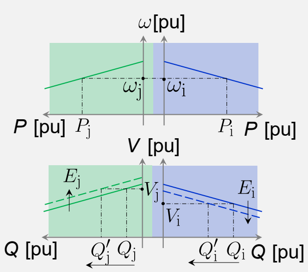
- ❑ Practical, vendor-neutral interoperability guidelines for the secondary control architecture of MGs incorporating multiple GFM-IBRs have not yet been established.
- ❑ This article proposes a generic, vendor-agnostic secondary control architecture compatible with all GFM-IBRs and synchronous generators.

Contributions

- ❑ Addresses practical challenges → Modbus registers (**packet loss**, **quantization error**), adverse effects on control actions
- ❑ Proposed strategies are suitable for any secondary control architecture to mitigate the practical issues
- ❑ No need for additional measurement devices within the MG by leveraging existing communications of vendor GFMs (Modbus).

Secondary Control Architecture





- ❑ Secondary control from the scope of only reactive power sharing among n number of GFMs connected to a common bus
- ❑ P-f and Q-V droop-based primary control
- ❑ Parallel of i^{th}, j^{th} GFM with equal ratings, unequal lines $X_j > X_i$
- ❑ P-f droop→ $n_i P_i = n_j P_j$ with $P_i + P_j = P_L$ (w/o secondary control)
- ❑ Q-V droop→ $m_i Q_i \neq m_j Q_j$ with $Q_i + Q_j = Q_L$ (w/o secondary control).

Dynamic Compensation by the Secondary Control

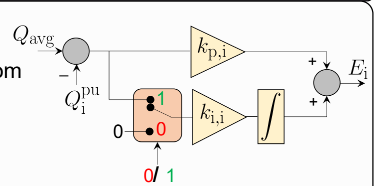
- ❑ QV droop w/sec. control:

$$V_i = V_{nom} - m_i Q_i + E_i$$

- ❑ Step1: Receive $Q_1, Q_2, ..Q_n$ from all GFMs and calculate:

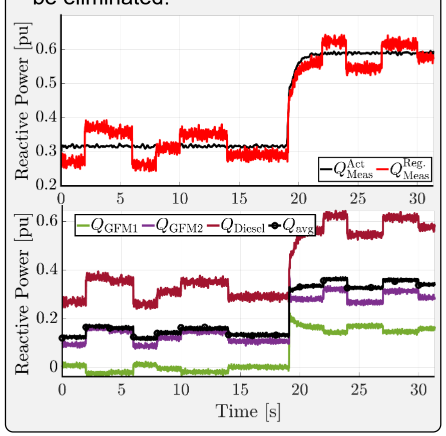
$$Q_i^{pu} = \frac{Q_i}{S_i}, i = 1,2, ..n$$

- ❑ $Q_{avg} = \frac{1}{n}(Q_1 + Q_2 + .. + Q_n)$
- ❑ Generate E_i using the control diagram.



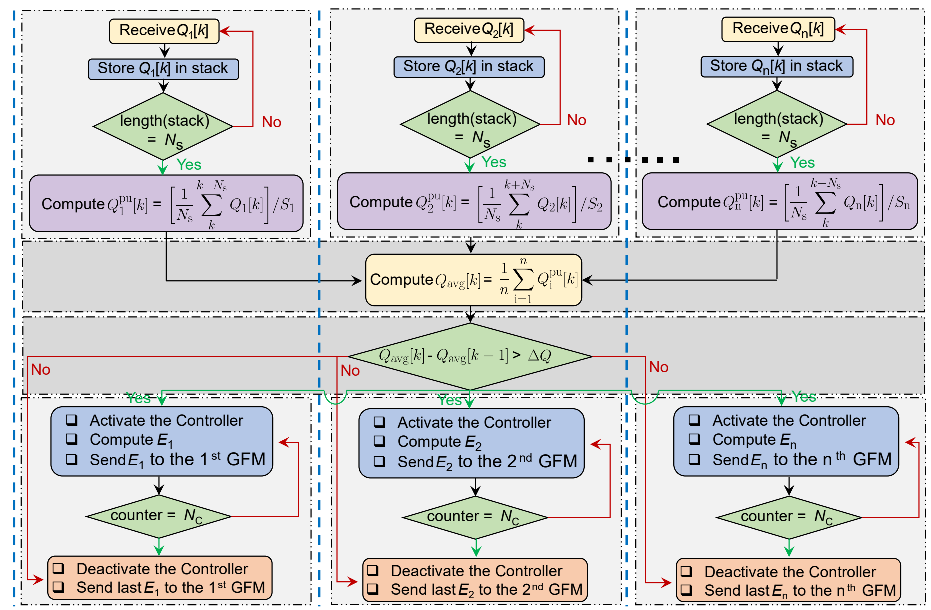
Practical Challenges

- ❑ Commercial GFMs use Modbus TCP/IP, RS-485, etc.
- ❑ Modbus is an ethernet-based system; it encapsulates Modbus data in TCP/IP packets and stores them in "holding registers" to read/write externally.
- ❑ Inherent simplicity and robustness, reliability, interoperability
- ❑ Low-bandwidth communication, compromised data precision, and accuracy of Modbus holding registers
- ❑ Continuous sampling causes undesired, significant fluctuation due to the packet lost, quantization error, and inevitable measurement high-frequency noise
- ❑ High-frequency noise is eliminated using the averaging; less-frequent and significant-in-amount fluctuations cannot be eliminated.

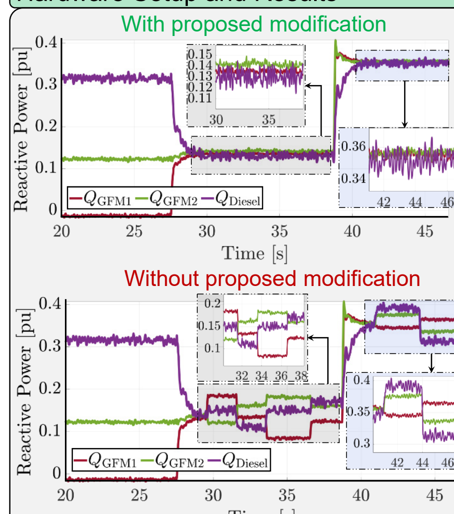


Proposed Modification (right-top fig.)

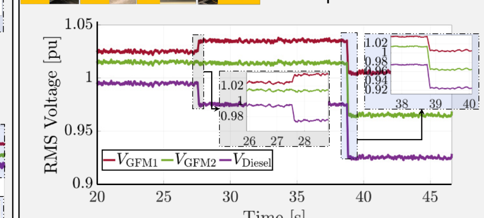
- ❑ Averaging of the measurements after data read
- ❑ Situational event-triggering of the algorithm
- ❑ Finite iteration of the compensation of the algorithm.



Hardware Setup and Results



- O Two 3-ϕ, 480-V, GFM (GFM1: 250 kVA, GFM2: 125 kVA)
- O 3-ϕ, 480-V diesel gen (187.5 kVA)
- O P-f droop is 0.6%, QV droop is 5%.



Conclusions and Future Work

- ❑ Practical approach for accurate reactive power sharing among GFM inverters
- ❑ Extension to f/V regulation with Q sharing.

This work was authored 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. Funding provided by the U.S Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office Agreement Number 38637.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.

2024 IEEE ECCE
Phoenix, Arizona
Oct 20–24, 2024
NREL/PO-5D00-91676