FREEDM SYSTEMS CENTER

Microgrid Power Flow Control with Integrated Battery Management Functions

Qian Long
qlong2@ncsu.edu

Prepared for IEA TEM #101
Aug 25th, 2020

NC STATE UNIVERSITY

NSF

Control HIL Microgrid Testbed @ NCSU

FREEDM SYSTEMS CENTER

GridWrx Lab

Communication Links

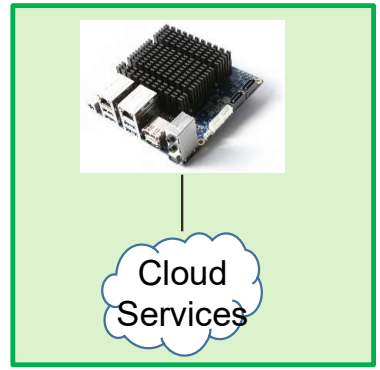
Modbus, DNP3, IEC 61850, Serial I/Os

Microgrid Controller

OPAL-RT

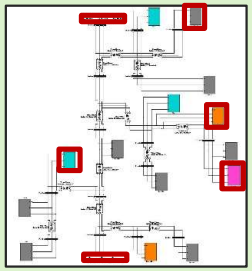
External Controller Interface

Embedded Industrial Controller

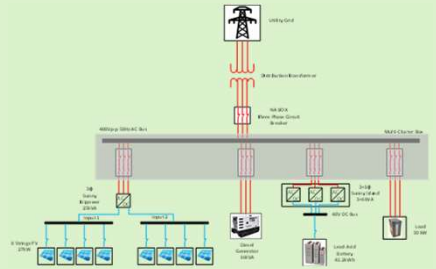


Cloud-based EMS Application

Community Microgrids



C & I Microgrids



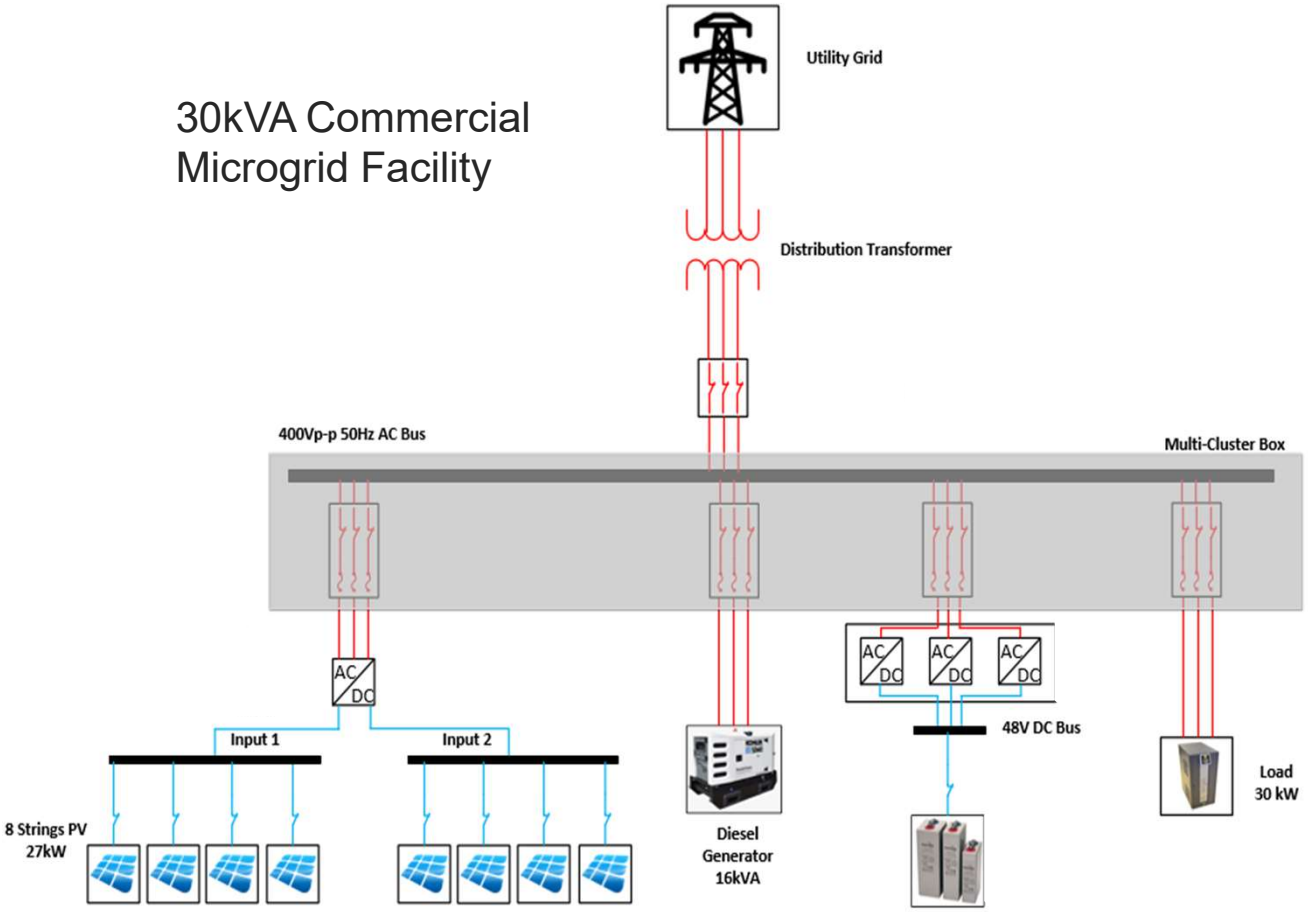
Serial I/Os

Microcontroller

Digital Relay

Research Background

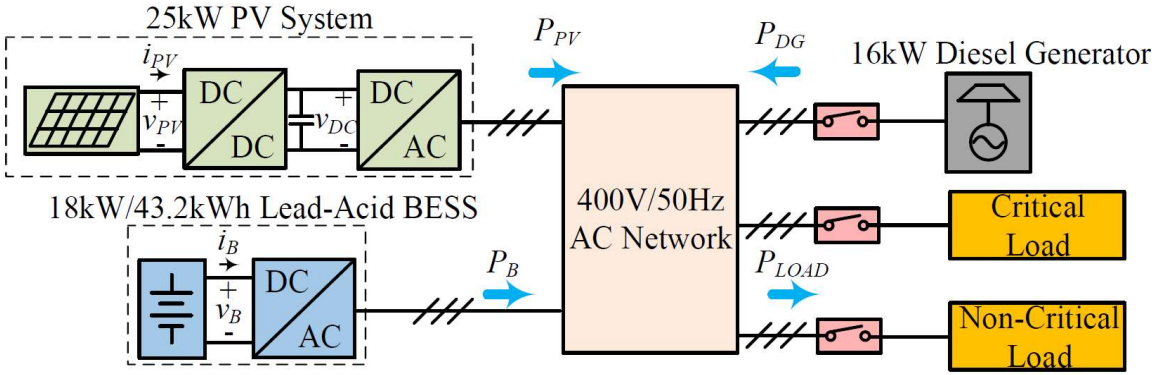
30kVA Commercial Microgrid Facility

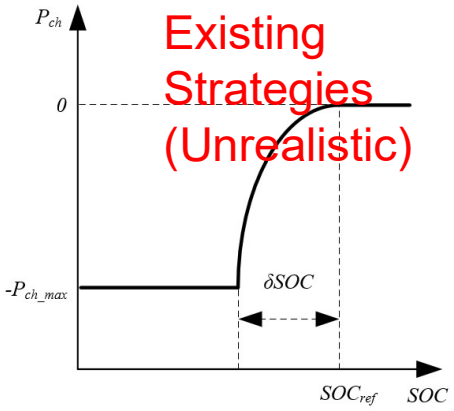


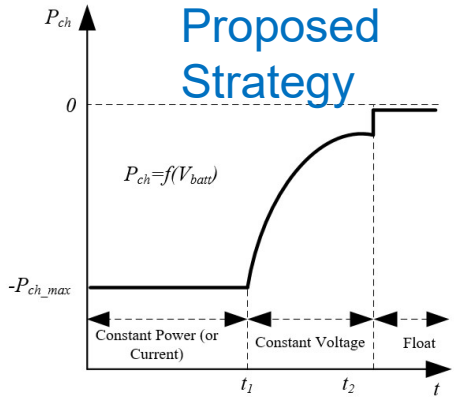
- High-fidelity hardware-in-the-loop (HIL) testbed that allows not only dynamic stability validation but also extended-time testing
  - Transient response of voltage and frequency (100μs ~ 1ms)
  - AC power (> 1s)
  - Energy storage dynamics, such as SOC and DC voltage (> 1s)
  - Master control logic (> 1s)

Parameters and control logics are extremely difficult to get

Background for Power Flow Control in Islanded Microgrids



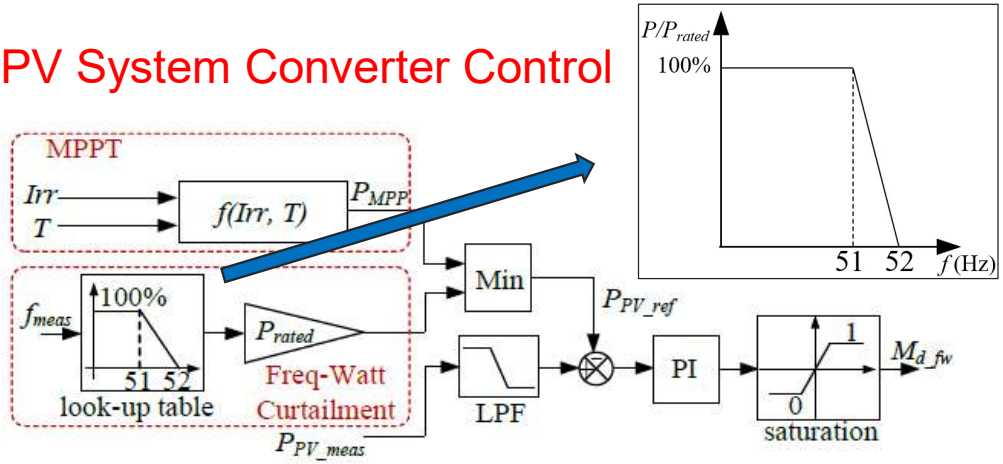




- **Main challenges: battery physical limits**
  - Battery DC voltage
  - Battery SOC
  - Battery output power
- **State-of-the-Art Approaches (Centralized or Decentralized)**
  - Pay little attention to battery DC voltage
  - Use $f(SOC)$ to control charging power during high SOC state
  - Consider no three-stage charging mechanism

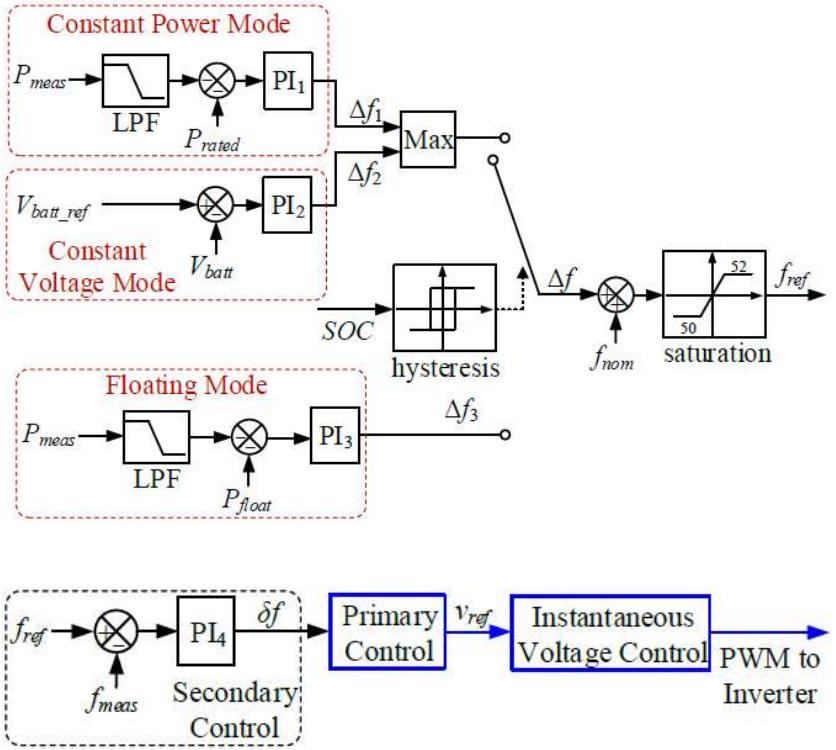
Frequency-Based Power Flow Control Design

PV System Converter Control

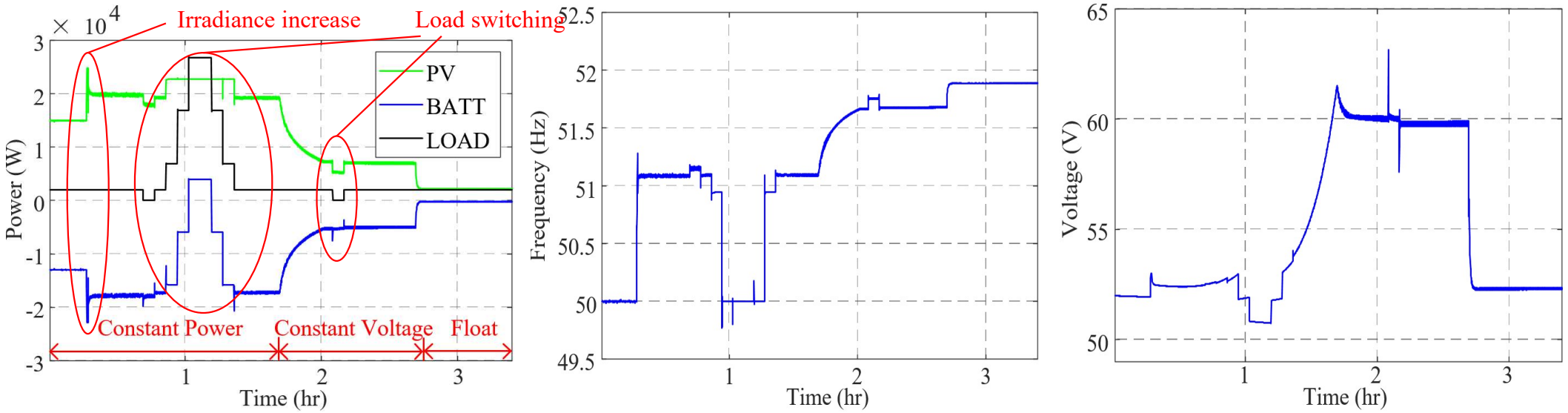


- PV curtailment corresponding to frequency
- Smooth mode switching between MPPT and frequency-based curtailment
- Frequency dictated by battery voltage and battery maximum charging power

Battery Inverter Secondary-Level Control



Real-Time Simulation Results



- Frequency-based three-stage charging control in islanded microgrid
- Avoid battery overvoltage on DC side
- Smooth mode transition with variable load consumption and PV generation

Conclusions/Recommendations

- **Proposes a microgrid power flow control that**
  - Coordinates power flow among solar system, energy storage system, diesel generator and load
  - Integrates battery management system that consider battery power, voltage and SOC constraints as well as three-phase charging mechanism
  - Maintains stability under different operating conditions (cloud cover, load disturbance, etc.)
- **To augment the control scheme for scale-up microgrids (including multiple solar/energy storage/diesel generators)**
  - Local control interactions
  - Supervisory control logic
  - Battery management coordination

References

1. Q. Long et al., "Community Microgrid Controller Evaluation using Hardware-in-the-Loop Testbed," in 2018 North American Power Symposium (NAPS), Fargo, ND, 2018, pp. 1-6.
2. F. Xie, H. Yu, Q. Long, W. Zeng and N. Lu, "Battery Model Parameterization Using Manufacturer Datasheet and Field Measurement for Real-Time HIL Applications," IEEE Transactions on Smart Grid, vol. 11, no. 3, pp. 2396-2406, May 2020.
3. Q. Long, H. Yu, F. Xie, W. Zeng, S. Lukic, N. Lu, D. Lubkeman, “Microgrid Power Flow Control with Integrated Battery Management Functions”, in 2020 IEEE Power & Energy Society General Meeting, Montreal, Canada, 2020.

Acknowledgement:
This research is funded by TOTAL S.A. and is made possible thanks to the great inputs from Dr. Wente Zeng, Mr. Gondras Victor-Emmanuel and Mr. Stanislas D’ Hurbache from TOTAL S.A.