

Successful Site Acceptance Tests for Microgrid-Integrated Battery Energy Storage

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Outline

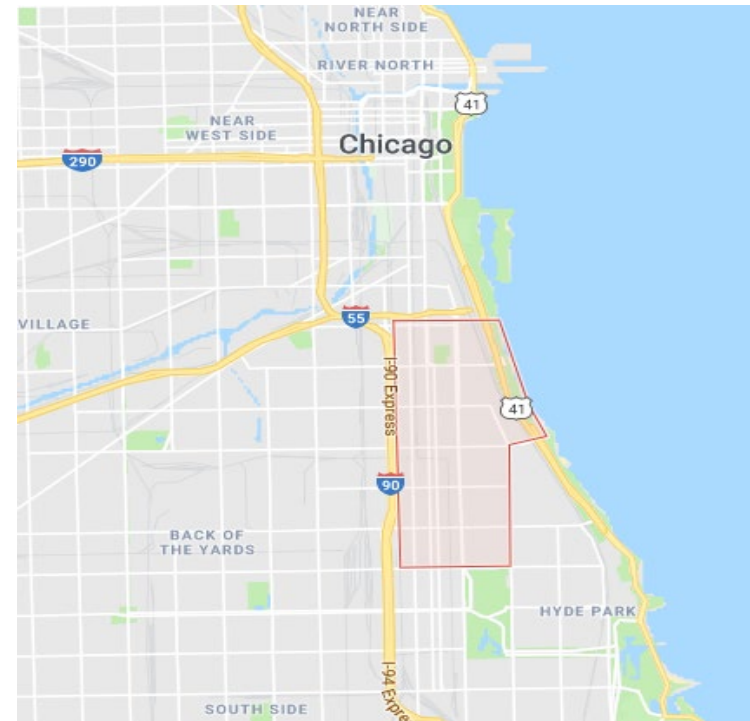
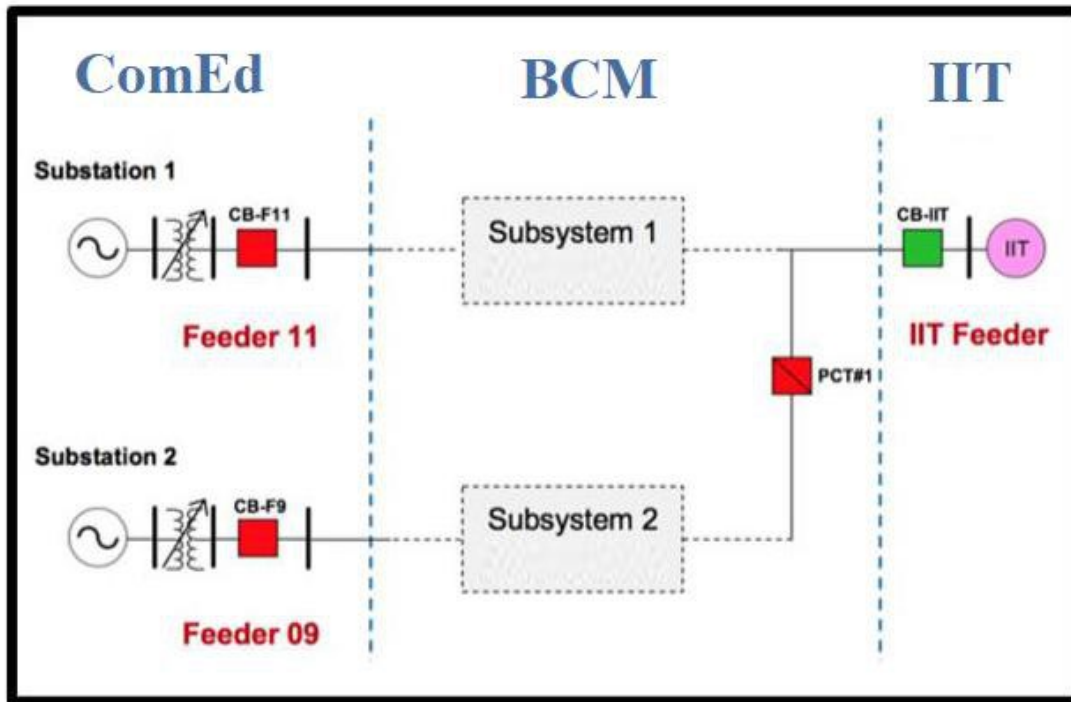
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Introduction

- Microgrids are anticipated to be one of the major components of future power grids.
- Microgrids aid power system reliability and resilience, allow for the integration of clean renewable energy.
- High penetration of renewable generation; i.e. solar PV, has resulted in new challenges in power systems, mainly due to their inherent variability.
- Battery energy storage systems (BESSs) may be leveraged to:
 - store the solar PV output in periods of high production,
 - discharge during periods of low generation and high-power demand,
 - capture the solar PV variability.
- This concept forms the basis of many recently developed PV-battery integration systems.

Bronzeville Community Microgrid (BCM)

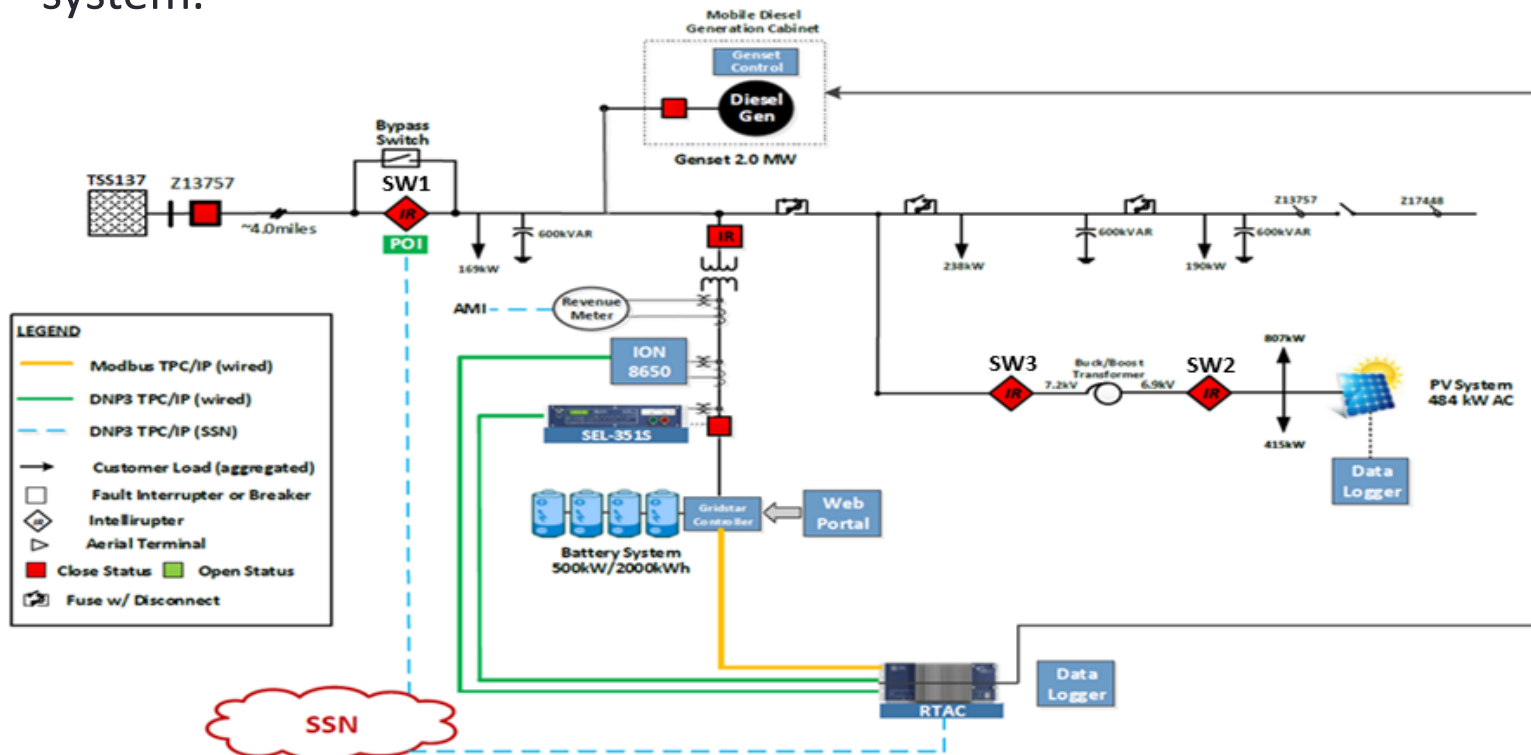
- ComEd is developing community microgrid in the South Side Chicago neighborhood of Bronzeville.
- The BCM is adjacent to the Illinois Institute of Technology (IIT) campus microgrid, which together create the world's first microgrid cluster.



Source: <https://www.google.com/maps>

One-line Diagram of the BCM

- The PV system
 - rooftop installations on 17 buildings,
 - nominal AC capacity of 484 kW,
 - DC capacity of approximately 587 kW,
 - controlled and communicated with via a single point of connection.
- The BESS unit is a utility-owned front-of-meter 500 kW/2 MWh DC-AC system.



Site Acceptance Tests (SATs)

- To ensure the BCM operation complies with interconnection standards, such as IEEE 1547, and that BESS and smart functionalities of inverters can be utilized to alleviate adverse effects of PV fluctuation, a series of tests must be conducted on both BESS and PV systems.
 - **P/Q Priority Test**
 - **Volt/VAR Control Test**
 - **Power Factor Control Test**
- Successful passing of the SAT indicates the potential of system controllers to implement advanced algorithms that continuously maintain BCM operation in compliance with interconnection standards.

P/Q Priority Test

Objective:

To ensure that the BESS can give higher priority to either its real power output or its reactive power output if commanded to do so.

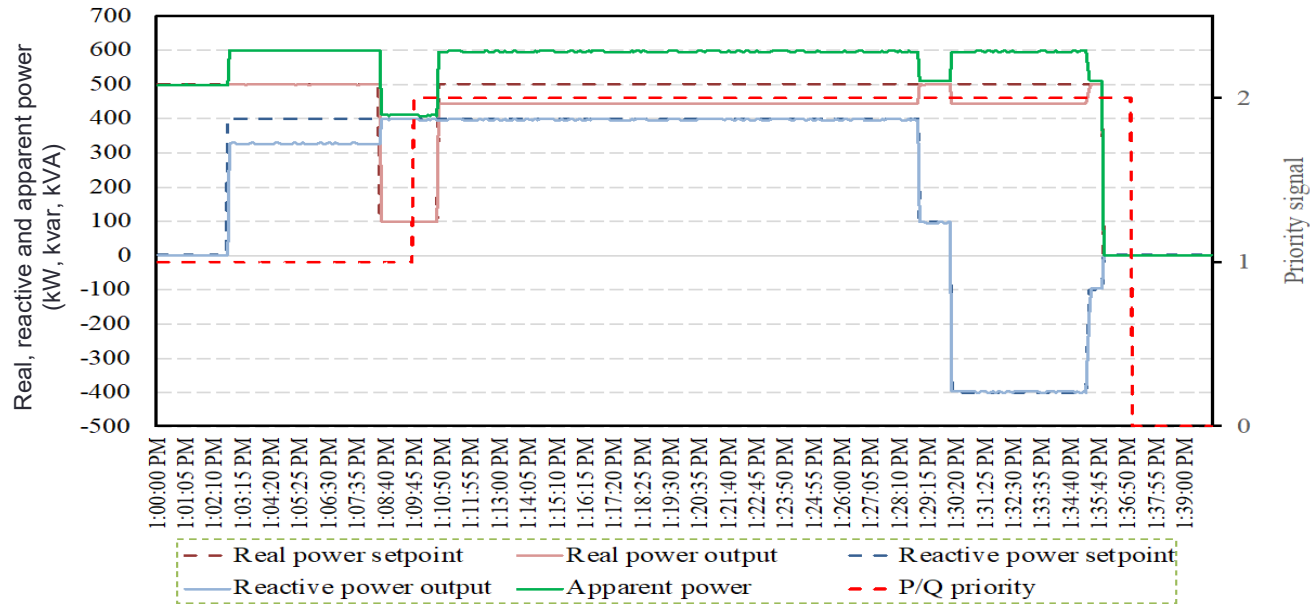
Priority signal:

- The priority signal is set to real power → the inverter controller is prompted to follow the real power setpoint.
- The priority signal is set to reactive power → the inverter controller is prompted to follow the reactive power setpoint.
- The inverter reaches its apparent power capacity → the quantity that is not prioritized will be curtailed.

Test setup:

- Priority signal = 1 → The priority is with the BESS real power.
- Priority signal = 2 → The priority is with the reactive power.

P/Q Priority Test - Real Power



1:00:00 - 1:09:45 : The priority signal = 1

→ The BESS real power output will be prioritized.

1:00:00 - 1:02:10 : The BESS reactive power setpoint = zero

→ No reactive power is produced by the BESS

→ The BESS real power output follows the real power setpoint of 500 kW

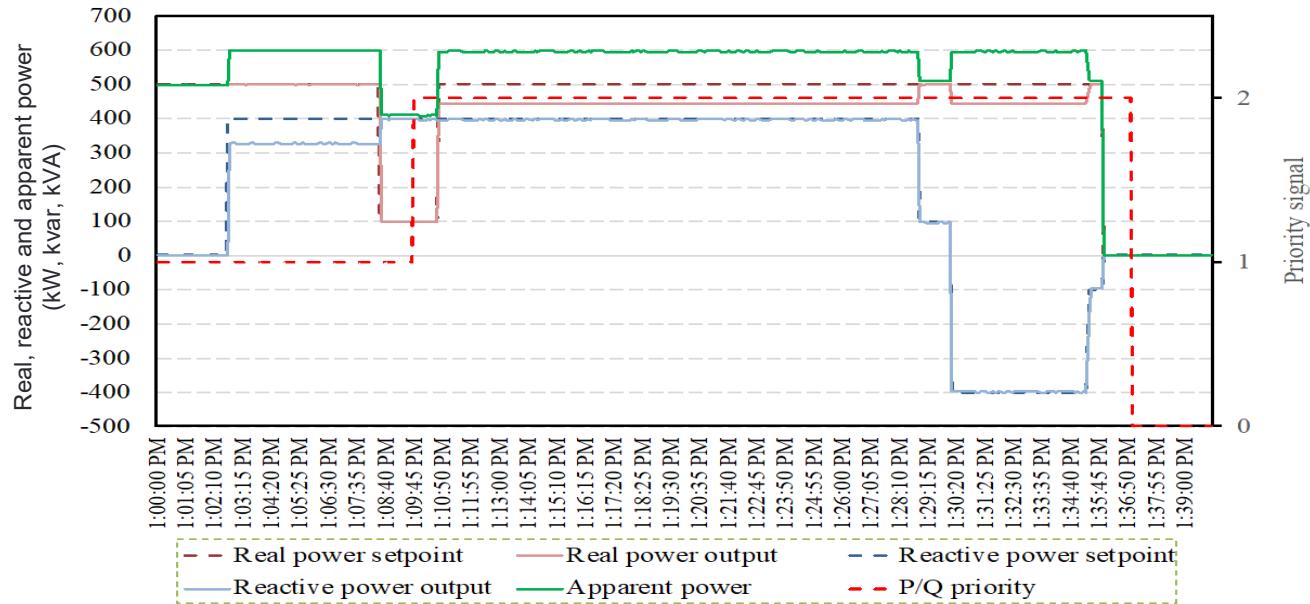
→ The apparent power output of the BESS remains at 500 kW.

1:02:10 - 1:09:45 : The reactive power setpoint of BESS = 400 kvar

→ The apparent power capacity of BESS = 600 kVA & the priority = real power

→ The reactive power output cannot reach 400 kvar and is curtailed.

P/Q Priority Test - Reactive Power



1:09:45 - 1:36:50 : The priority signal = 2

→ The BESS reactive power output will be prioritized.

1:09:45 - 1:10:50 : The real power setpoint = 100 kW & reactive power setpoint = 400 kVA

→ Since the resulting apparent power = 412.31 kVA < nominal BESS size of 600 kVA

→ Real and reactive power outputs follow their corresponding setpoints.

1:10:50 - 1:36:50 : The real power setpoint = 500 kW

→ The resulting apparent power > the nominal BESS size of 600 kVA

→ since the priority signal = reactive power, the BESS real power must be curtailed.

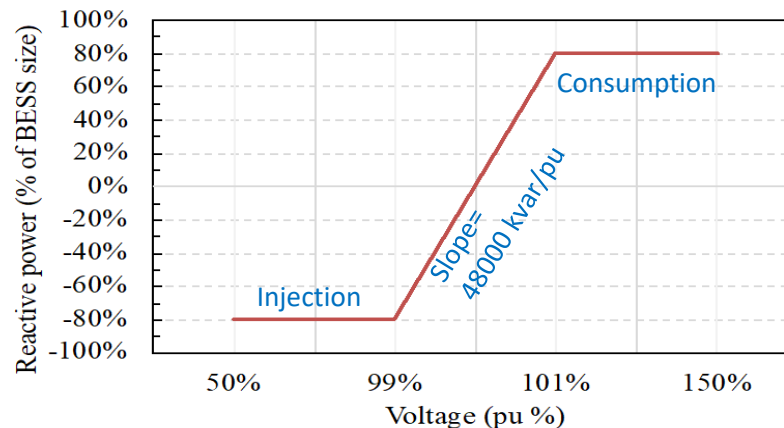
Volt-Var Control Test

Objective:

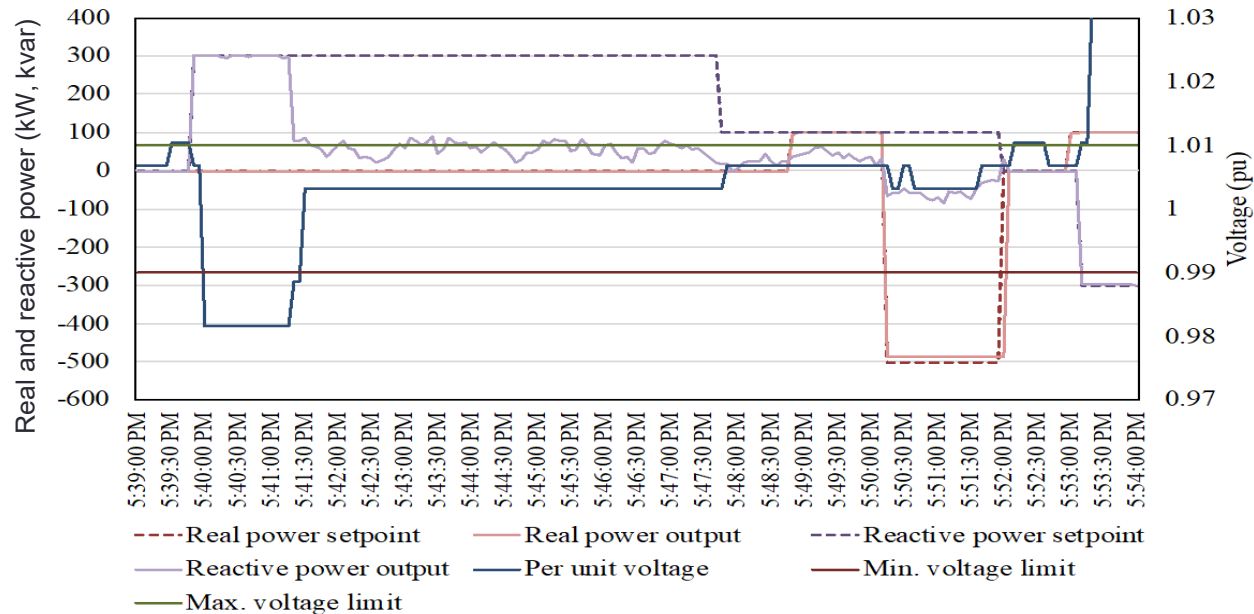
To evaluate the reactive power capabilities of the BESS in response to voltage variations.

A four-point Volt-var control curve:

The BESS inverter in Volt-var control mode → its reactive power output will vary according to the specific Volt-var curve.



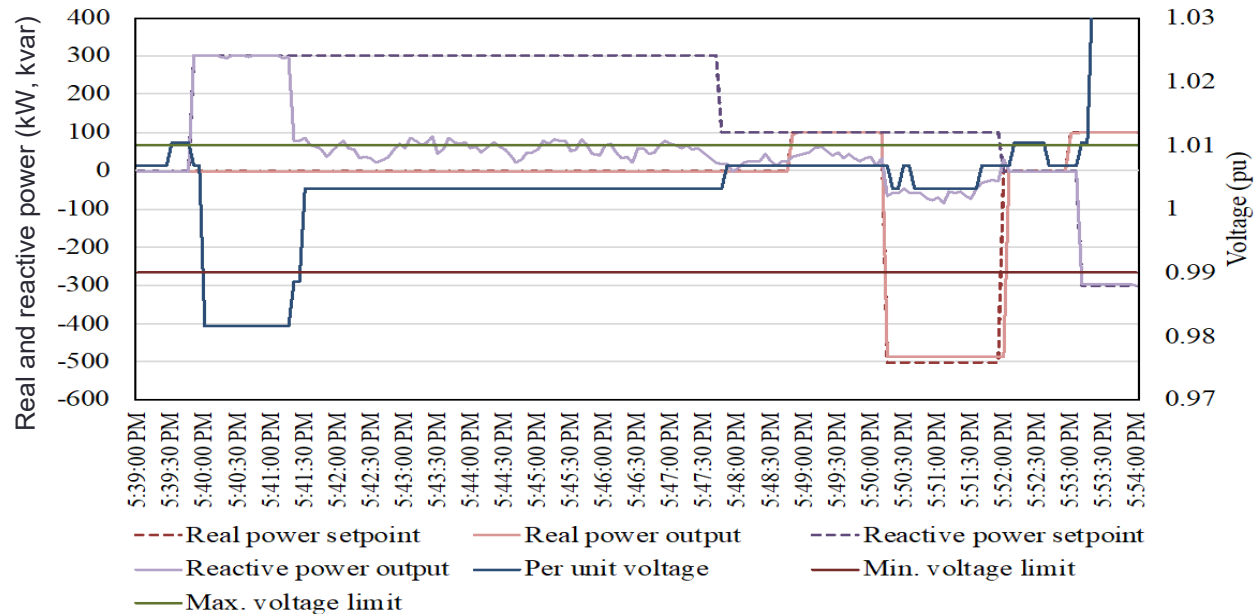
Volt-Var Control Test (cont'd)



5:41:30 : The Volt-var control mode of the inverter is turned on

- The reactive power stop following its setpoint
- Since the voltage < 0.99 pu
- The reactive power consumption reduces, to reach 80% of its kVA size
- The voltage bounces back to within the 1 percent deviation from the nominal value
- The inverter's reactive power output varies according to the linear regime in the left-hand-side of a four-point Volt-var control curve.

Volt-Var Control Test (cont'd)



5:50:00 : The reactive power injection

→ Prevents voltages from dropping below 0.99 pu.

5:52:00 : The Volt/VAR control mode is turned off.

→ The reactive power injection increased prompting voltage to rise by 5:53:30.

Power Factor Control Test

Objective:

To verify the ability of the BESS inverter to follow a leading and lagging power factor setpoint.

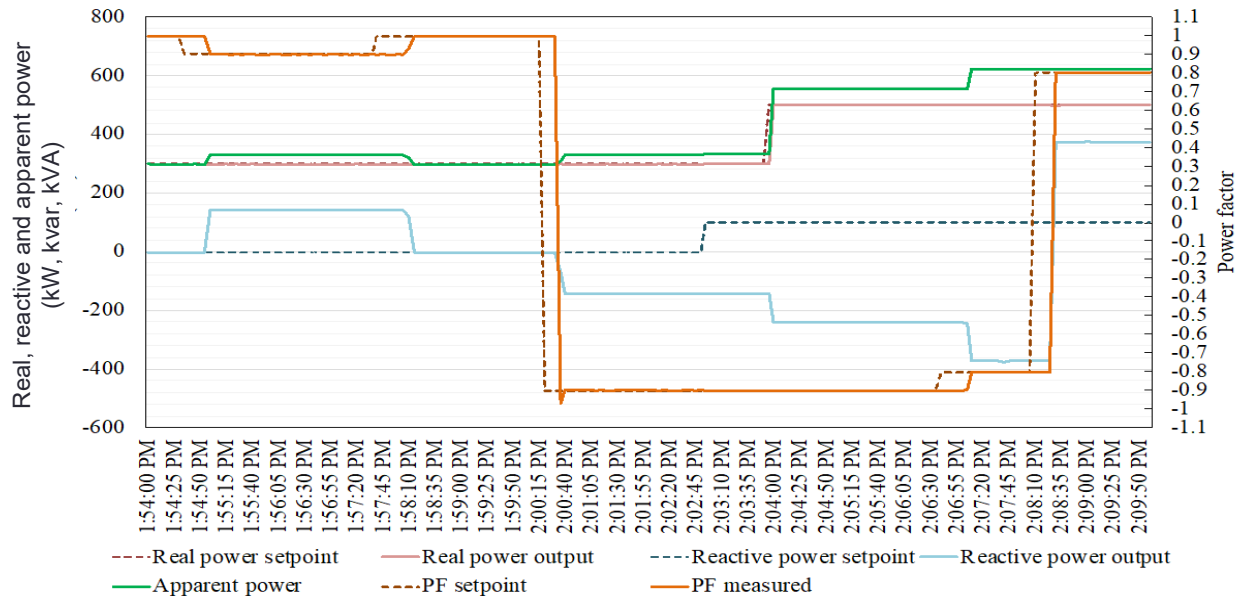
Power factor mode:

- The BESS is set to power factor mode → its reactive power is adjusted automatically so that regardless of the BESS real power output, the BESS power factor reaches its given setpoint.

Initial setup:

- The real power setpoint = 300 kW
- The power factor setpoint = unity
- The reactive power output of the BESS inverter stays at 0 kvar.

Power Factor Control Test (cont'd)



1:54:25 : The inverter power factor setpoint = 0.9

→ The reactive power consumption of the inverter reaches 144 kvar by 1:55:15.

1:57:45 : The power factor setpoint = unity

→ With a delay, the inverter reactive power output goes back to 0 to ensure the power factor measured conforms to the unity power factor command.

2:00:15 : The power factor setpoint = 0.9 leading

→ The reactive power injection of the inverter reaches 144 kvar at 2:00:40.

Conclusion

- One of the important goals of the BCM project is to control the inherent fluctuations of PV technologies via the flexibility of BESS.
- Successful implementation of complex PV-battery control algorithms relies upon smart functionalities of inverters which, in turn, require that PV and BESS systems follow their setpoint command accurately.
- This paper summarized the successful completion of the P/Q priority test, the Volt/Var control test, and the power factor control test.
- Detailed analysis revealed that in these three tests, the BESS inverter successfully followed the given commands.
- Successful passing of SAT is a steppingstone to future work that will implement advanced algorithms via pertaining controllers in order to continuously maintain BCM operation in compliance with interconnection standards.

Thank you

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