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# Optimal Volt-Var and Freq-Watt Inverter Settings for Islanded Microgrid

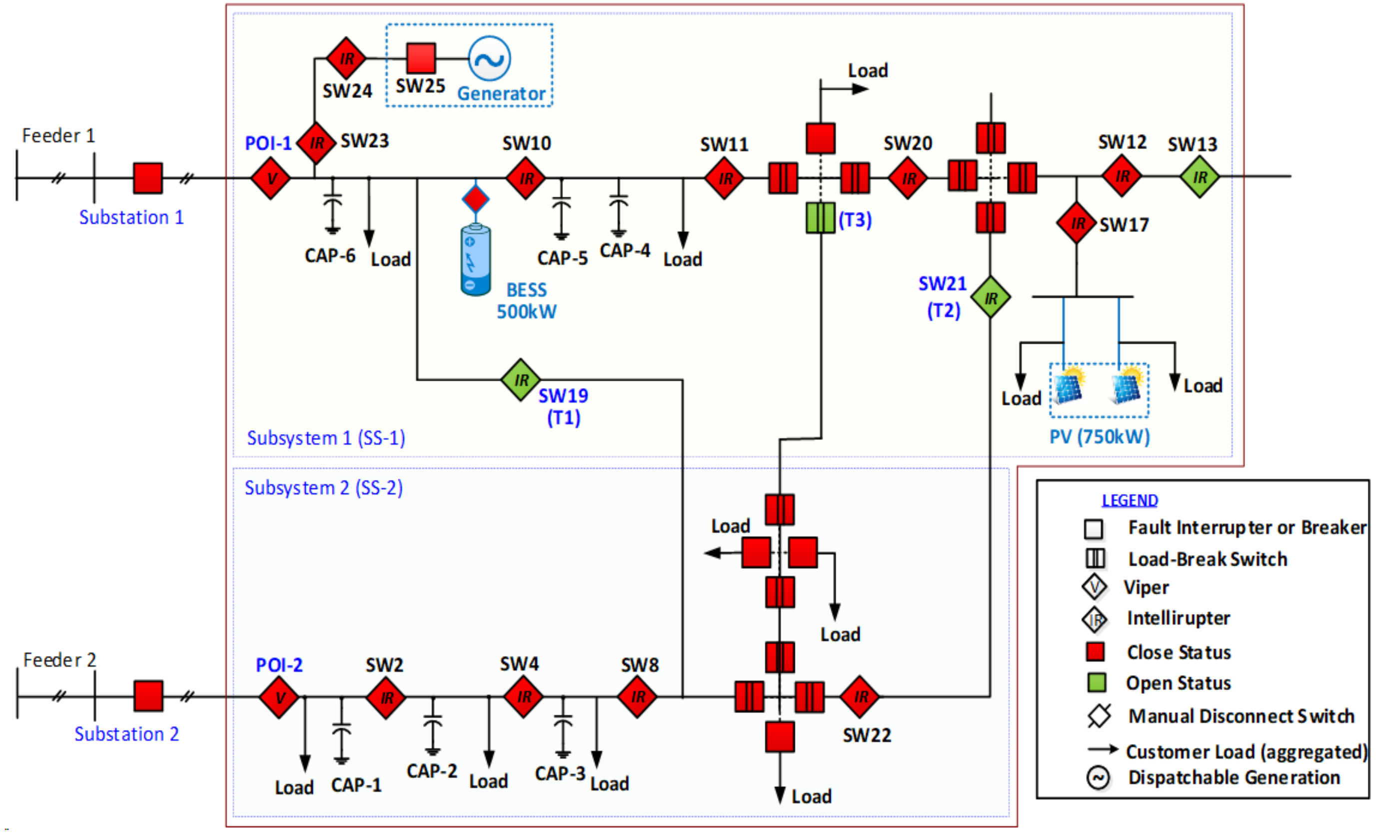
Smart Grid Emerging Technology | Honghao Zheng

# Background and Motivation

- ComEd's Bronzeville Community Microgrid is being powered by 750 kW solar PV, 500kW/2000kWh Battery Energy Storage System and 4.8 MW gas generator and has peak load around 7MW.
- Microgrid enables reliability, resiliency and sustainability, however, there are challenges in operating a microgrid especially in islanded mode – voltage and frequency fluctuations.
- Renewables such as solar PV are interfaced with the grid via inverters, thus referred to as inverter-based resources.
- Per IEEE standard 1547-2018 – DERs are expected to provide Voltage and Frequency support capability for reliability.
- This paper explores these fundamental challenges in islanding BCM and proposes an approach for optimal inverter settings for DERs to improve microgrid dynamic performance of BCM

# System Model

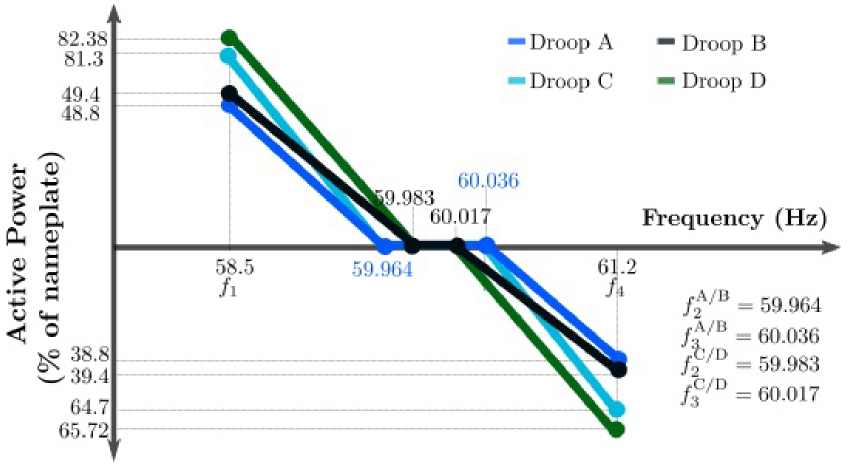
- BCM consists of two 12 kV distribution feeders named as subsystem 1 (SS-1) and subsystem 2 (SS-2).
- SS1 connects at POI-1
- SS2 connects at POI-2
- The two subsystems are interconnected via three normally open tie switches T1, T2 and T3
- The subsystem SS-1 has a 4.8 MW gas generator, a utility scale 500 kW/2000 kWh BESS unit, and a 750 kW solar PV
- In interconnected mode, total peak load is approximately 7 MW.



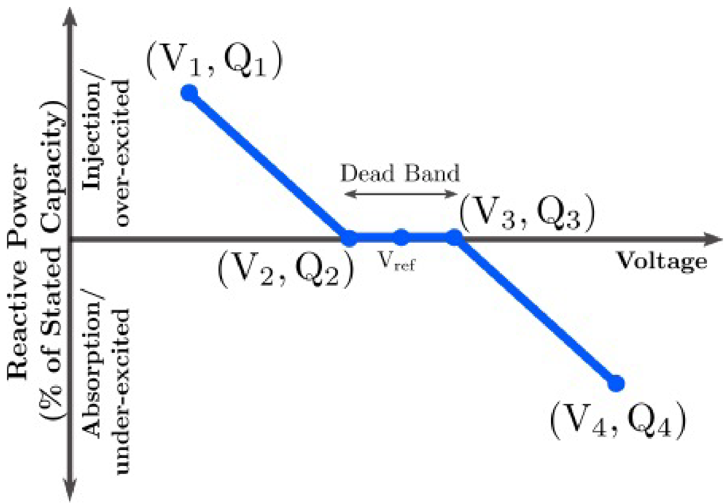

Single line diagram of Bronzeville Community Microgrid

# Proposed Method (1/2)

- IEEE Standard 1547-2018[1] defines smart inverter functions for enabling grid support and ride through capabilities of inverter-based grid integrated DERs.
- Two key functions with objective of identifying optimal settings for the inverters in microgrids to support voltage and frequency and enhance the microgrid operational robustness are explored:
  - Frequency Watt Droop Function
  - Volt-var (Voltage Reactive Power ) Droop Function
- Droop settings are in accordance with std. 1547-2018.




Frequency Watt Droop Function Curves[1]




Volt-var Droop Funciton Curve[1]

1 IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

# Proposed Method (2/2)

- Table 1 shows the frequency droop settings and Table 2 shows four voltage droop settings considered in this study.

| $f_i$ | Range of Freq (Hz) | $P_i$ |
|---|---|---|
| $f_1$ | 58.5 | $P_{pre} + P_{UF}$ |
| $db_{UF}$ :$f_2$ | 59.964-59.983 | 0 |
| $db_{OF}$ :$f_3$ | 60.017-60.036 | 0 |
| $f_4$ | 61.2 | $P_{pre} + P_{OF}$ |

Table 1- Frequency droop settings considered for DER smart inverter

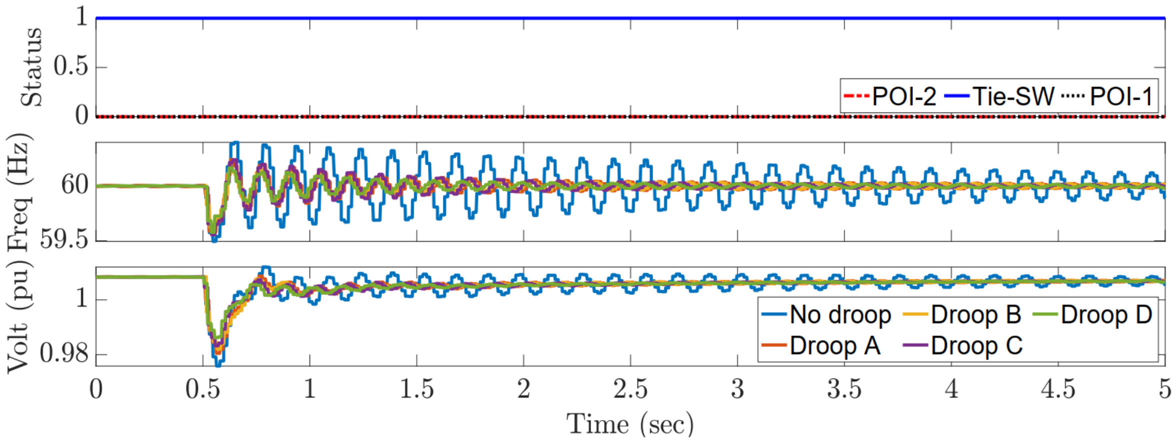
| | Droop A | | Droop B | | Droop C | | Droop D | |
|---|---|---|---|---|---|---|---|---|
| $V_i$ | V (pu) | $Q_i$ | V (pu) | $Q_i$ | V (pu) | $Q_i$ | V (pu) | $Q_i$ |
| $V_1$ | 0.92 | *44% $S_{rated}$, inject* | 0.92 | *70% $S_{rated}$, inject* | 0.92 | *44% $S_{rated}$, inject* | 0.92 | *70% $S_{rated}$, inject* |
| $V_2$ | 0.98 | *0* | 0.98 | *0* | 0.99 | *0* | 0.99 | *0* |
| $V_3$ | 1.02 | *0* | 1.02 | *0* | 1.01 | *0* | 1.01 | *0* |
| $V_4$ | 1.08 | *44% $S_{rated}$, absorb* | 1.08 | *70% $S_{rated}$, absorb* | 1.08 | *44% $S_{rated}$, absorb* | 1.08 | *70% $S_{rated}$, absorb* |

Table 2- Voltage droop settings considered for DER smart inverter

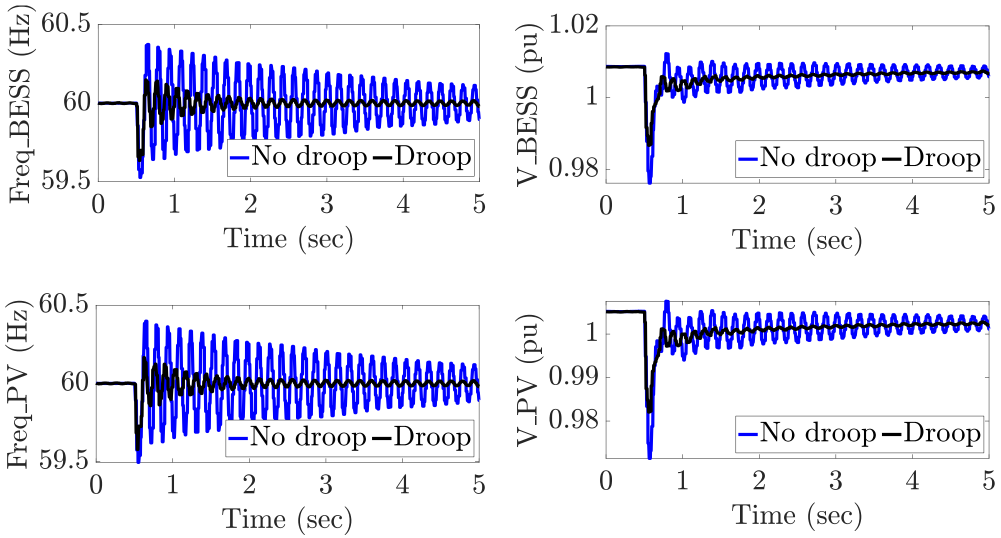
# Results (1/3)

### *Case 1: Step Increase in Load during Islanding*

- Without frequency/watt droop function, the frequency response has a transient peak of 60.4226 Hz i.e., 0.4226 Hz above nominal.
- This deviation from the nominal is reduced with droop settings A – **D** by approximately 40.8%, 61.73%, 43.63%, and **63.64%** respectively.
- Similarly, voltage drops **0.976 pu** without droop settings, and with droop settings A – **D**, voltage drops to 0.98 pu, 0.982 pu, 0.983 pu and **0.986 pu**, respectively
    - Droop settings D was thus picked as the most optimal setting and used for further testing
- Both voltage and frequency recovers as gas generator governor responds




Case 1-system response at generator POC without and with different droop settings

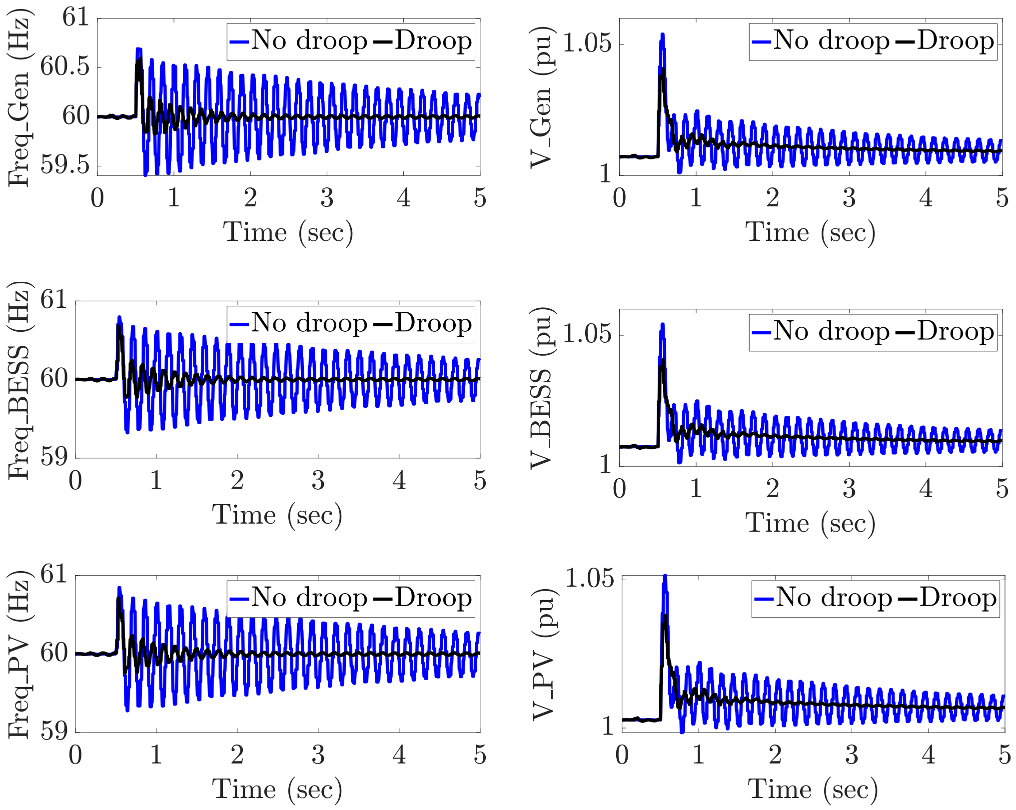



Case 1-voltage and frequency without and with proposed droop control

# Results (2/3)

- ***Case 2: Step decrease in load during Islanding***

- The frequency response transient peak reduces by approximately 14%.
- The voltage transient peak reduced from 1.054 to 1.04 pu for generator, from 1.054 to 1.041 pu for BESS, and from 1.05 to 1.038 pu for PV.
- Voltage-var and Frequency-watt droop function made the system voltage and frequency response more robust.
  - Frequency and voltage drop is smaller and oscillations damp faster.
- Both voltage and frequency recovers as gas generator governor responds

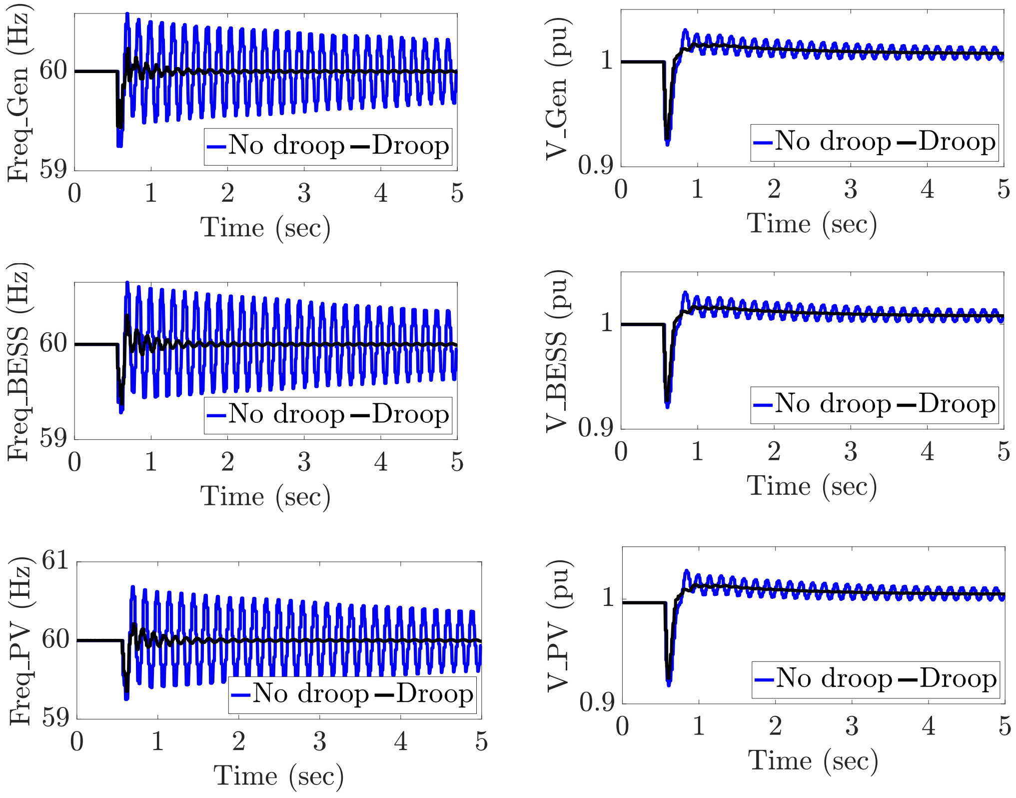



Case2-voltage and frequency without and with proposed droop control

# Results (3/3)

- ***Case 3: Unplanned Islanding***

- The active and reactive power at the POI-1 before islanding are positive, thus the load in the MG is more than generation.
- Thus, at the instant of islanding there is a dip in frequency and voltage.
- System response compared to no droop case.
- Voltage-var and Frequency-watt droop function made the system voltage and frequency response more robust.
  - Frequency and voltage drop is smaller and oscillations damp faster.
- Both voltage and frequency recovers as gas generator governor responds




Case3-voltage and frequency waveforms without and with proposed droop control

# Conclusion

- An approach for optimal volt-reactive power and frequency-active power droop settings has been presented for inverter-based resources connected to a microgrid
- The microgrid voltage and frequency response during the transient conditions can be improved by appropriate volt-reactive power and frequency-active power droop settings especially during an islanded microgrid mode
- Successfully tested and demonstrated the improvement under multiple scenarios such as load rise, load drop  during islanded mode and microgrid islanding
  - Frequency and voltage deviations are minimized
  - Frequency and voltage recovery is faster
  - The generator oscillation is also damped faster
- Optimal parameters for the smart inverter functions such as volt-reactive power and frequency-active power droop settings will enable more robust and stable operation of microgrid in islanded mode and transition of modes

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# Thank you

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