CERTS Microgrid

Microgrid Workshop

17 June 2005

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LBNL, SNL

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Northern Power Systems

Tecogen

Youtility Inc

American Electric Power

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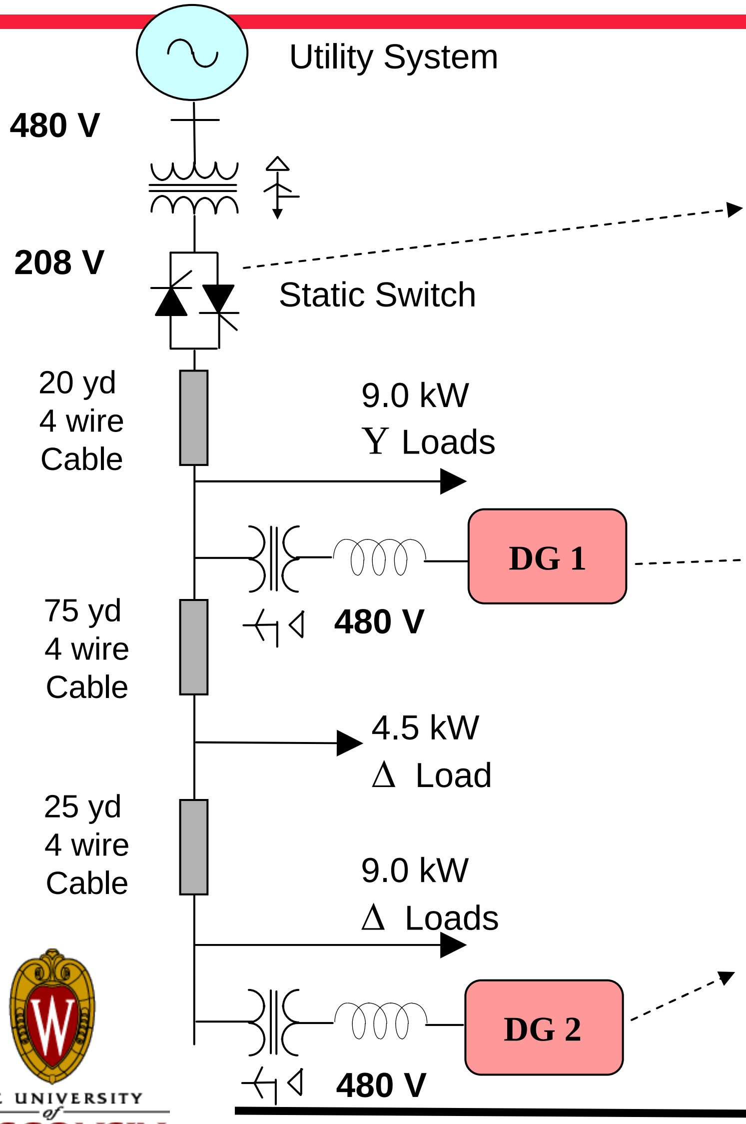
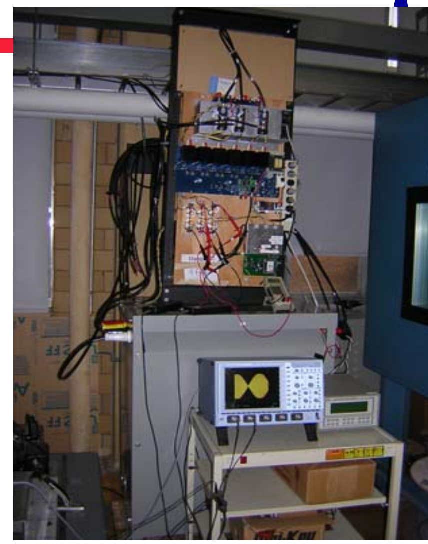
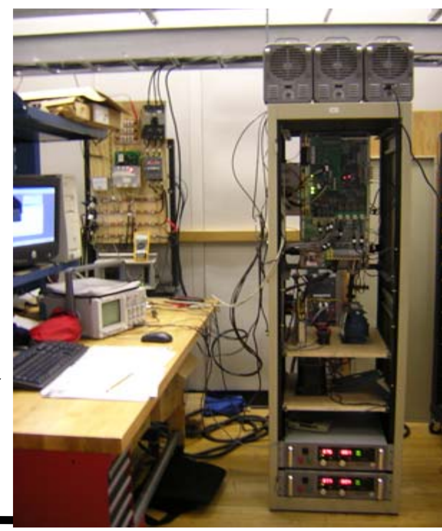
Generic Microgrid:

- Clusters sources with loads
- Single controllable unit to utility
- Smoothly move between parallel and islanded modes

University-of-Wisconsin's μgrid



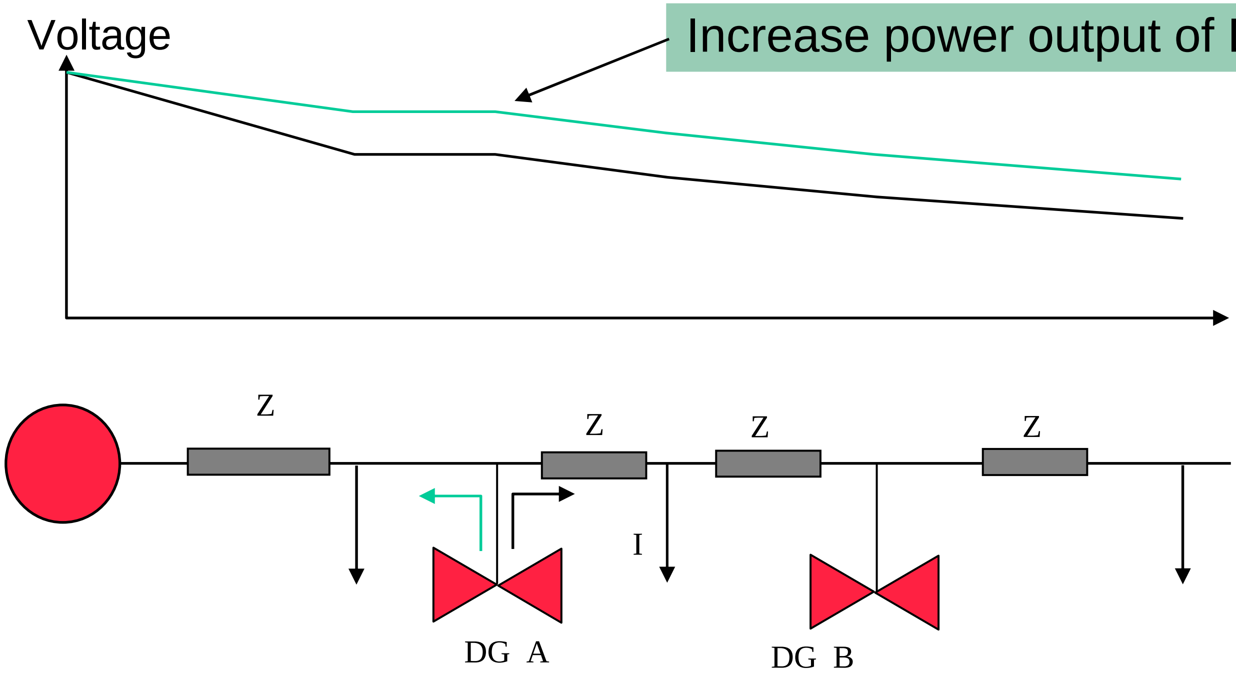




Major Microgrid Issues

- **Stability** (interactions between grid and other microsources)
- Power balance when islanding (load sensors & fast re-dispatch of microsource)
- Custom site engineering

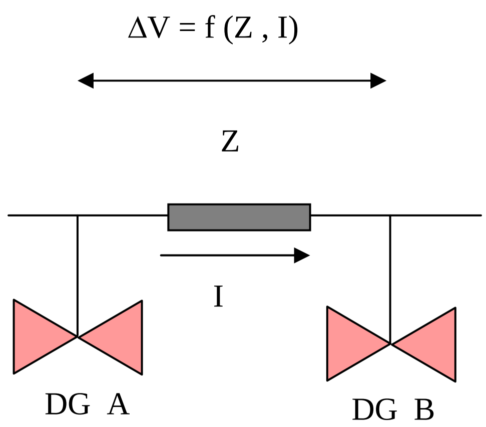
Stability: Fixed Power Factor

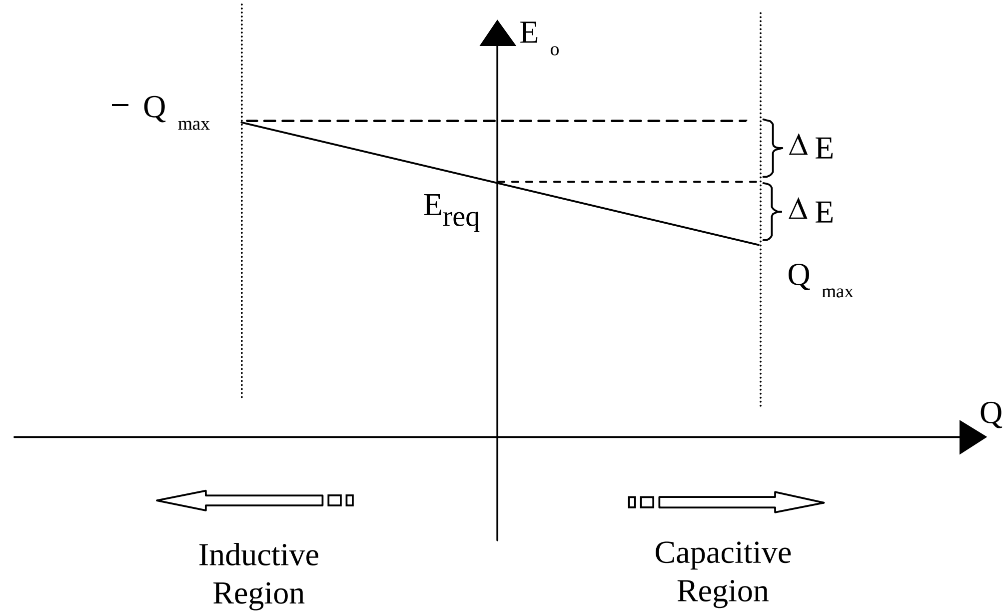


- $\Delta V = f (Z , I)$
- Change in power output changes ΔV
- Resulting in change in µsource current
- Can result in change in ΔV
- Oscillation in P and V

Need to control voltage at each inverter

CERT's Q versus E Droop for stability



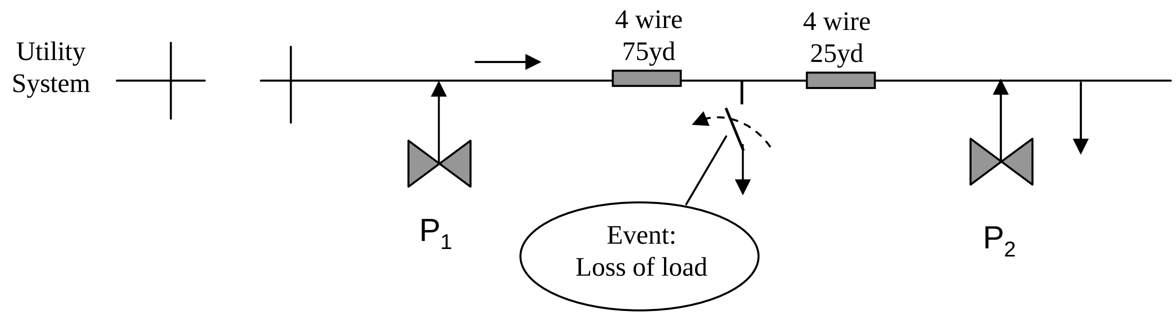


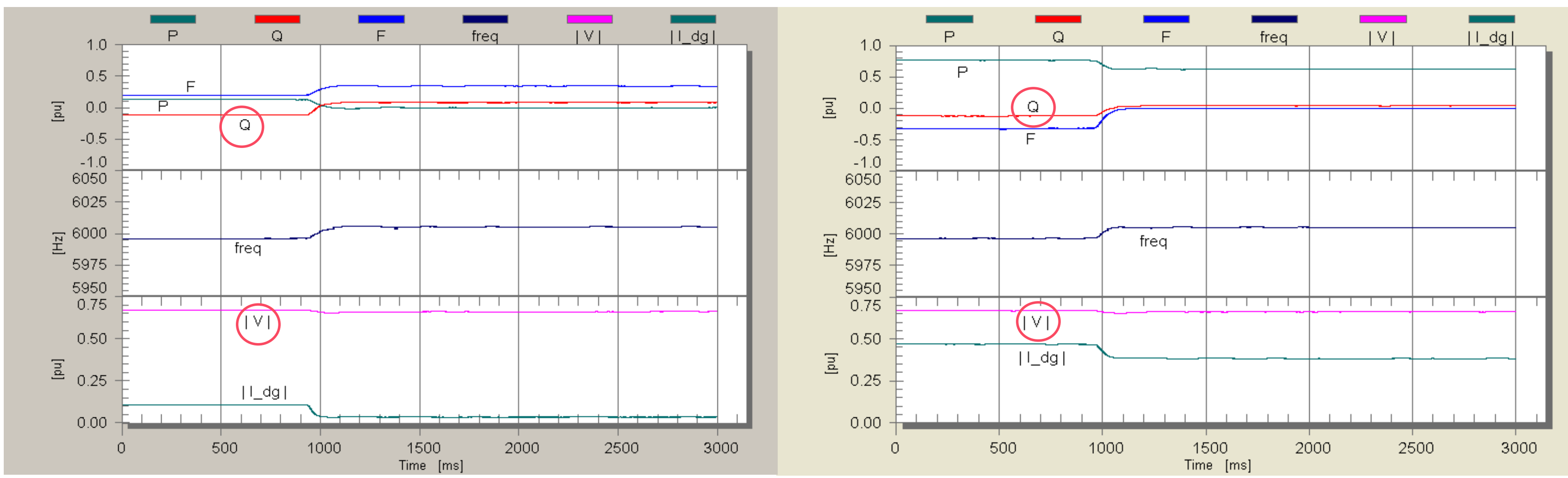
$$E_o = E_{req} - m_Q Q$$

$$m_Q = \frac{\Delta E}{Q_{max}}$$

- **Voltage difference between sources is function of impedance and current between them.**

UW’s μgrid traces: Voltage Regulation





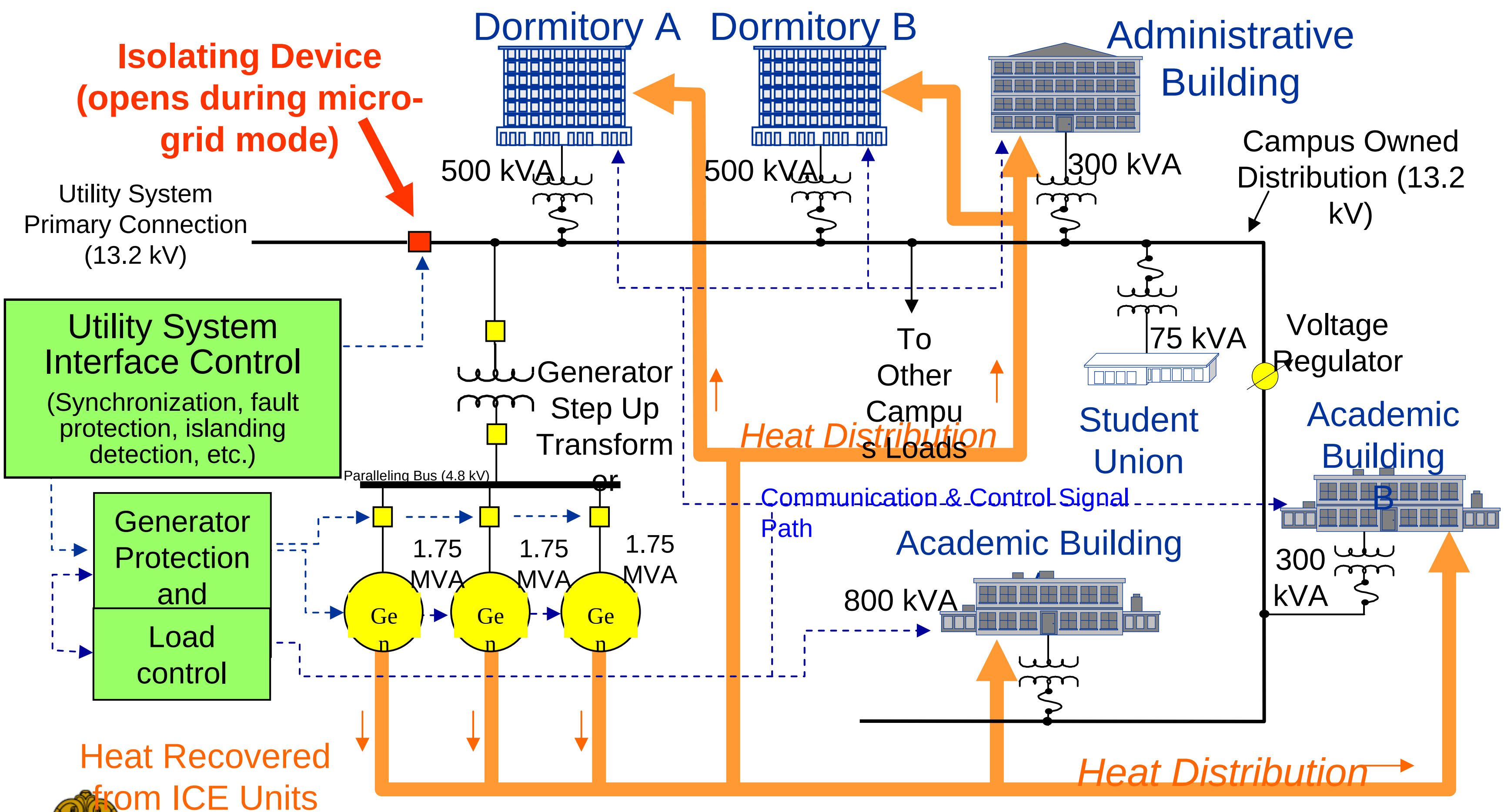
Unit P_1

Unit P_2

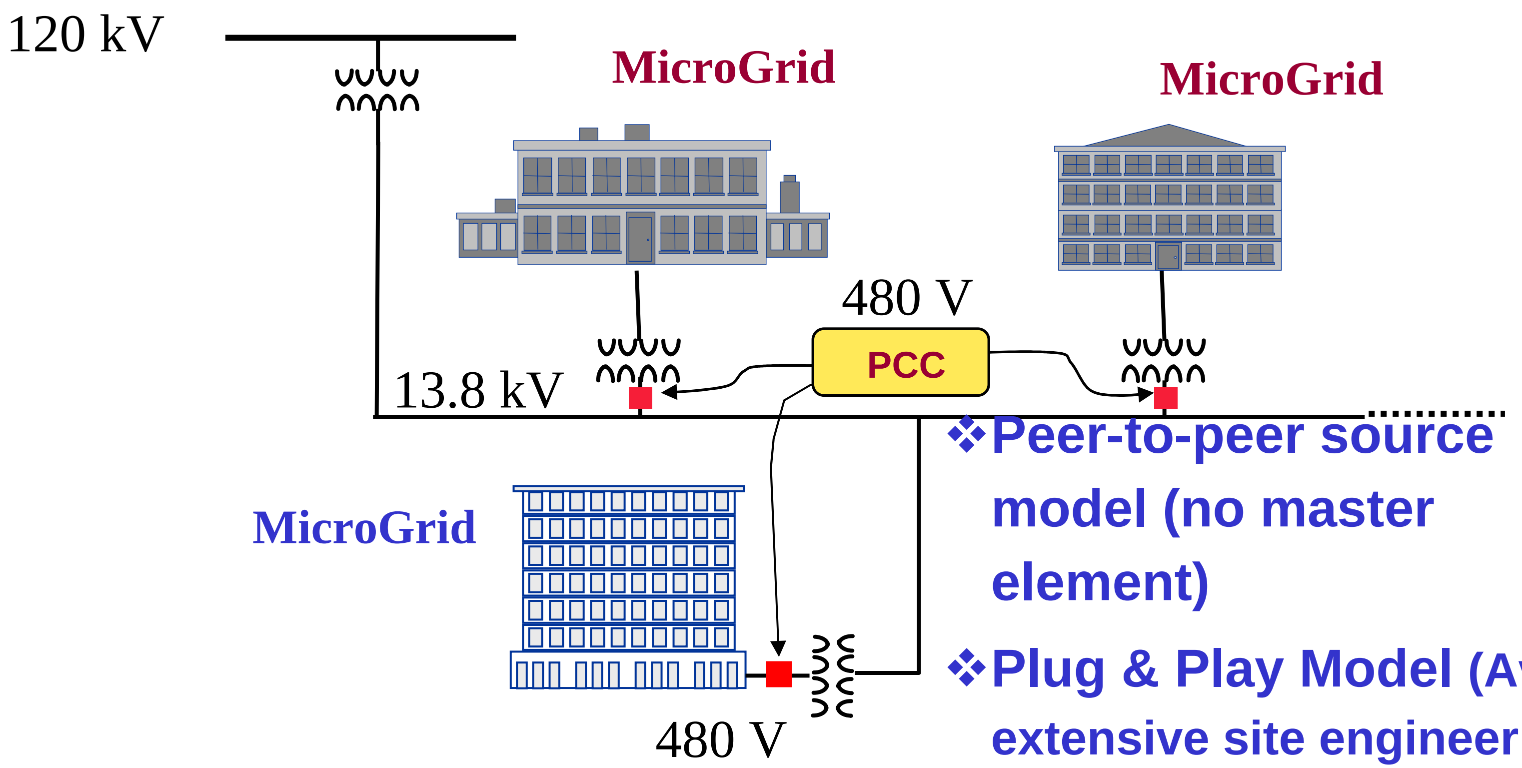
Major Microgrid Issues

- Stability (interactions between grid and other microsources)
- Power balance when islanding (load sensors & fast re-dispatch of microsource)
- Custom site engineering

Power balance Problem: Fast control



CERTS MicroGrid



- ❖Peer-to-peer source model (no master element)
- ❖Plug & Play Model (Avoids extensive site engineering & allows placement near heat load)
- ❖Power balancing using local information

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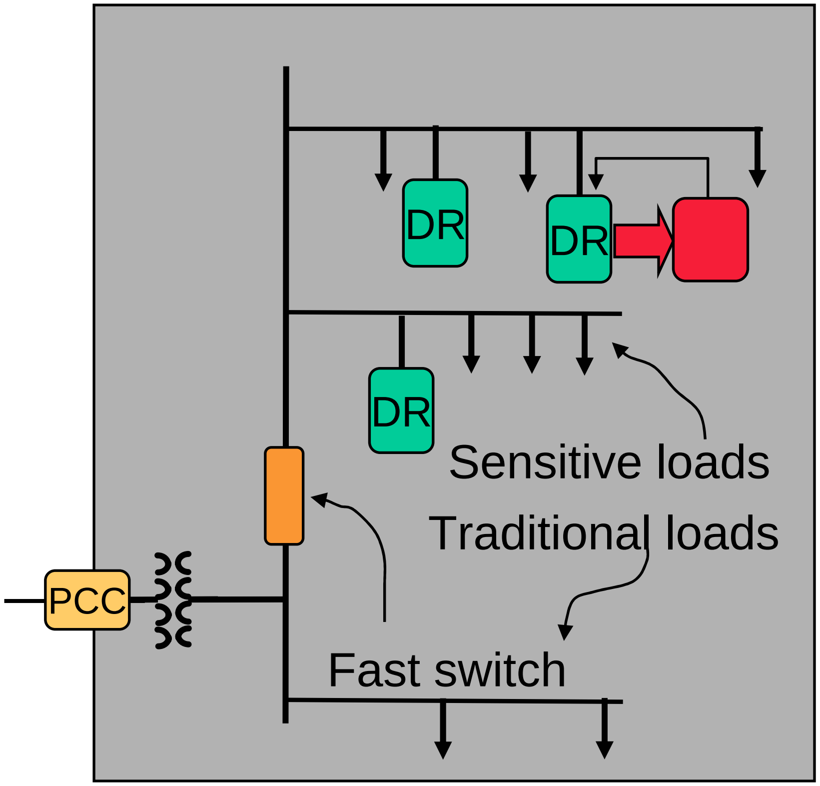
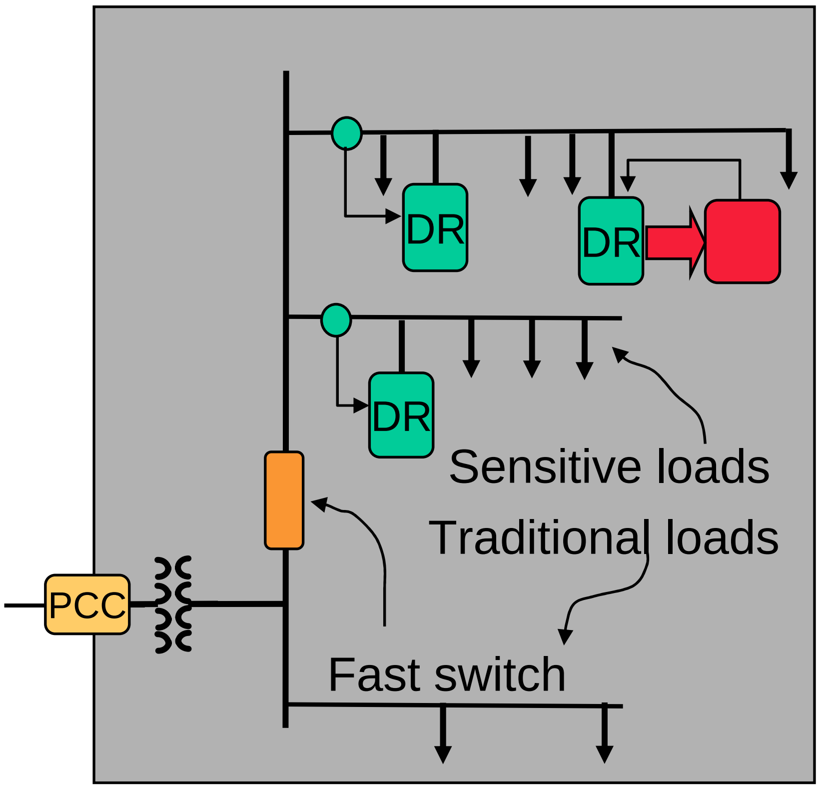
CERTS Microgrid Configuration



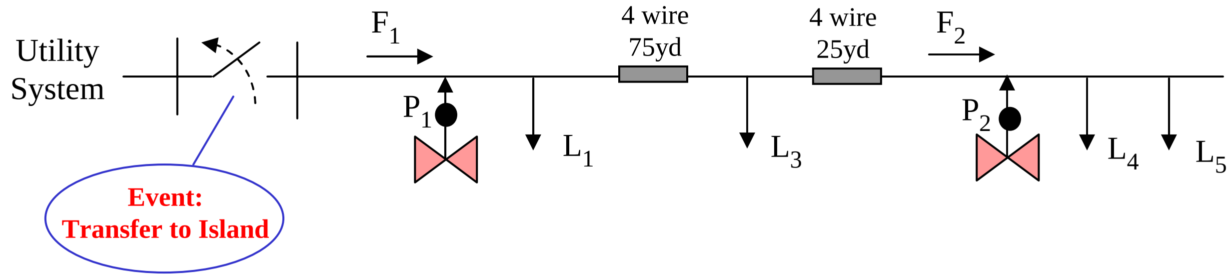
- Separate load types (sensitive)
- Fast islanding switch
- Single PCC (1547 LAPS)
- No load control required

Operational Concept



- Intentional islanding
- No communications for load balancing
- Load balancing uses local information at each unit
- Automatic re-synchronizing of the fast switch

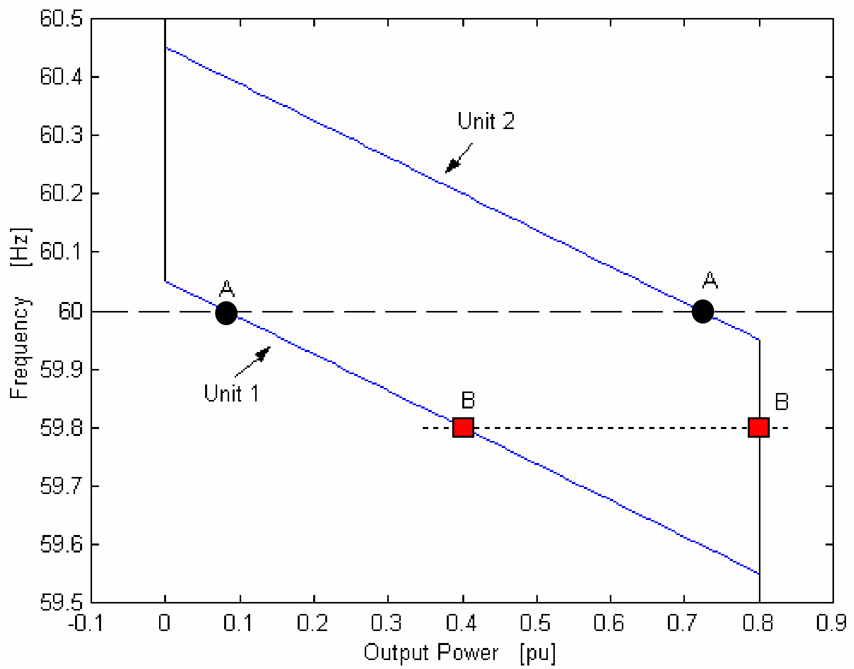
Load balancing: P versus Frequency Droop



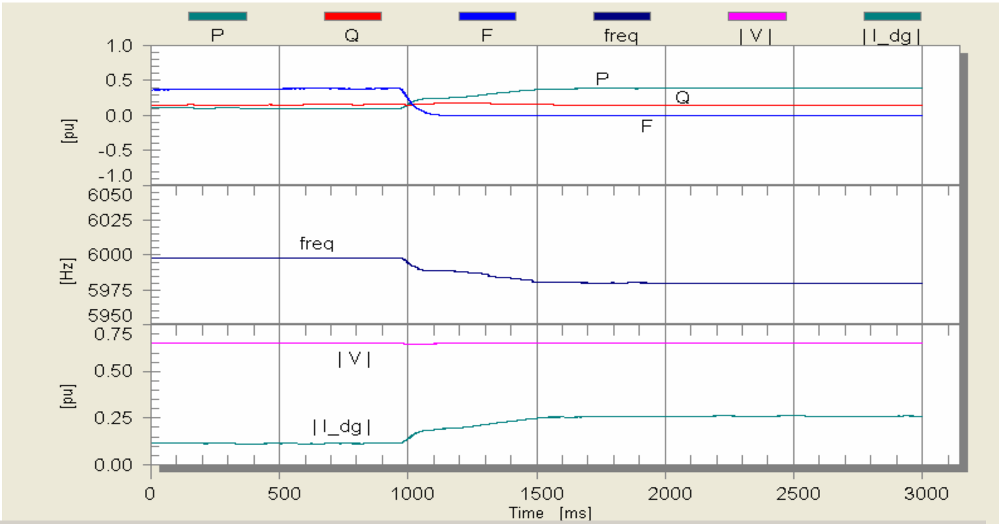
Event shows Unit 2 reaching maximum output power after islanding.

Control of P_1 and P_2

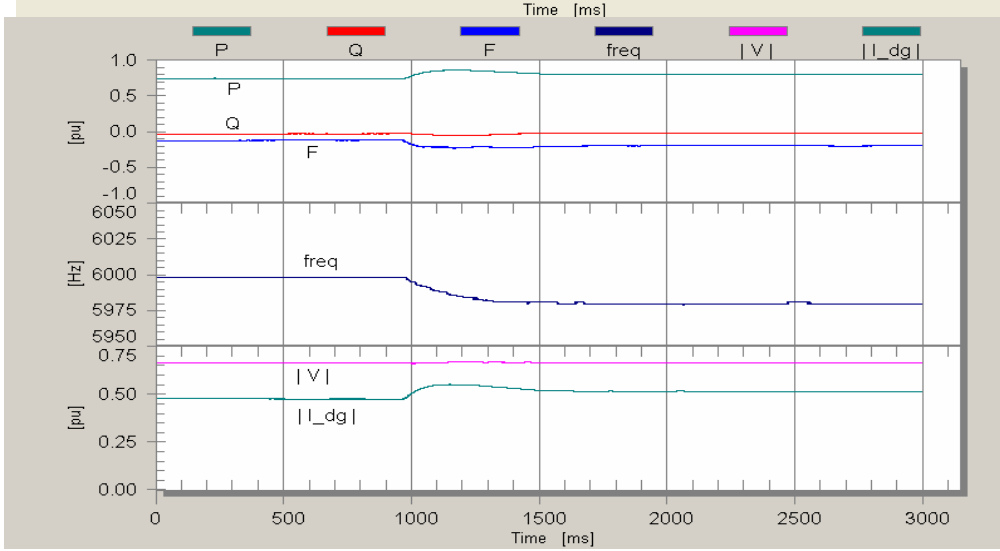
	● A – Grid	■ B – Island
P_1 [pu]	0.08 = 10%	0.4 = 50%
P_2 [pu]	0.72 = 90%	0.8 = 100%
Frequency [Hz]	60.00	59.8
Load Level [pu]	1.2 = 150%	1.2 = 150%
Grid Flow [pu]	**0.4 = 50%**	0.0



Wisconsin's μgrid traces: Islanding

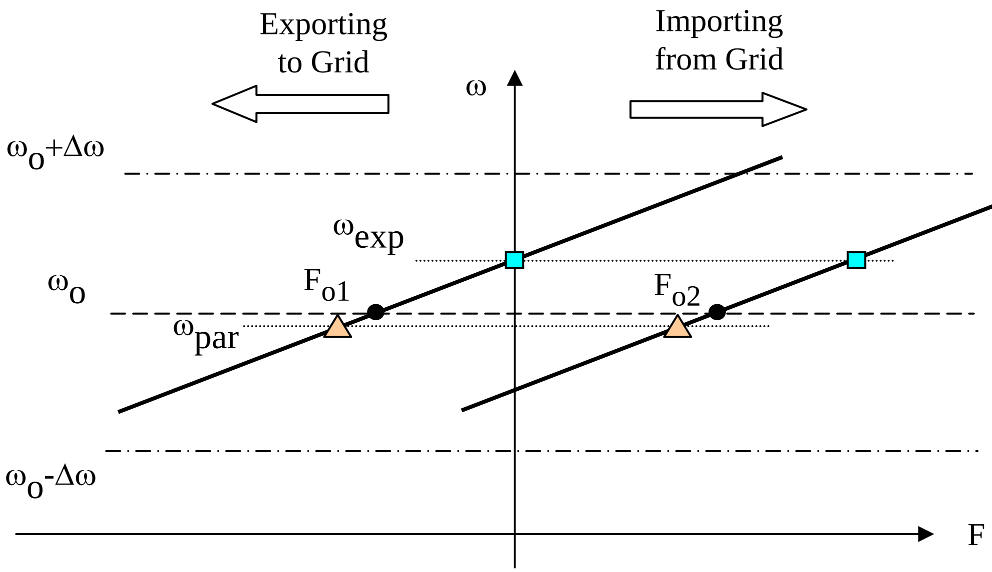


Unit 1



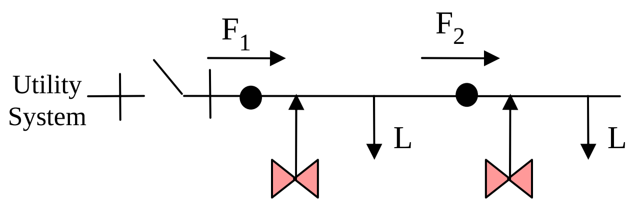
Unit 2

Zone Control: Load Tracking

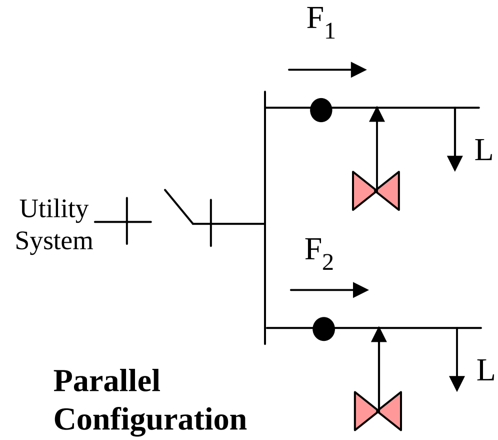


$$m_F = \frac{\Delta\omega}{P_{max}}$$

$$\omega_i = \omega_o - m_F\left(F_{o,i} - F_i\right)$$

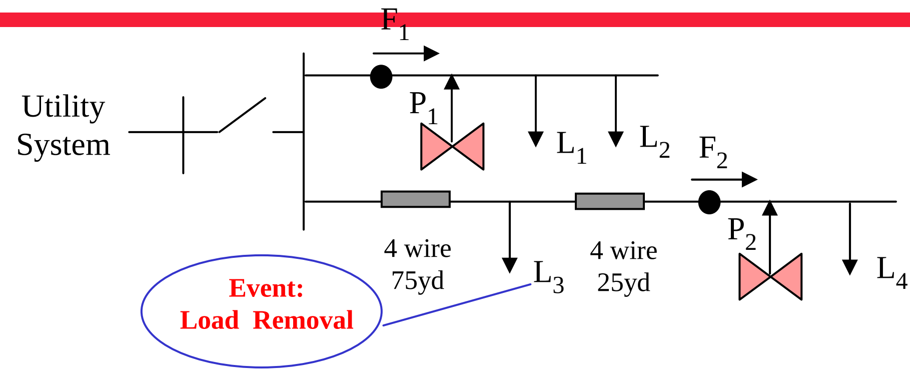


Series Configuration



Parallel Configuration

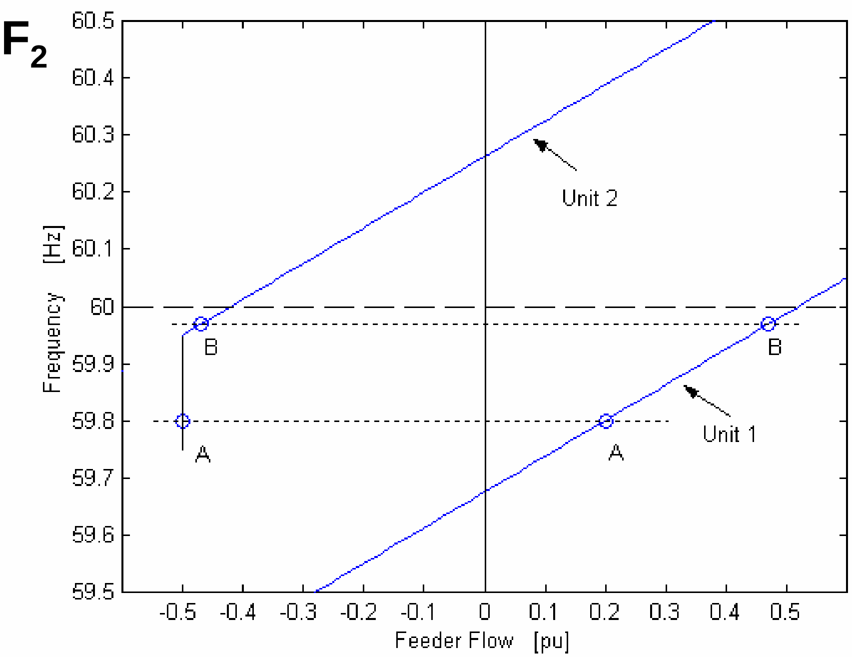
Zone Power Control: Parallel Case: $F_1 = - F_2$



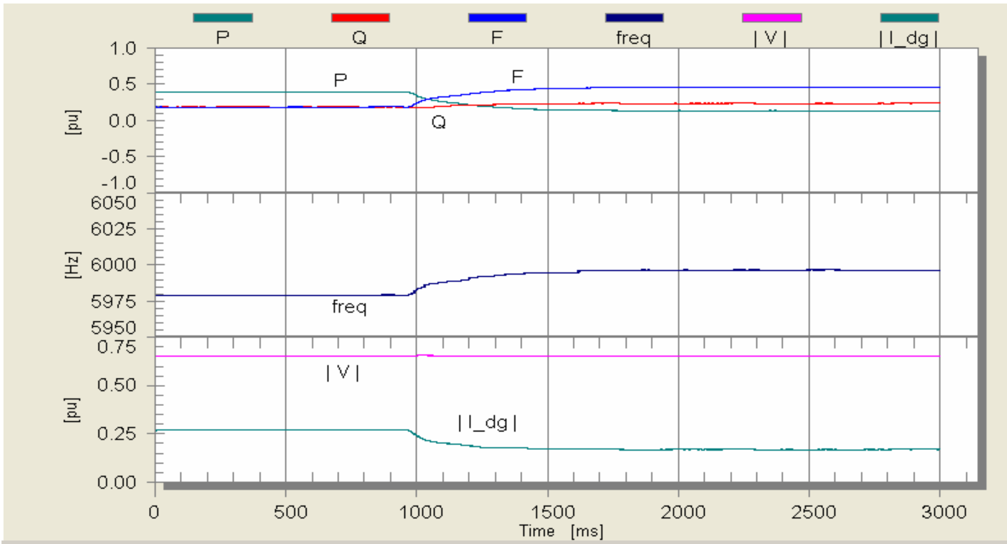
Event shows Unit 2 backing off from maximum output power after a load is removed.

Parallel Configuration, Control of F_1 and F_2

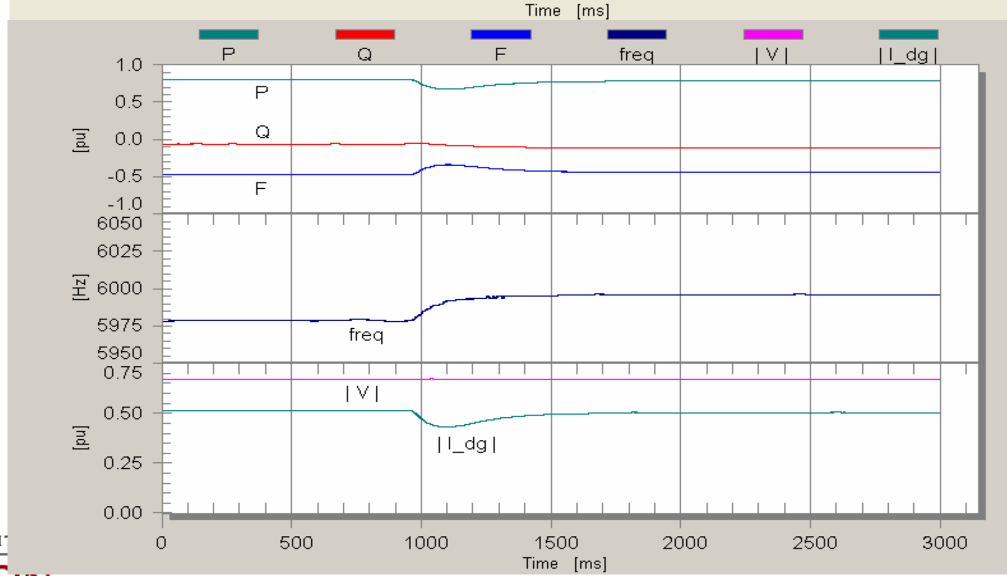
	A – L_3 on	B – L_3 off
P_1 [pu]	0.4 = 50%	0.13 = 16%
P_2 [pu]	0.8 = 100%	0.77 = 96%
Frequency [Hz]	59.80	59.968
Load Level [pu]	1.2 = 150%	0.9 = 112%
Grid Flow [pu]	0.0	0.0



U of W’s μgrid traces: Parallel Case: F_1 = - F_2



Unit 1



Unit 2

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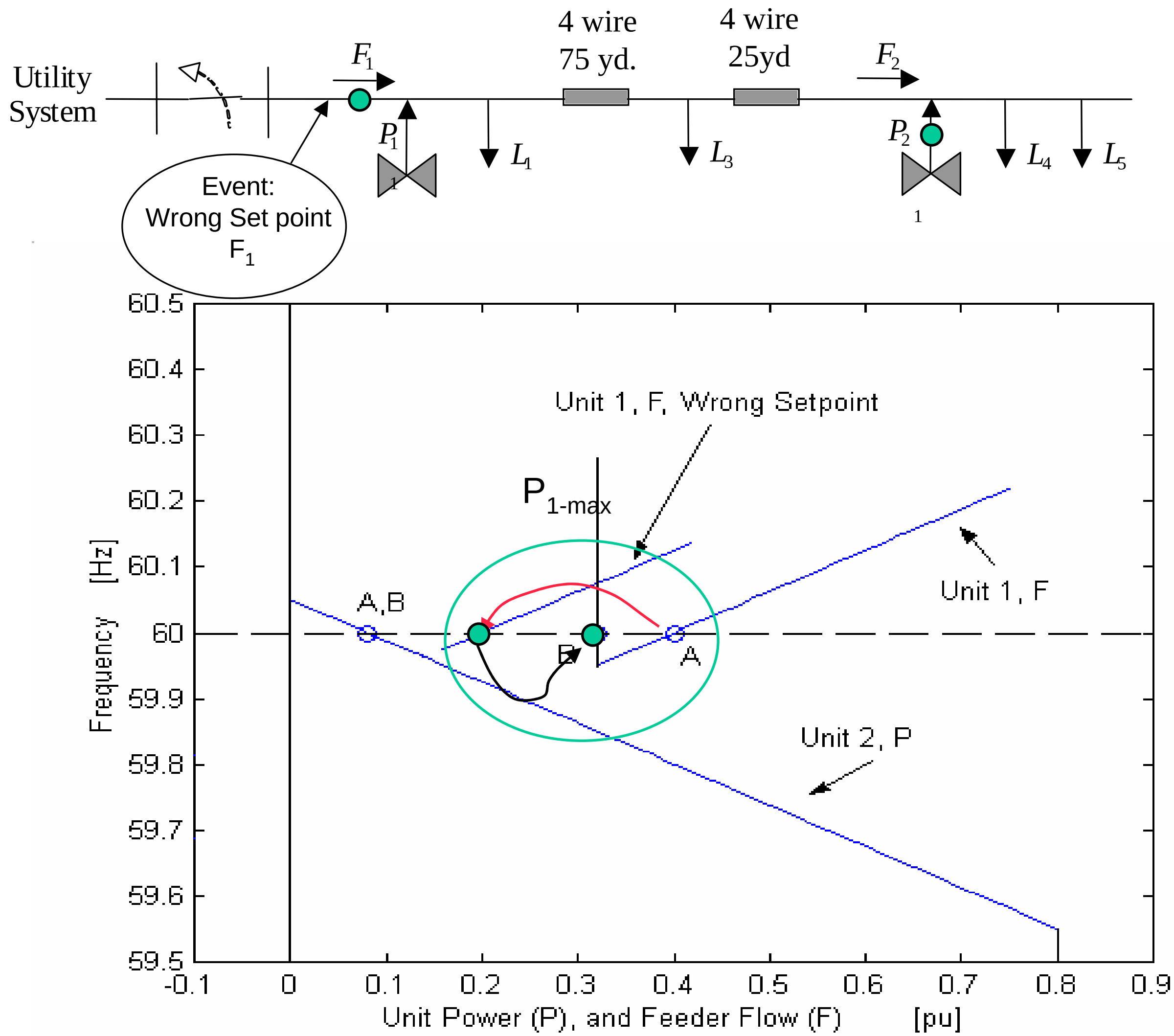
Import From Grid, Setpoints are 90% and 10% of Unit Rating; Choosing a Wrong Setpoint



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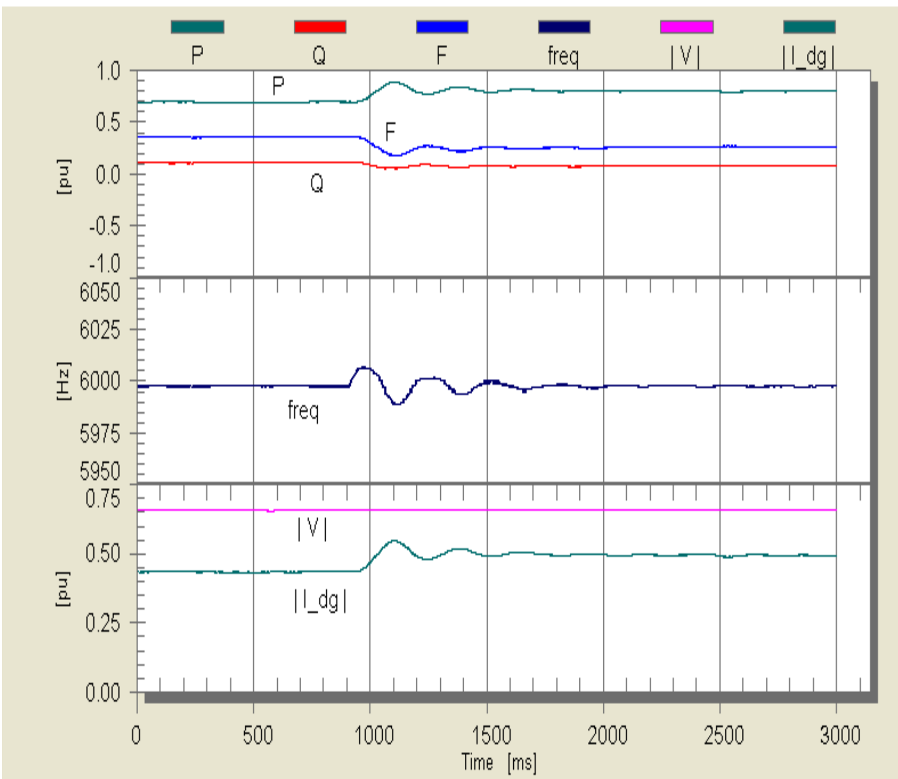
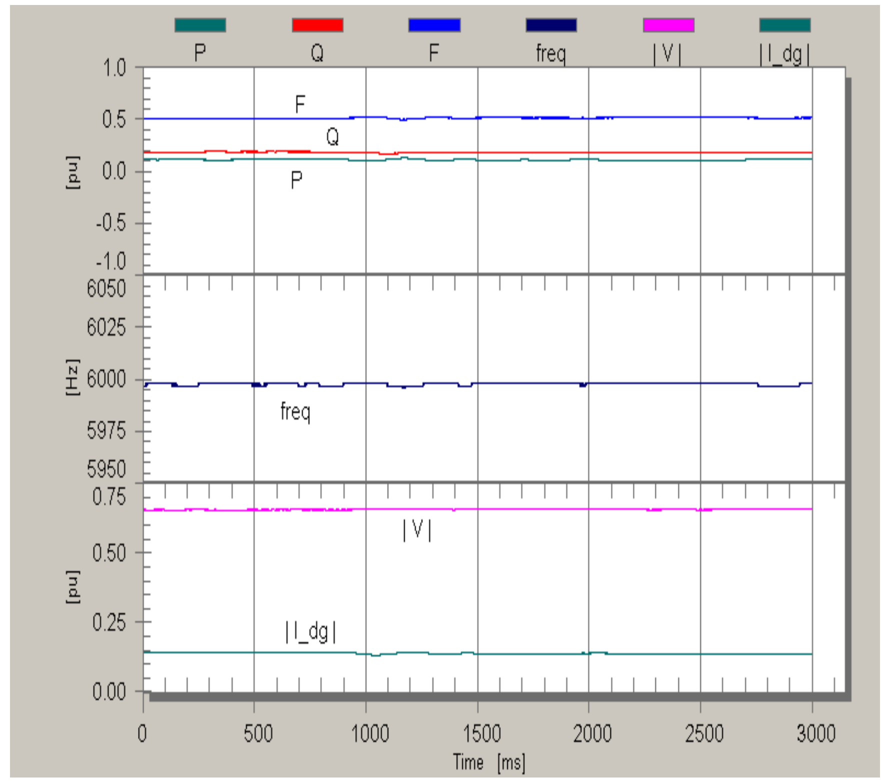
Dynamics of Units; Wrong Setpoint

Unit 1



Unit 2



Summary of micro-source controls

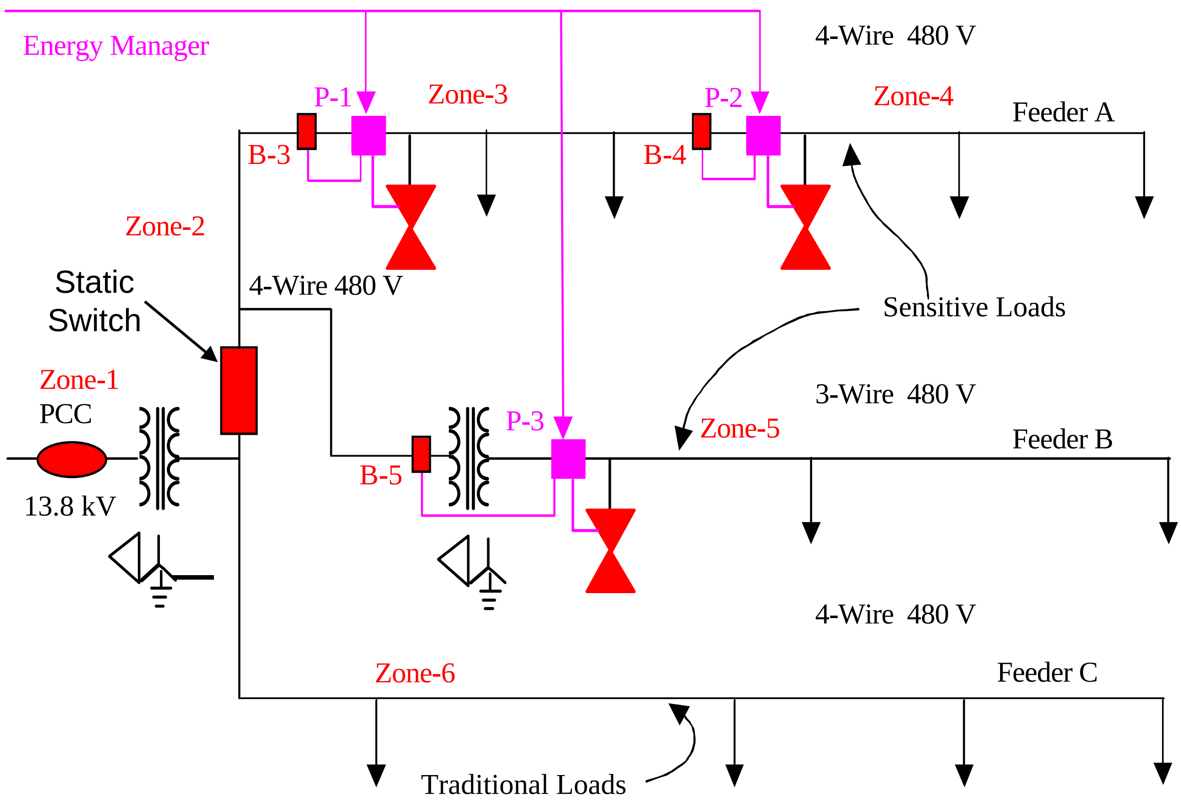
Existing DG controls; P at unity pf or constant Q

- High penetration levels create interaction problems
- Can not smoothly move between grid connected and island operation

CERTS controls

- Voltage control with droop
- Power versus frequency droop
- Automatic re-synchronizing to utility grid

Microgrid Test Bed Layout



Micro-source | Power Flow Controller | Point of Common Coupling | Breaker

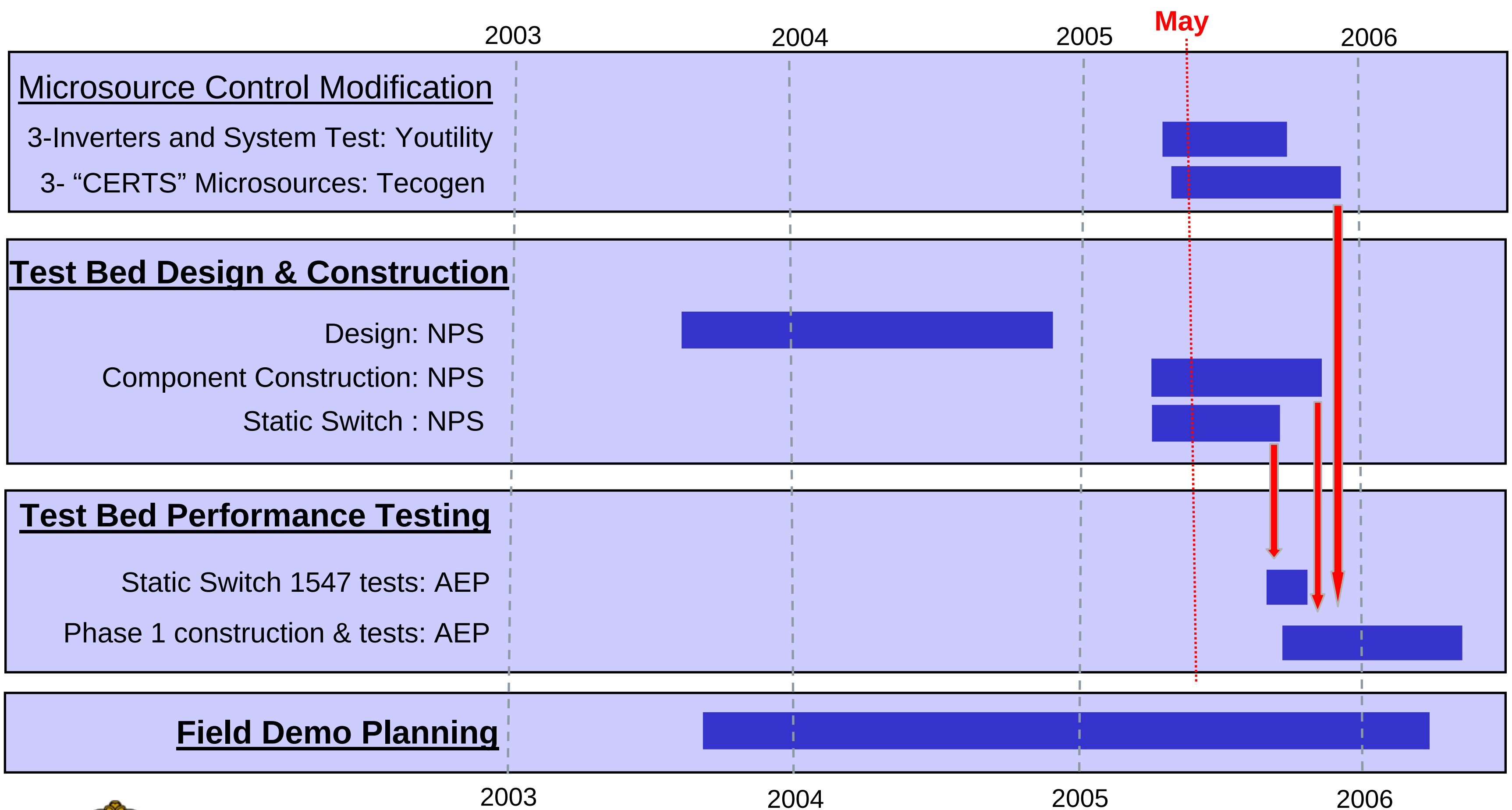
Grid connected

- Load changes
- Control of load flow
- Voltage control
- Protection
- P/V dispatch

Isolated operation

- Separation
- Load pick-up
- Voltage and Q control
- Protection
- Automatic re-syn.

Microgrid Test Bed Timeline



Key Tests

- Load Flow control
  Unit Power, Zone flow & Mixed

- Grid-to-Island-to-Grid
  Power vs. freq power balance
  Re-closing of the Static Switch using local information

- Protection including Static Switch
  Internal, grid side & IEEE 1547events