Laboratory Scale Microgrid Test-Bed Hardware Implementation

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In Partnership with:

PHOENIX CONTACT
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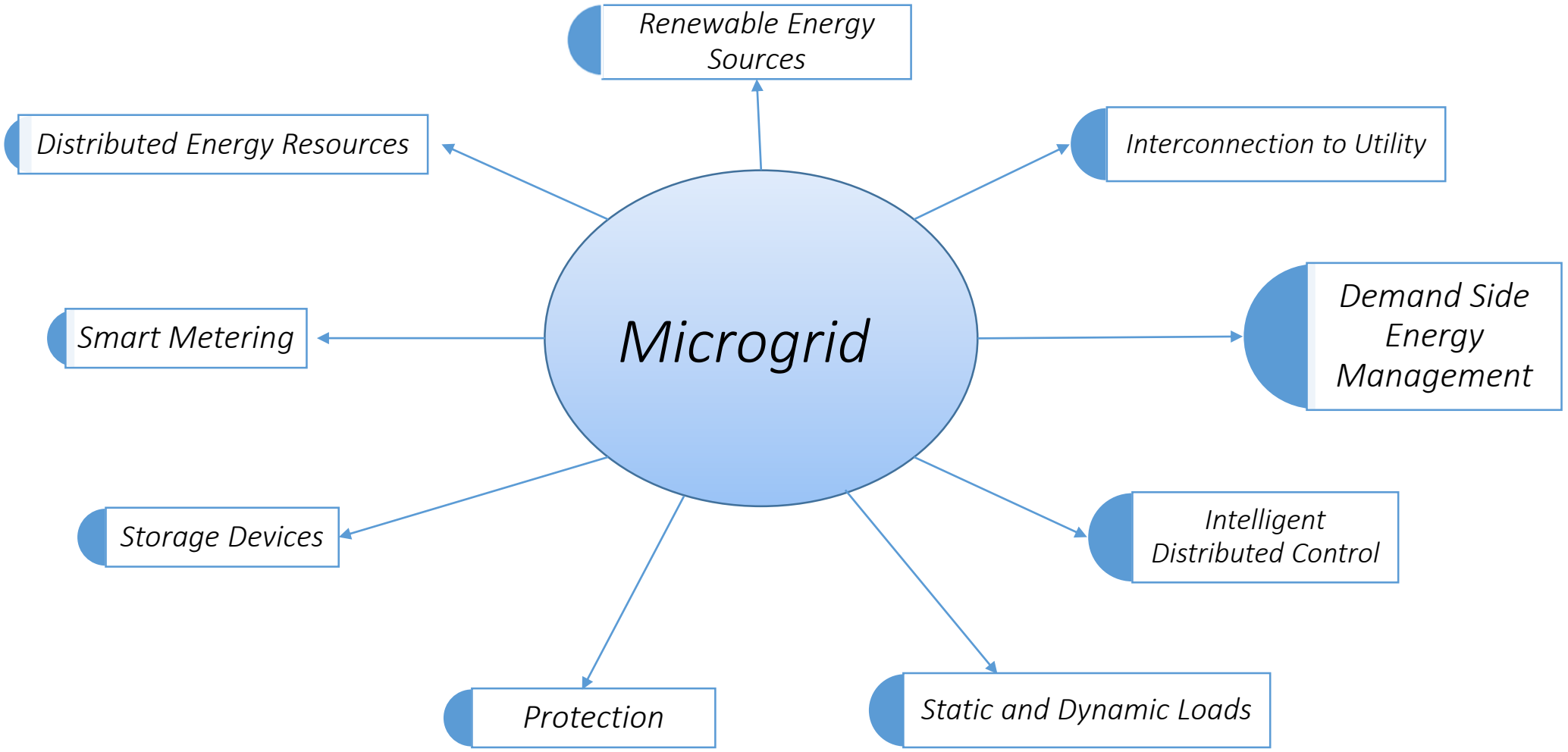
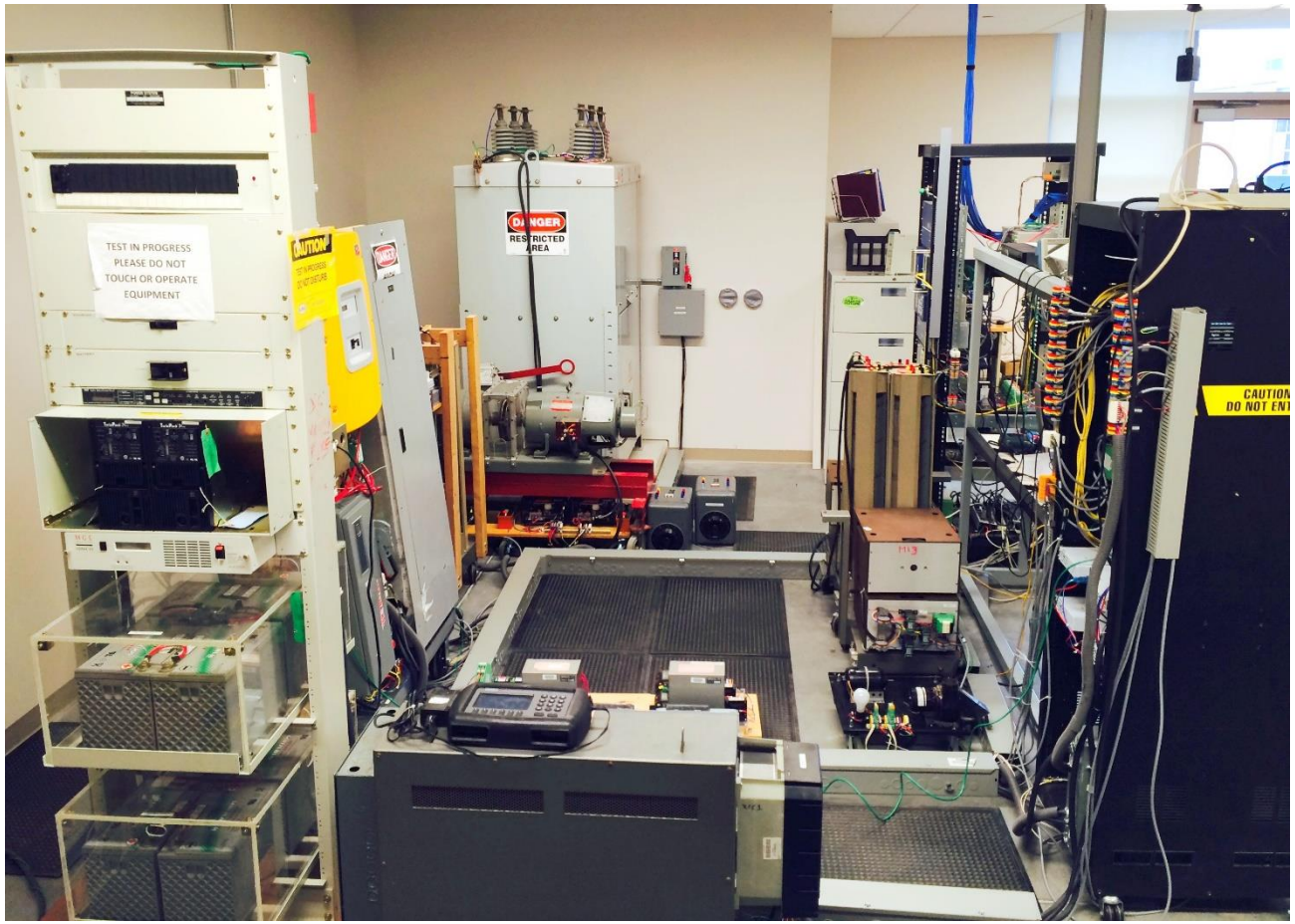
Outline

- *Features of a Microgrid*
- *Microgrid Test Bed at Penn State Harrisburg*
- *Intelligent Distributed Control using Multi-Agent System*
- *Compliance with IEEE 1547*

Features of a Microgrid



Microgrid Test-Bed Layout



- *Three Electrical Buses:*
  - *208V 60Hz 20A*
  - *48V DC Storage Bus*
  - *48V DC Load Bus*
- *Total Power Capability- up to 12kW*

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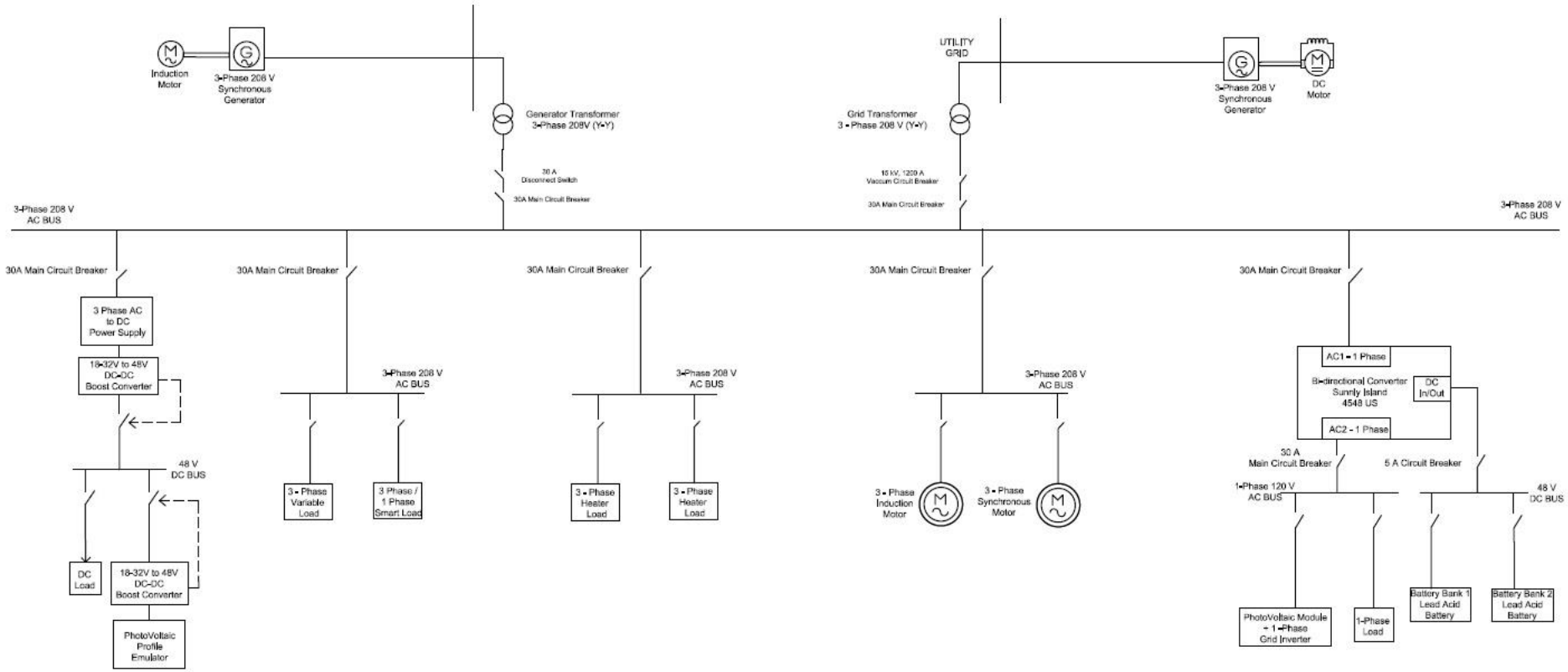
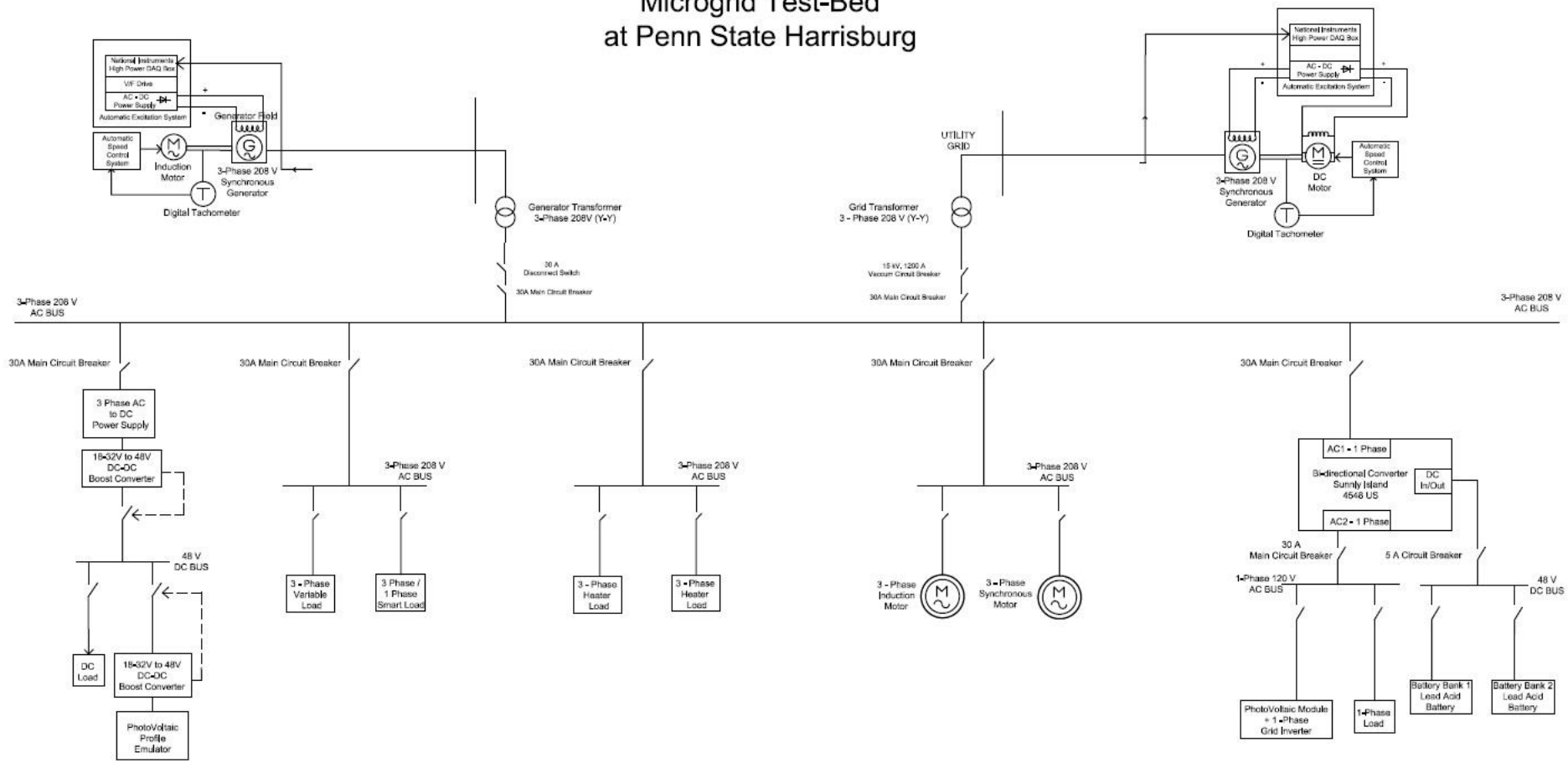
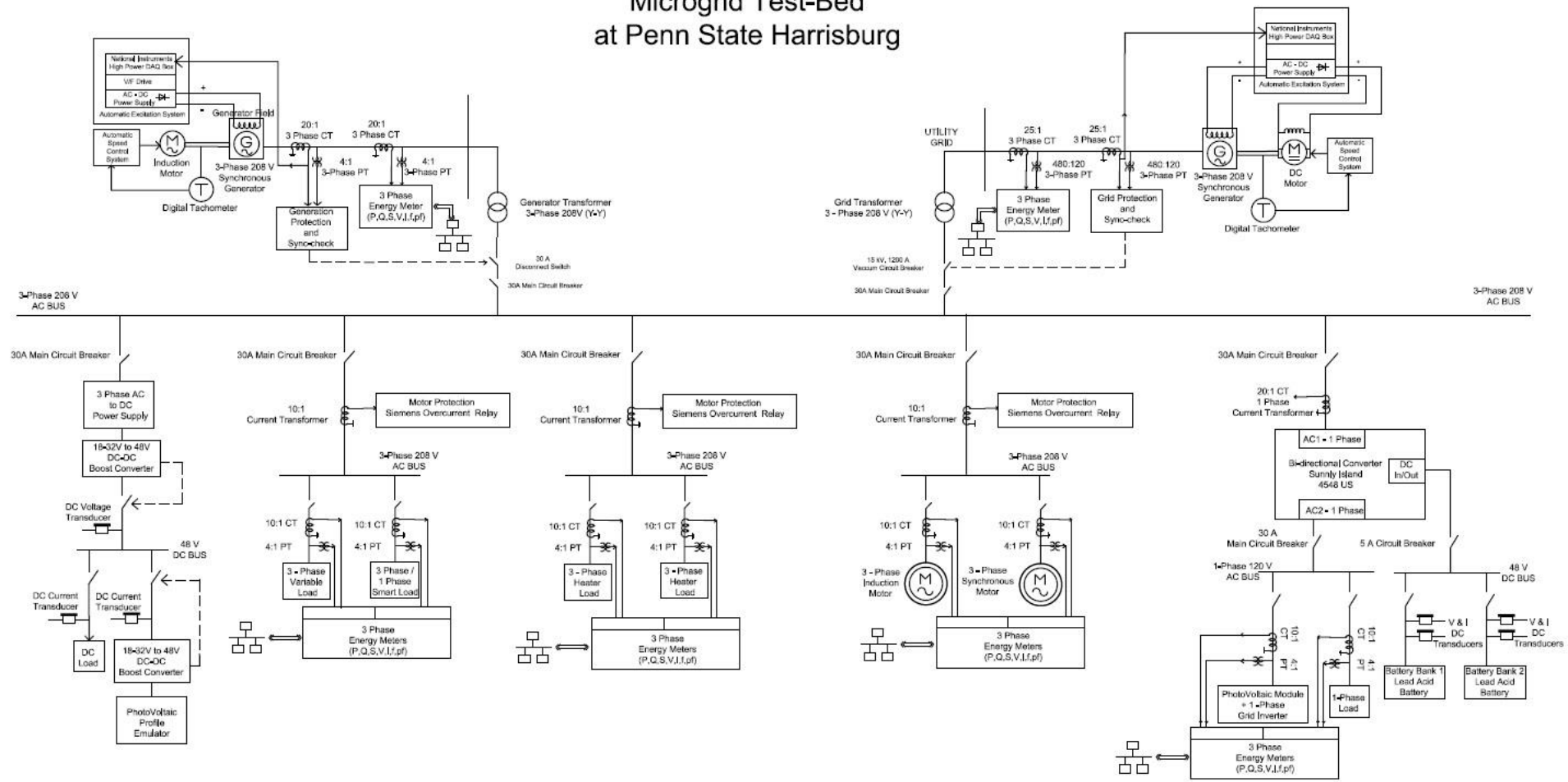
Microgrid Test-Bed
at Penn State Harrisburg



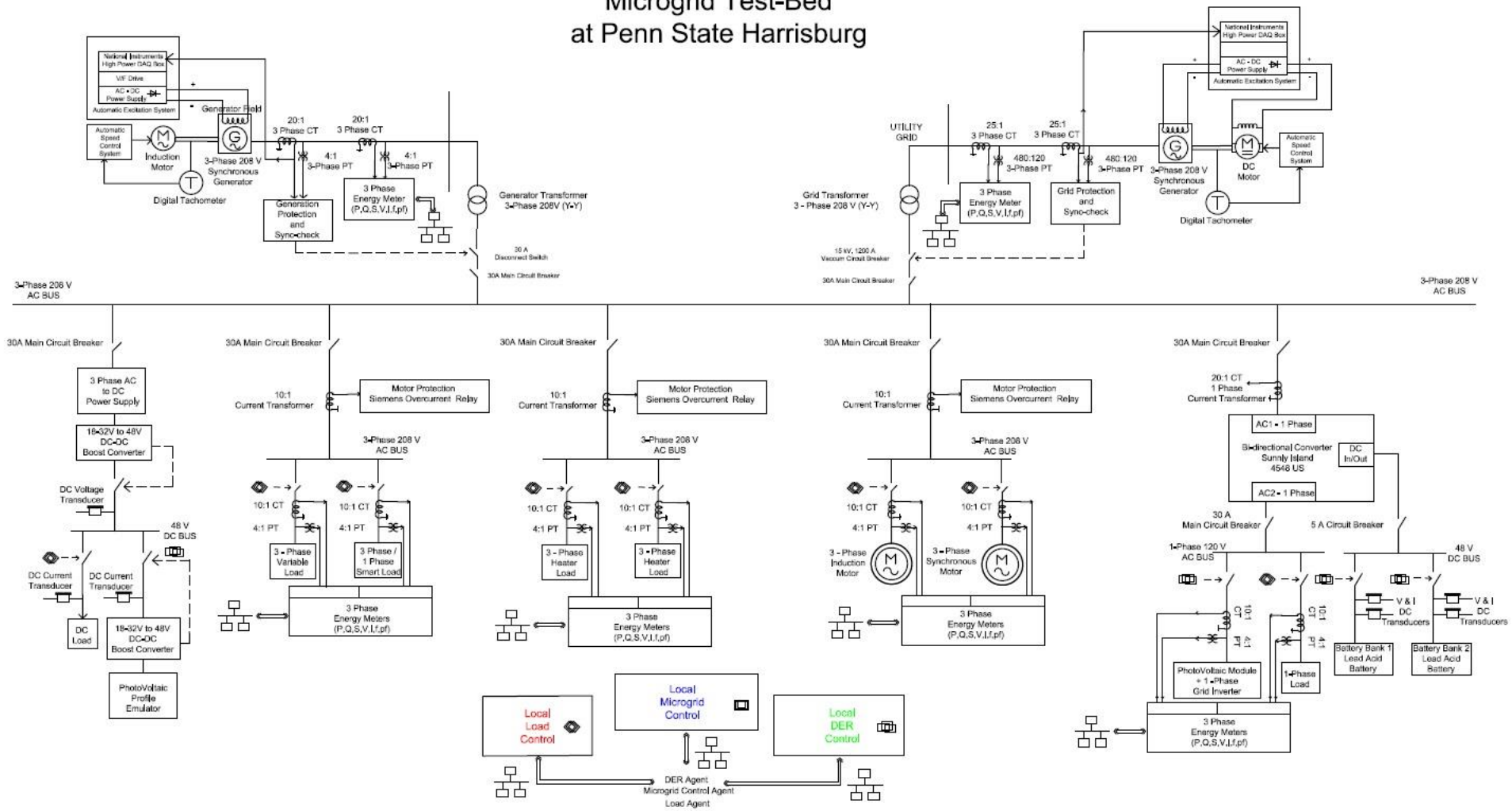
Microgrid Test-Bed
at Penn State Harrisburg



Microgrid Test-Bed at Penn State Harrisburg



Microgrid Test-Bed
at Penn State Harrisburg



Utility Breaker
15kV ABB Vacuum Circuit Breaker

5 HP Utility Generator
3 phase 208V

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4 kW PhotoVoltaic Emulator

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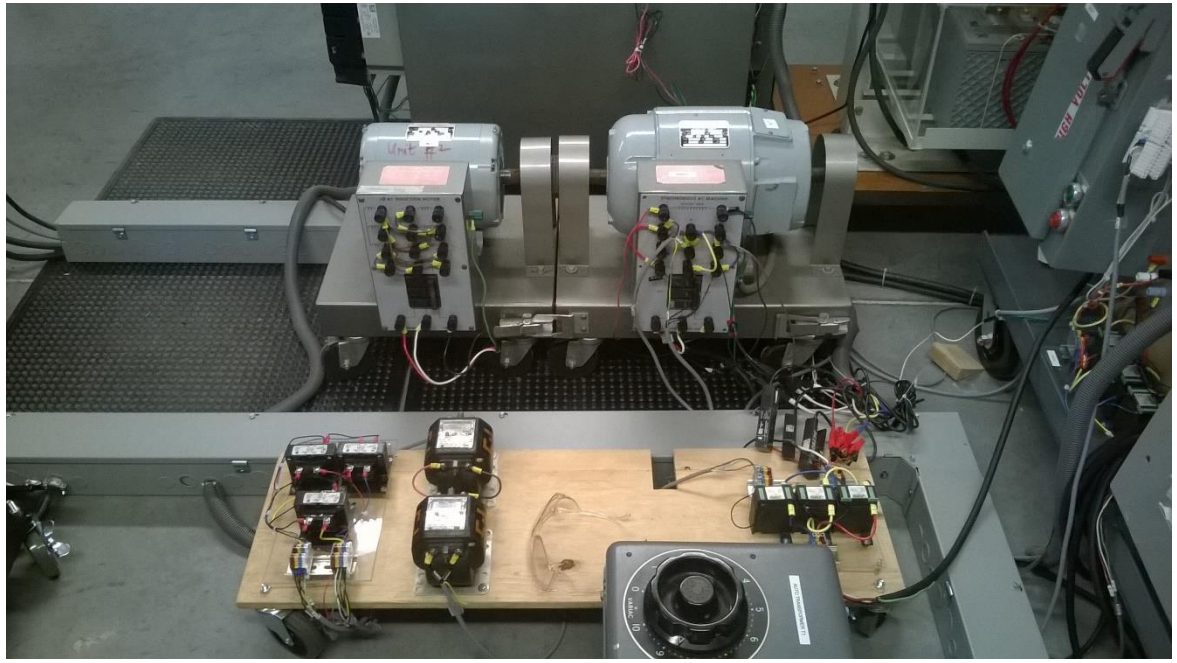

3 HP Microgrid Generator
3 phase 208V

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Demand Side Energy Management

Smart Load

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4.5 kW
Bidirectional Converter/
Battery Charger
SMA Sunny Island

48V 180Ah Battery Bank

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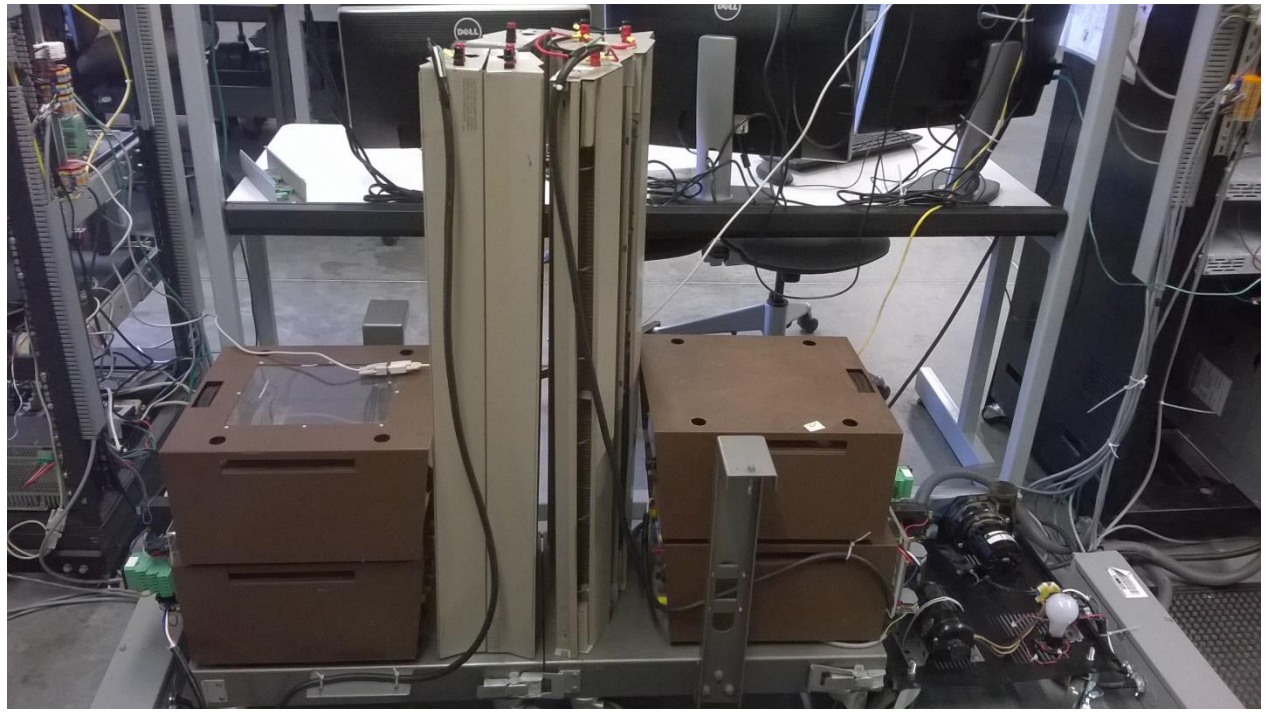

Static and Dynamic Loads

Smart Metering

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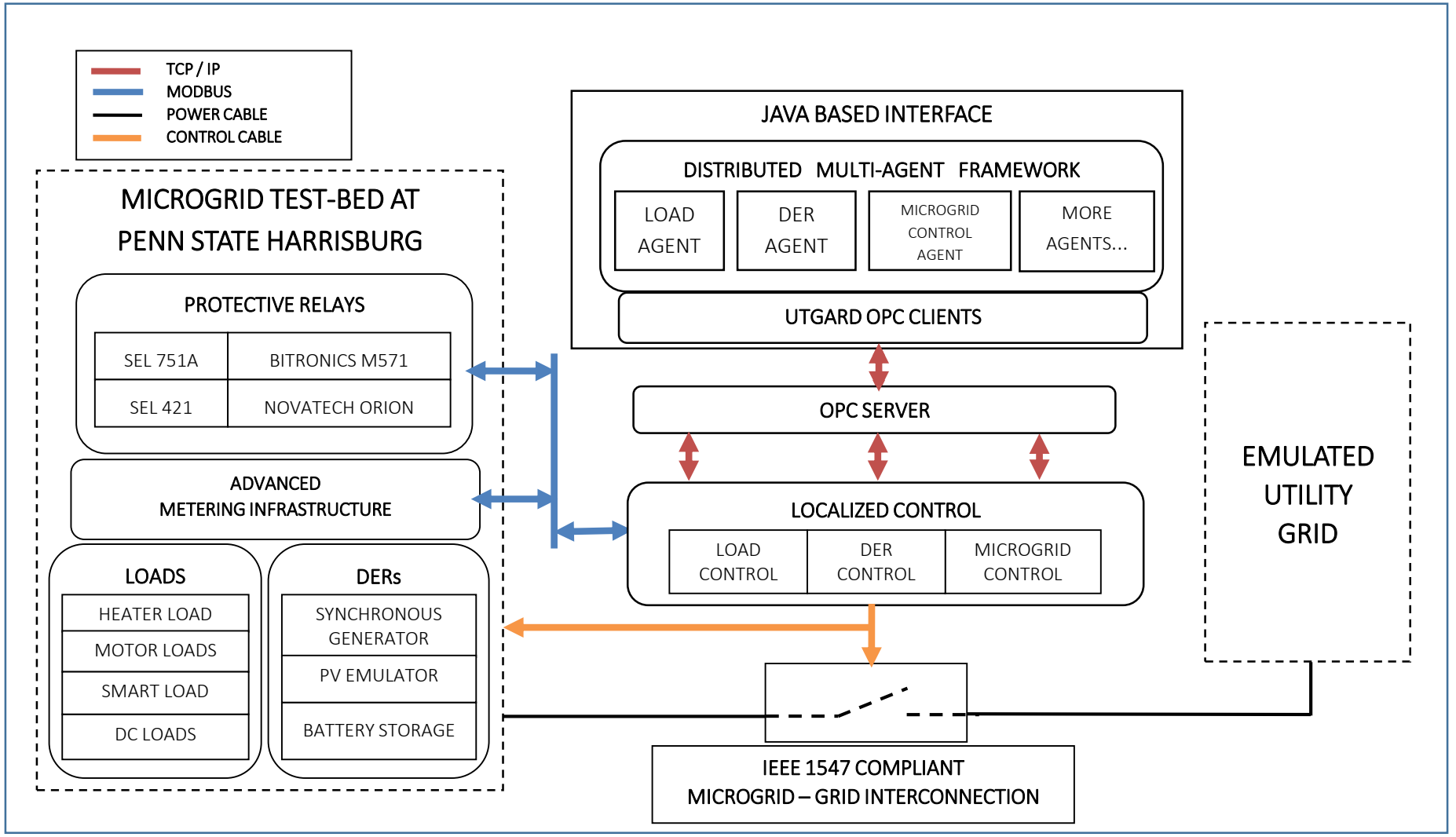
SEL
SEL-751A
SEL-421
SEL-387
SCHWEITZER ENGINEERING LABORATORIES

SEL Relays

Distributed Control System Hardware



Intelligent Distributed Control

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Multi-Agent System Control Objectives for Microgrid Test-Bed at PSH

- To monitor the status of microgrid operation with the help of digital protective relays and smart meters
- To serve critical loads within the microgrid 24/7
- To island microgrid from the grid during outages and emergencies to protect the power system infrastructure and sensitive loads within the microgrid

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Multi-Agent System Control Objectives for Microgrid Test-Bed at PSH

- To improve microgrid transient stability and achieve peak load shaving
- To perform accurate short-term load and energy forecasting
- To minimize the cost of operation of DERs using economic dispatch algorithms

Multi-Agent System Knowledge Modeling

Microgrid Operation Facts	Value
Microgrid Status (1 – healthy, 0 – fault)	1 or 0
Grid Status (1 – healthy, 0 – fault)	1 or 0
Fault Status (1 – true, 0 – false)	1 or 0
Islanded Mode (1 – true, 0 – false)	1 or 0
Grid Connected Mode (1 – true, 0 – false)	1 or 0

Load Demand Facts	Value
Total Load Demand Forecast	kW
Critical Load Demand Forecast	kW
Non-Critical Load Demand Forecast	kW
Total Load Demand	kW
Critical Load Demand	kW
Noncritical Load Demand	kW
Peak Load Demand	kW

DER Facts	Value
DER Availability (1 – true, 0 – false)	1 or 0
Connection Status (1 – online, 0 – offline)	1 or 0
Capacity Factor	%
Max Supply Capacity	kW

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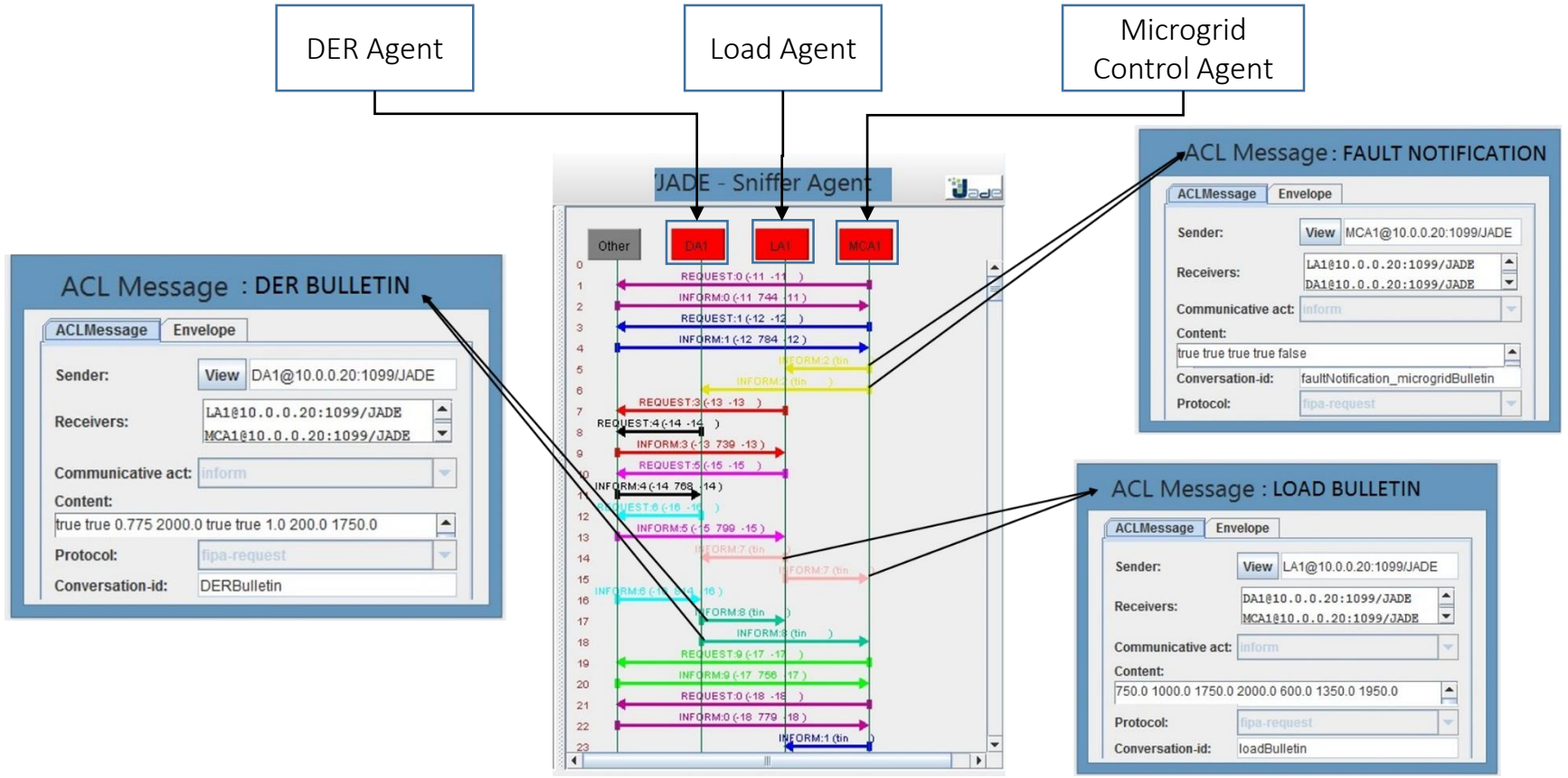
Intelligent Distributed Control using Multi-Agent System



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Compliance of Test Bed to IEEE 1547

Four Features are realized:

- Voltage and Frequency Control
  - Voltage Regulation according to ANSI C 84.1-1995 Range A.
  - Frequency of Operation-within 59.3Hz to 60.5Hz.

- Synchronization: Δf=0.3Hz, ΔV=10% and $\Delta \phi$=±20% (Test Bed designed for Δf=0Hz, ΔV=2% and $\Delta \phi$=±5%).

- Islanding: Normal operation of the Microgrid-should not be disturbed at times when the microgrid islands itself from the utility, maintain voltage and frequency stability when operating in island mode.

- Protection: Faults that occur within the microgrid has to be cleared within the microgrid itself and faults that occur outside the microgrid should not affect the operating units within a microgrid-Nodal Protection System Incorporated.

Conclusions

- The concept of a Microgrid Test-Bed at a laboratory scale was realized for research and educational purposes.
- Microgrid operation was ensured to comply with IEEE 1547 Standard requirements.
- Multi-Agent System was successfully deployed during fault scenarios, grid-connected and islanded mode of operation, etc.
- Provision for test-bed expansion is provided to incorporate ring main bus system and wind emulation system, etc.

Thank you.

Questions?

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