EPRI Update on Latest Research and Testing of Control Systems

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Microgrid & DER Controller Symposium
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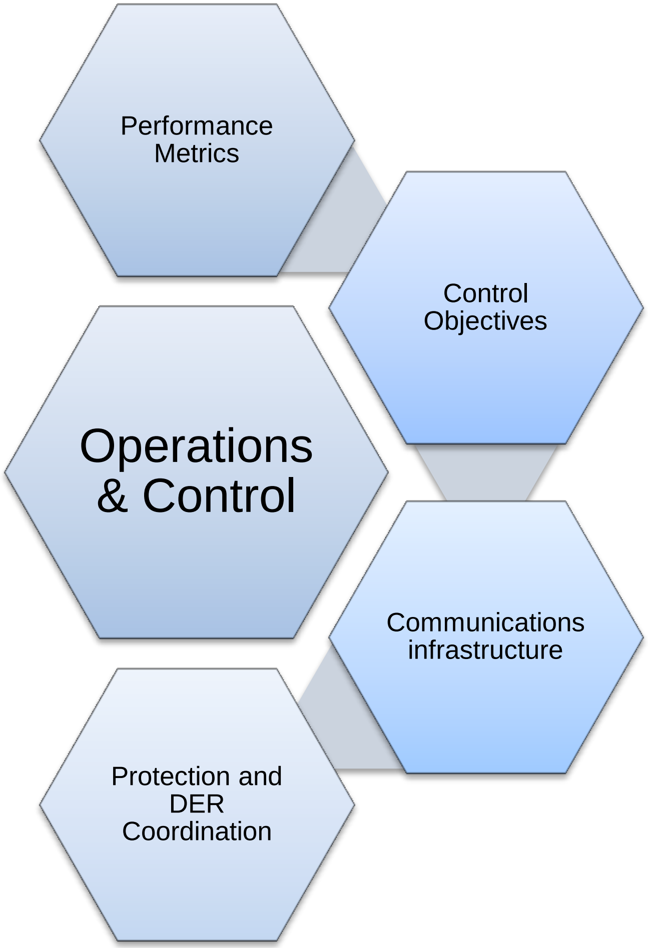
A Practical Microgrid Goal by 2020…

Maximize project lifecycle value for economic and technically feasible opportunities in our evolving grid environment

- Creating a microgrid is complicated ….
  - Involves multiple power, operations management and control system components from diverse vendors that must be integrated and optimized for interoperability and security
  - Integrated controls, communication & coordination, and new protection approaches are needed
  - Assets within the microgrid must comply with the distribution system operator's interconnection requirements



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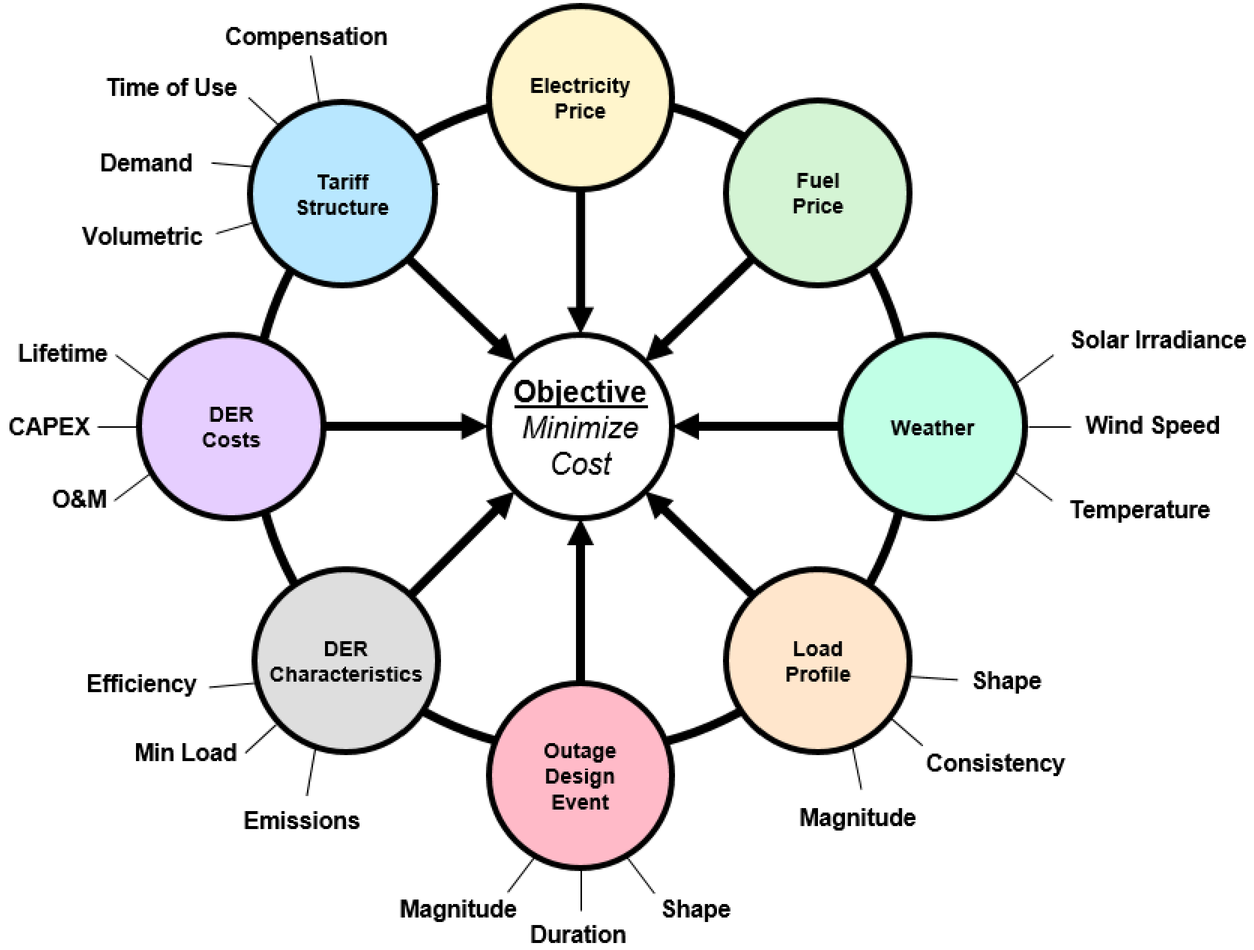
Key Parameters Impacting Microgrid Operations and Cost



A variety of factors, many interconnected, impact the overall design and cost of a microgrid. Certain factors are considered fixed inputs (i.e. assumptions) while other factors are varied to in order to evaluate the sensitivity of their impact on overall cost.

Microgrid Business Models Can Impact Controller Operation

THIRD-PARTY MODEL

- End user(s) or 3rd party own and finance microgrid
- End user(s) or 3rd party determine economic dispatch (potentially with utility guidance)
- Utility, end user(s) or 3rd party agree on appropriate islanding conditions
- End user(s) see net change in bills

UNBUNDLED MODEL

- Utility or 3rd party owns and finances microgrid on behalf of end user(s)
- Utility or 3rd party dispatches DER assets on behalf of customer(s)
- Utility and end user(s) agree on appropriate islanding conditions
- End user(s) pays utility for grid assets, pay implementer (utility/3rd party) for microgrid assets, receives credit from DER

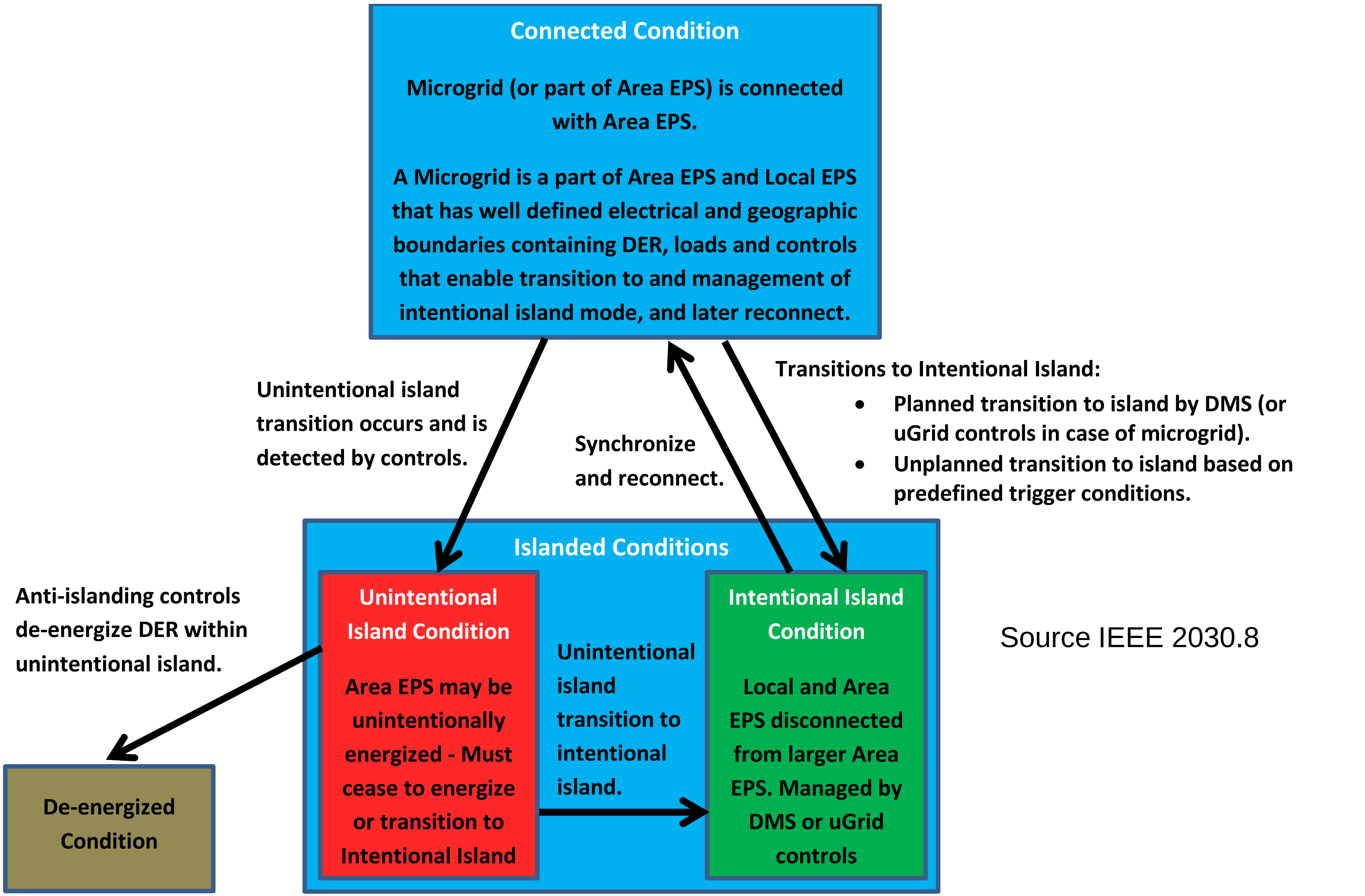
INTEGRATED UTILITY MODEL

- Utility owns and finances microgrid
- Utility dispatches DER assets based on system economics
- Utility and end user(s) agree on appropriate islanding conditions
- End user(s) pays utility for resiliency/premium power service

CUSTOMER CONTROL ⟵⟶ UTILITY CONTROL

For more information – “Microgrids: Expanding Applications, Implementations, and Business Structures”. EPRI/SEPA whitepaper.

Transitions and Impact of Controls



Source IEEE 2030.8

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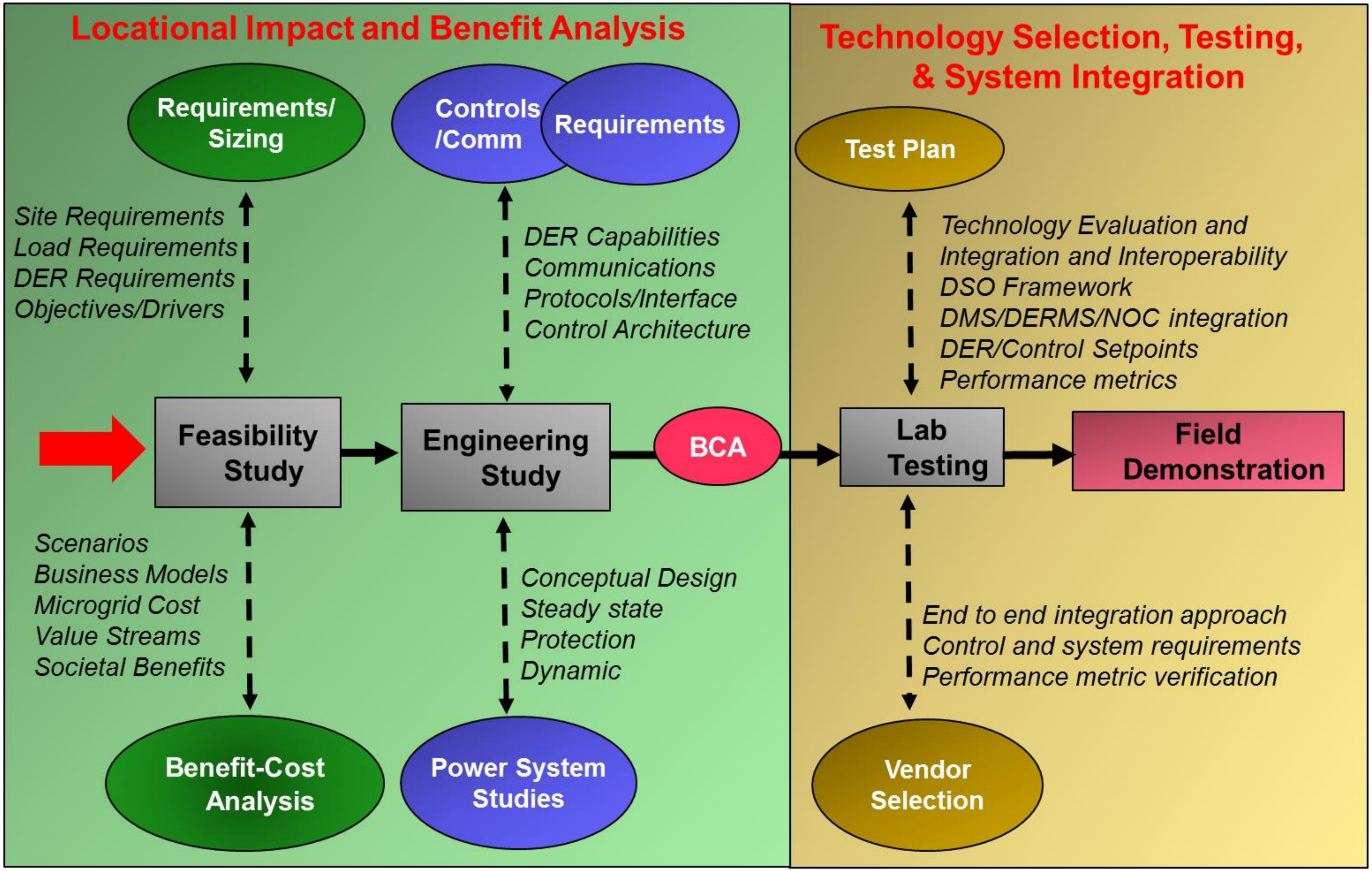
Develop Consistent Approaches to Evaluate Microgrid Adoption: *Evaluation, Design, Testing & Demo*



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EPRI Microgrid Feasibility and Design Projects

List of Current Microgrid Controller Projects

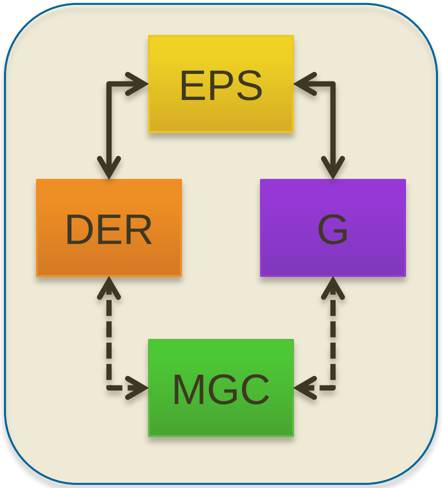
- **DOE Microgrid Projects**
  - FOA 997 Controller (End Date May 2017) Spirae Controller
  - DMS Structuring Project Phase 1/2 (October 2015 – November 2017) Schneider & GE Controller
  - ADMS Test bed (November 2016 – November 2019) Schneider & GE Controller
  - ARPA E with UTK TI Controller

- **DoD Microgrid Projects**
  - Transportable Microgrid (Dec 2016-Dec 2018). SEL Controller
  - Fort Hunter Liggett (Sep 2016 – Dec 2017). LBNL Controller

- **NYSERDA Microgrid Projects**
  - Phase 2 BNMC NYSERDA Spirae/OpusOne Controller

- **Utility Funded Demonstrations**
  - NCEMC, Xcel, HydroOne, Central Hudson

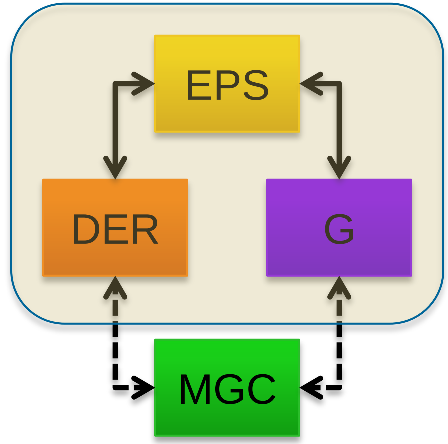
Microgrid Controller Test Options – Which is Better?



Pure simulation

Abstract or real-time

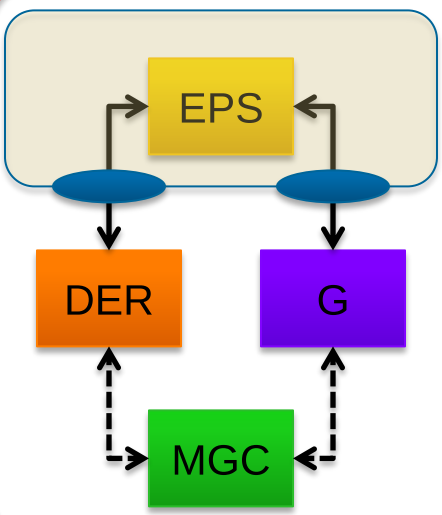
Need to integrate MGC



CHIL

Interface real controller

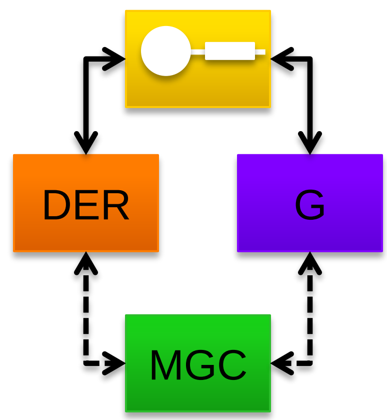
Real-time simulation



CHIL & PHIL

Interface real controller and assets

Power interface, more complex



Power

Real controller and assets

Simple EPS model

CHIL = Controller Hardware-in-the-Loop; PHIL = Power Hardware-in-the-Loop

MGC = Microgrid controller; DER = Distributed Energy Resource; G = Generator; EPS = Electric Power System

Need IEEE 2030.8 to Define Microgrid Controller Testing Procedures and Evaluations

Test case:	Met Requirement?
A.1.1: DER available (renewables only); Wave offline.	✓
A.2.1: System importing power at PCC	✓
A.2.2: System importing power at PCC (loss of one generator)	✓
A.3.1: System exporting power at PCC	✓
A.3.2: System exporting power at PCC (loss of one generator)	✓
A.4.1: System net-zero power at PCC	✓
A.4.2: System net-zero power at PCC (loss of one generator)	✓
A.4.3: System net-zero power at PCC (loss of communications MG/Wave)	✓
B.1.1a: Planned disconnection using microgrid controller interface	✓
B.1.1b: Planned disconnection (high renewable penetration)	✓
B.1.2: Planned disconnection (loss of one generator)	✓
B.2.1: Unplanned disconnection via manual breaker trip	✓
B.2.2: Unplanned disconnection via manual breaker trip (loss one generator)	✓
B.2.3: Unplanned disconnection via protective relay trip	✓

Need for an Uniform Way to Evaluate Multiple Vendor Control Systems

- Single product compliance
  - Does it meet IEEE 2030.7 core level functions?
  - Does it meet additional customer requirements?
- Product comparison
  - How do these controllers compare?
- *Requires testing in the context of a microgrid system*

- Site-specific compliance
  - Is it capable of managing *this* microgrid's assets in order to meet *these* interconnection requirements?

Legend
Function currently supported (Green)
Function partially supported (Blue)
Function not currently supported, but on the product roadmap (Yellow)
Function not on the product roadmap (Red)

Functions for a Microgrid Controller				Wave Applications					
				Core	Monitor and Control	Microgrid Import/Export	Advanced Energy Storage	Market	Demand Response
Grid Tied Functions: Grid Services	Connect/Disconnect (non-islanding)				Green	Green	Green		Green
	Utility SCADA and DMS coordination			Green					
	Connectivity and interface with power flow models, utility DMS and DERMS			Blue					
	Market interface for capacity, energy, and ancillary services							Yellow	
Local Services (Optimization)	Load and weather forecasting			Green					Green
	Energy management and dispatch	Max generation level control		Green	Green	Green	Green		
		Power quality (PQ), outage, fault detection		Blue	Green	Green	Green		
		Voltage regulation	Volt-VAR management and PF control	Yellow	Green	Blue	Blue		
			Power (Volt/Watt or Freq/Watt) curtailment/control		Green	Green			Green
			Power smoothing	Yellow	Green	Yellow	Yellow		
		DG, storage, load management			Green	Green	Green	Green	Green
		Voltage and frequency ride-through			Blue				
Operator Services	State/Status monitoring			Green					
	Communication with DSO/ISO/RTO							Yellow	
	User interface and data management			Green					
	Billing			Red					
	Event logging			Green					

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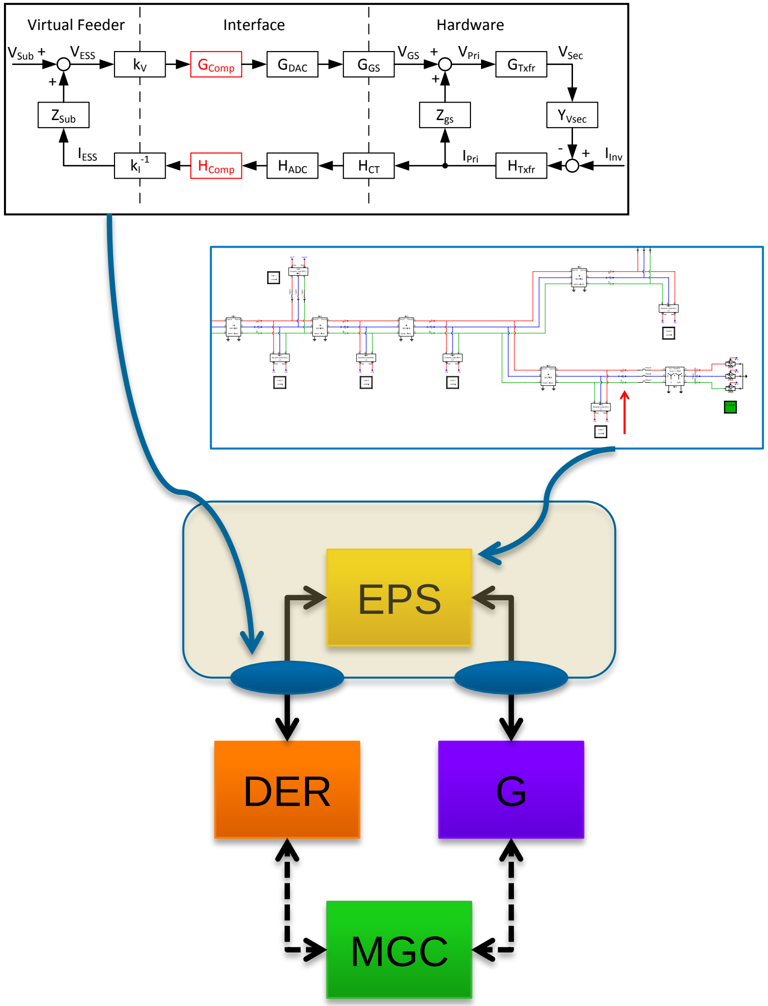
CHIL & PHIL for Site-Specific Evaluation

- Model of site EPS
- Actual or representative DER
  - reduce modeling inaccuracies
  - proprietary controls



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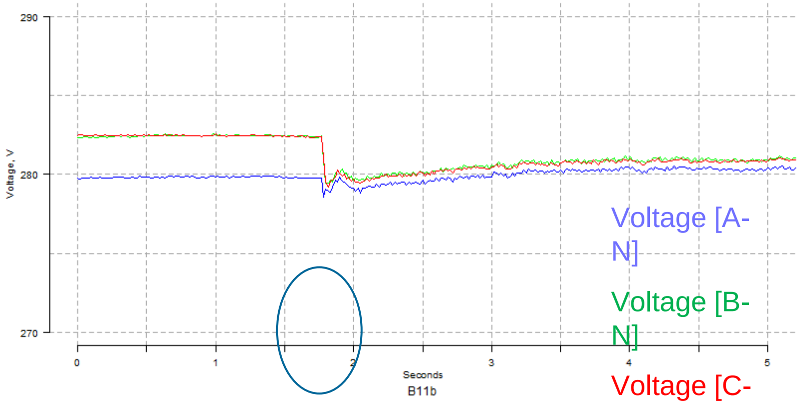
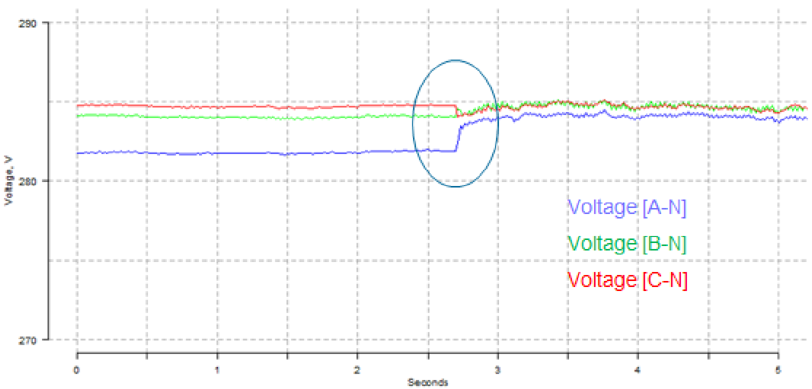
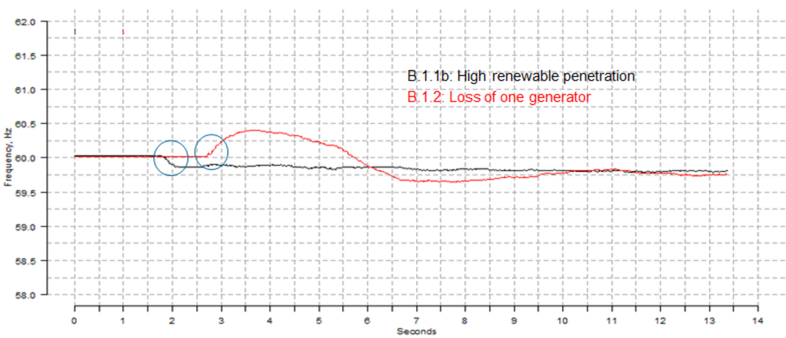
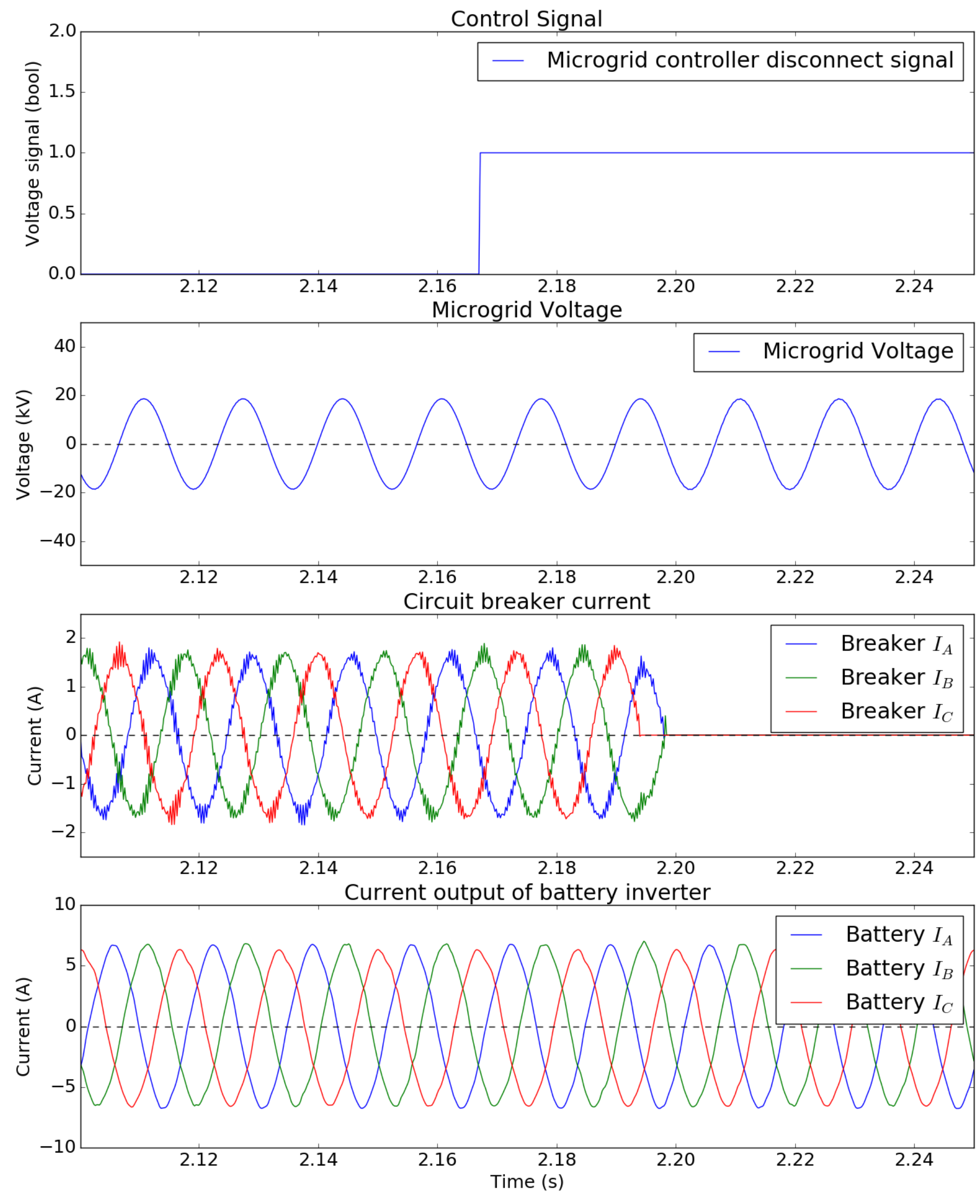
Verify Controller Functions and Capabilities



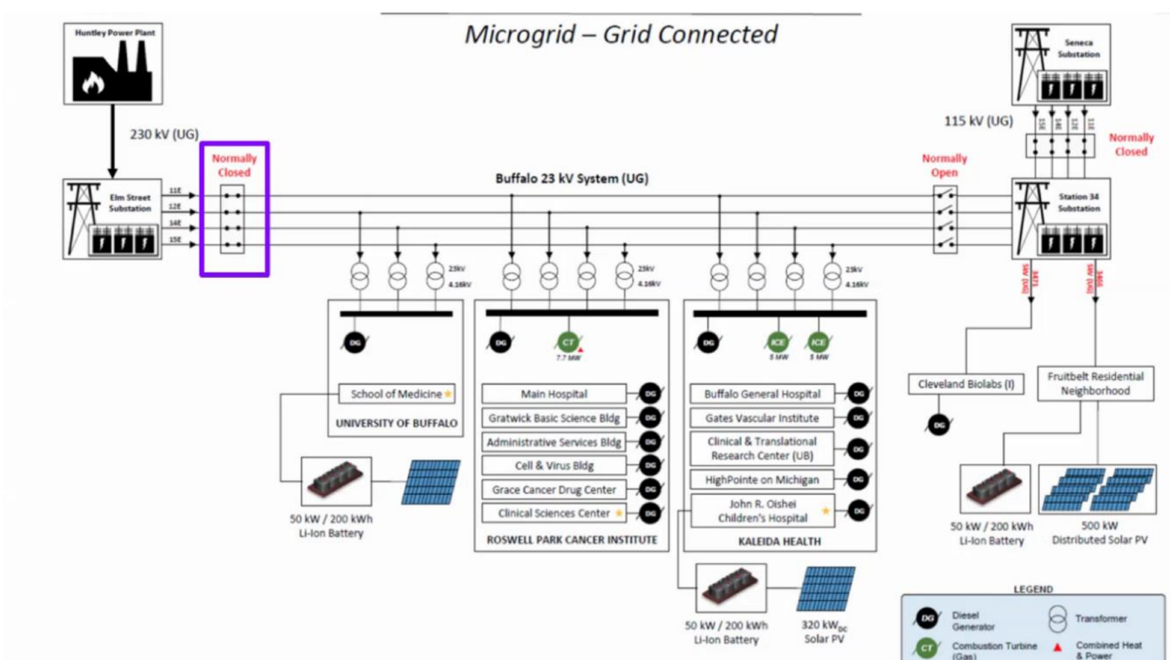


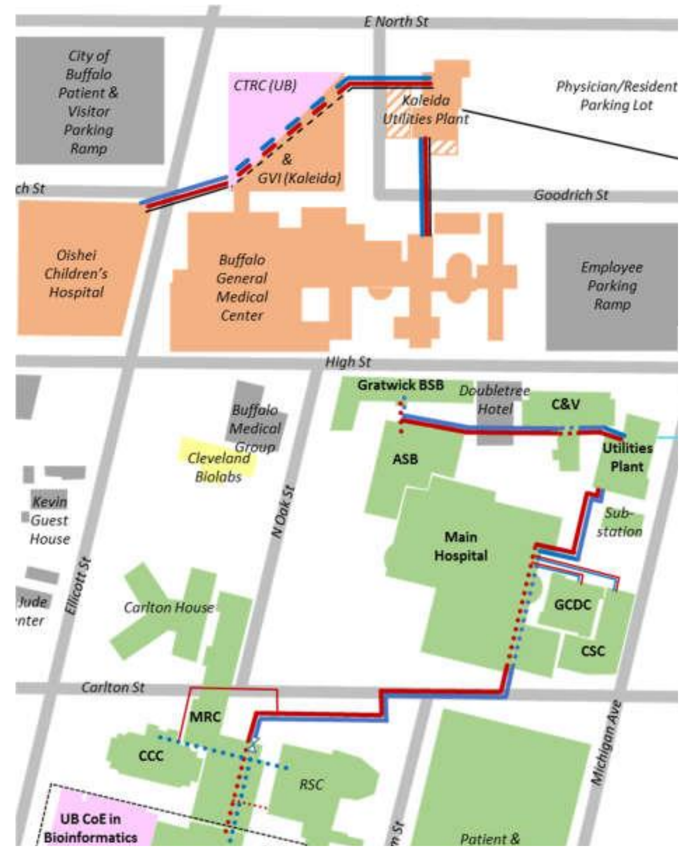




CHIL/PHIL Test @NREL

PHIL & CHIL evaluation of microgrid controller for Buffalo Niagra Medical Campus (BNMC) site





DOE FOA 997 functional requirements

CHIL: Spirae Wave controller

PHIL: ESS inverter (representative)

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DMS-DERMS-Microgrid Controller-DER

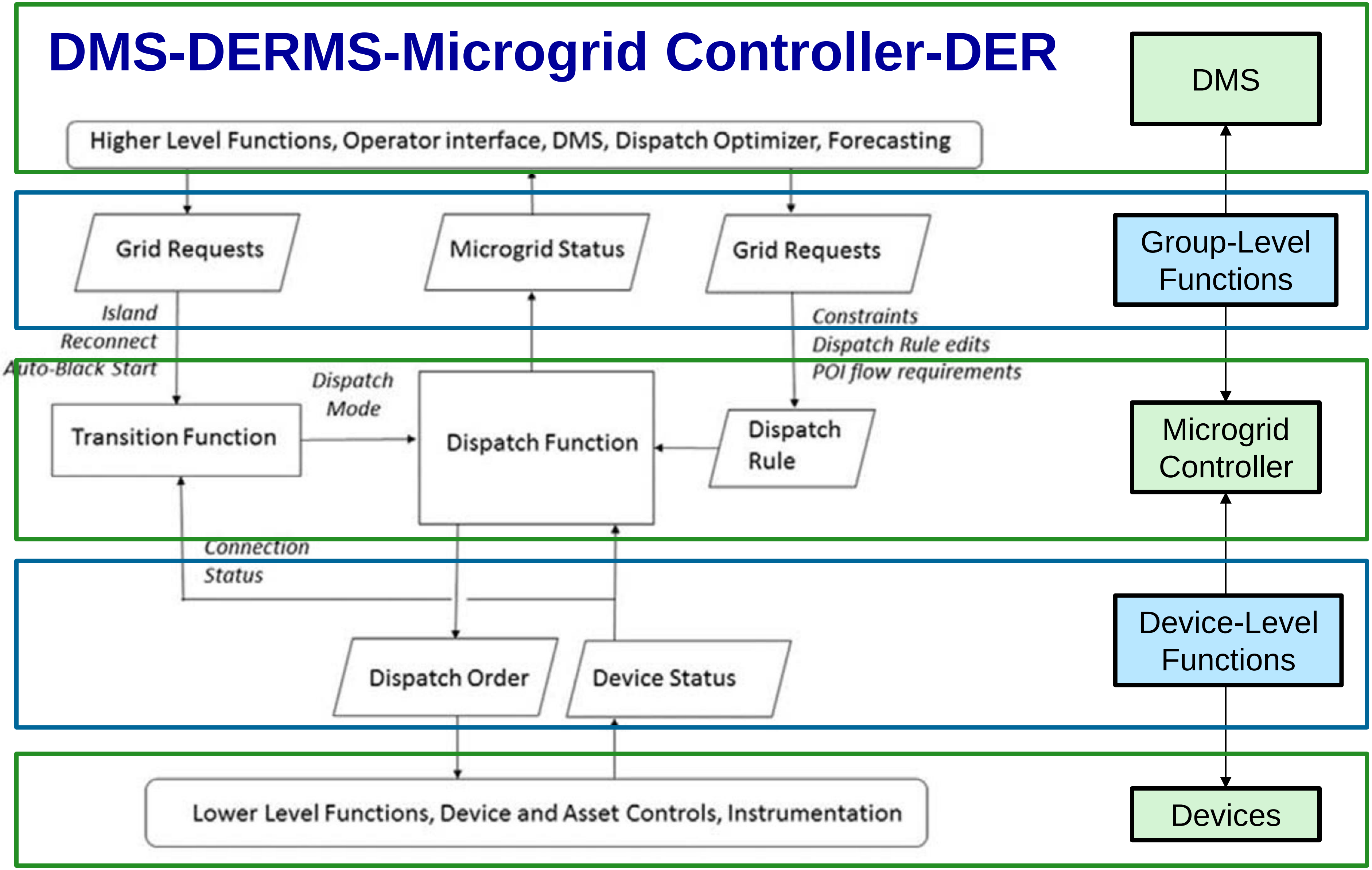


Figure 3. Relationship between transition and dispatch functions.

Establish End-to-End Connectivity

DMS

DMS Applications

- VVO
- FLISR
- OLPF
- …

Microgrid Controller

Microgrid Internal Functions

- Dispatch
- Transition
- …

Devices

Device Internal Functions

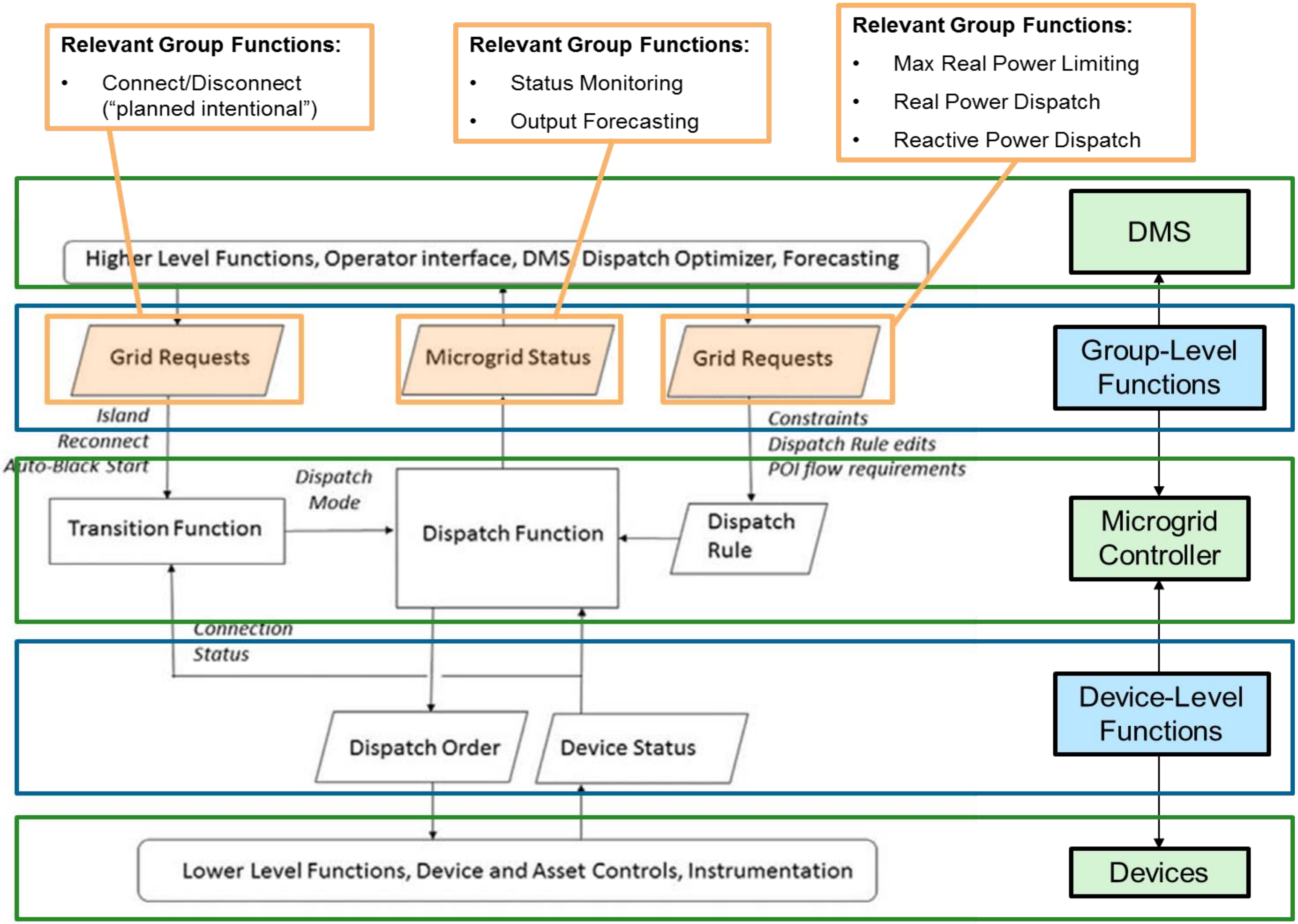
DER Group Functions

- Status Monitoring
- Output Forecasting
- Max Real Power Limiting
- Real Power Dispatch
- Reactive Power Dispatch
- Connect/Disconnect

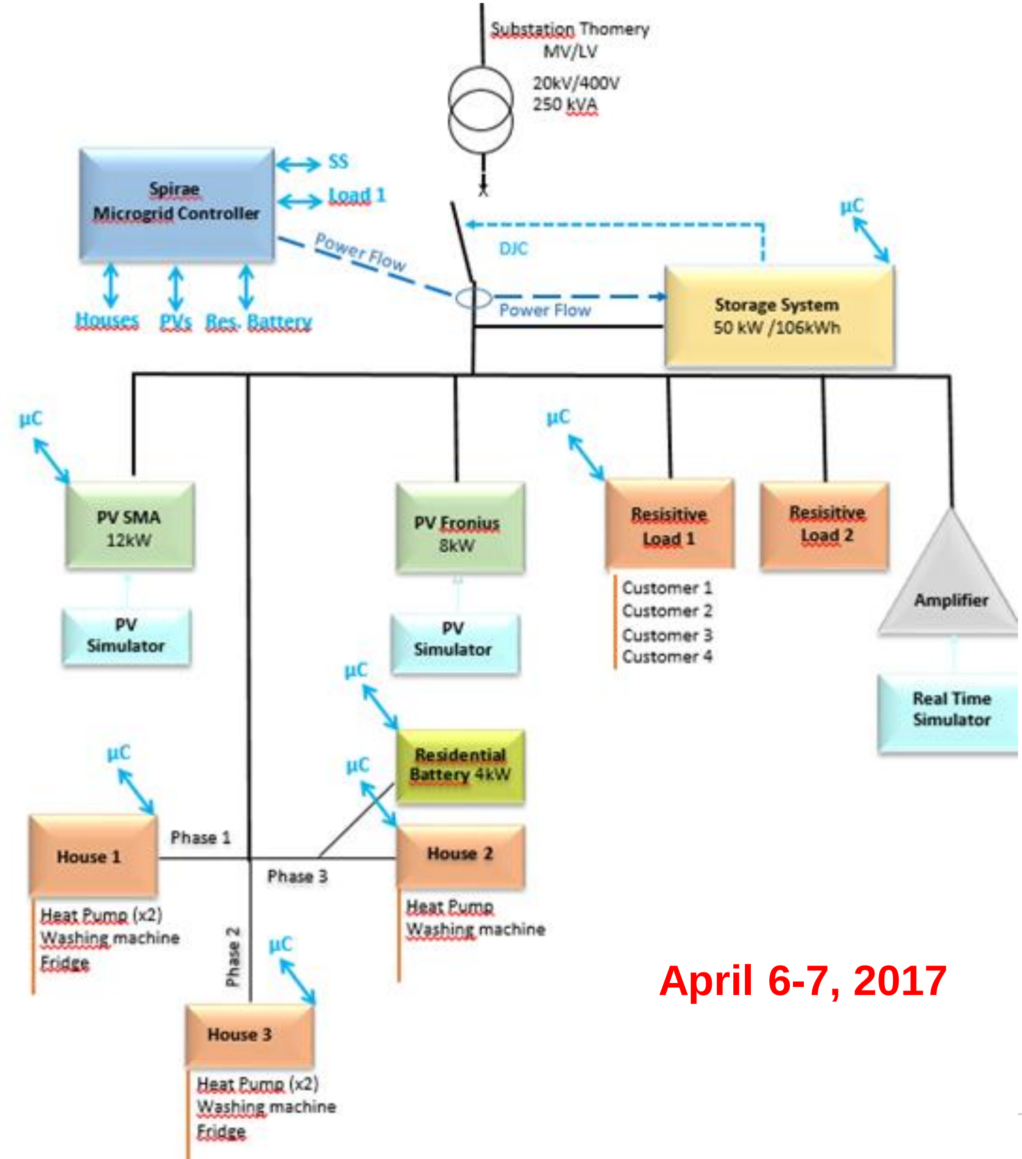
DER Device Functions

- Status Monitoring
- Output Forecasting
- Fixed PF
- Volt-VAR
- Volt-Watt
- …

DER Group Functions and Messages



Microgrid Controller Testing @ EDF Concept Grid



April 6-7, 2017

Benefits of Testing at EDF's Concept Grid:

- Verify capabilities of Wave controller in an environment not limited by the scale or capacity of the power system it is controlling
- Verify communication latency issues

Equipement type	symbol	Equipment details
Air conditioner	A/C 1	Mitsubishi 1 kVA
	A/C 2	Mitsubishi 1.4 kVA
	A/C 3	Daikin 3.5 kVA
	A/C 4	Daikin 3.5 kVA
inverter	=\~ 1	SMA STP 15000TL-10
	=\~ 2	Fronius IGplus 150V-3
	=\~ 3	SMA Sunny island SI6.0H-11
Washing Machine	WM 1	Electrolux 2.2 kVA
	WM 2	Electrolux 2.2 kVA
	WM 3	Boch 2.4 kVA

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