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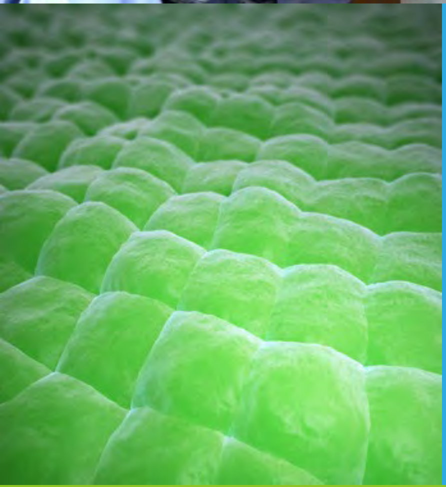
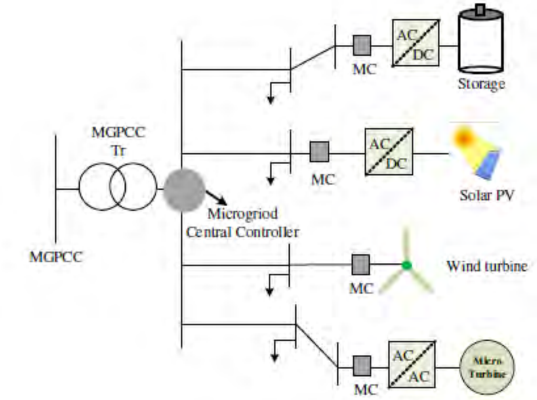


Idaho National Laboratory Overview for Microgrids and MARVEL

Idaho National Laboratory

Overview of Microgrids



- What is a microgrid? A Microgrid is an integrated energy system consisting of distributed generators, energy storage, and/or flexible loads which operates as a single, autonomous grid either in parallel to or islanded from an upstream utility or other power grid.
- Why is it important? Due to increased needs for energy security and resiliency of power supply, end consumers are more concerned with power quality and reliability in recent years.
- How can microgrids Help? Supplying power to critical infrastructures such as hospitals, military bases, data centers, and communication infrastructures during upstream grid outages by operating in islanded mode, providing other services while in grid-connected mode, microgrids help realize optimal use of distributed energy resources.
- What are other benefits? Optimally manage distributed generations, energy storage systems, and responsive loads in both normal as well as abnormal operating conditions. During normal operating conditions for either grid connected or islanded, energy efficiency and economic operations are typical considerations. However, during abnormal operating conditions and transitions, technical aspects such as stability, resiliency, and energy security become primary concerns.

Some Reasons Why Potential Users Want Microgrids and Distributed Energy Resources

- More control over power/energy supply, energy security/resiliency
- Reliability, availability, resiliency improvement; more fuel sources, distributed
- Particular use cases (i.e. fuel use/shipment reductions, demand management, voltage support, power quality improvements/flexibility, T&D congestion mgmt., upgrade mitigation, outage mgmt./backup power, etc.)
- Energy management and use control
- Improved power system knowledge/metering and control
- Optimize investments, asset sizing and improve system architectures, usability (i.e. UPS with lead acid batteries and diesel gensets vs. more flexible energy storage and genset options)
- Enable optimal loading on gensets, non-spinning reserve, turn off gensets at times and still pick up load changes, allow time to spin up additional gensets
- Green energy goals and knowledge of energy supply

Many Distributed Generation Resource Options

- Solar, wind, run-of-river/stream/canal hydro, micro-hydro, geothermal, GSHP
- Natural Gas (CHP, CCP, gas turbines, internal combustion, microturbines, fuel cells, linear generators)
- Diesel, other fuels (LPG, CNG, LNG, etc.; up and coming: hydrogen, ammonia, synfuels, small/microreactor nuclear)
- Battery storage (Li-ion, flow batteries, advanced lead acid, NiCd or NiMH, etc.)
  - Many potential applications and value streams for battery storage (frequency and voltage regulation, peak shaving, capacity, congestion management, backup power and outage reduction/management, etc.)
- Other storage, controllable load: pumped hydro, desalinization systems, hydrogen production/storage, etc.
- Thermal storage, building thermal and load management (ice, chilled water, hot water, building temp controls, thermal mass, solar heating (active and passive), efficient systems and controls, etc.)
  - Include energy efficiency measures and designs

Energy balance, resource characteristics and asset choices are key

- develop business case and economics, <u>define requirements effectively!</u>
- systems planning, integration and controls choices are critical (i.e. acquire equipment with the capabilities and functionality needed now or in future, such as inverters that can operate in islanded modes, output control, etc.)

Microgrid Control Considerations

- Inverter control options: PQ control, MPPT, P-f and Q-V control (droop), closed-loop voltage and frequency control
- Controls approach when combining inverter based generation and storage with spinning generation; primary, secondary and tertiary algorithms
- Some microgrid operation and control use-case categories:
  - Frequency control
  - Voltage control (grid-connected and islanded)
  - Energy management (grid-connected and islanded)
  - Ancillary services (grid-connected)
  - Grid-connected to islanded transitions, intentional and unintentional
  - Islanding to grid-connected transitions
  - Protection (can include adaptive approaches)
  - Black start
  - User interface and data management

Ascension Island: wind, diesel, synchonous generator, desalination hybrid energy microgrid system.

FE Warren AFB wind turbines: utilized for microgrid energy security and controls demonstration, 2009.

RAPID-MG, i.e. Microgrid-in-a-Box

- This is a first-of-a-kind system for portable, medium-high energy density power grid storage applications with a size that can power a 125kW-250kW sized commercial/end-user building/facility, for multiple hours, with switchable power ratings between 415/230VAC, 50Hz, three-phase to 480/277VAC, 60Hz three-phase, and including advanced controls for specified functions during both grid-tied and islanded operations that are suitable for military or commercial/utility applications.

- The control mode features available in this system are newly released, and allow for stacked mode uses and droop settings adjustments during operations with communications and commands from advanced secondary/tertiary control systems.
- System can stay in voltage-source in most applications, or switched to P-Q if needed.
- Portable and deployable energy blocks are connected into and managed by the microgrid controls system as needed/available. These can include solar, wind, micro-nuclear, fueled resources, hydrogen-based, etc.
- RAPID-MG stands for Resiliency/Relocatable Alternative Power Improvement/Distribution - Microgrid

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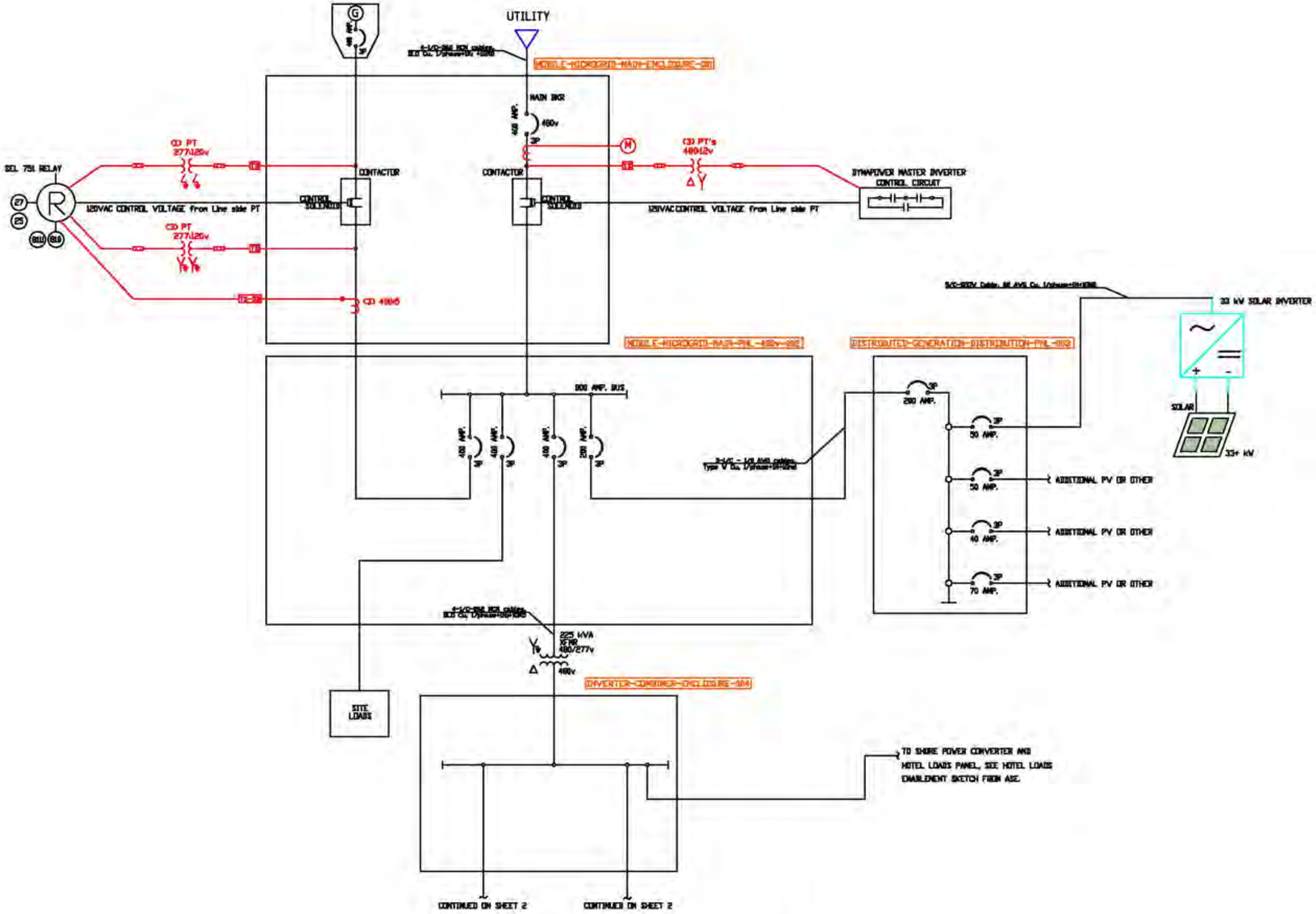
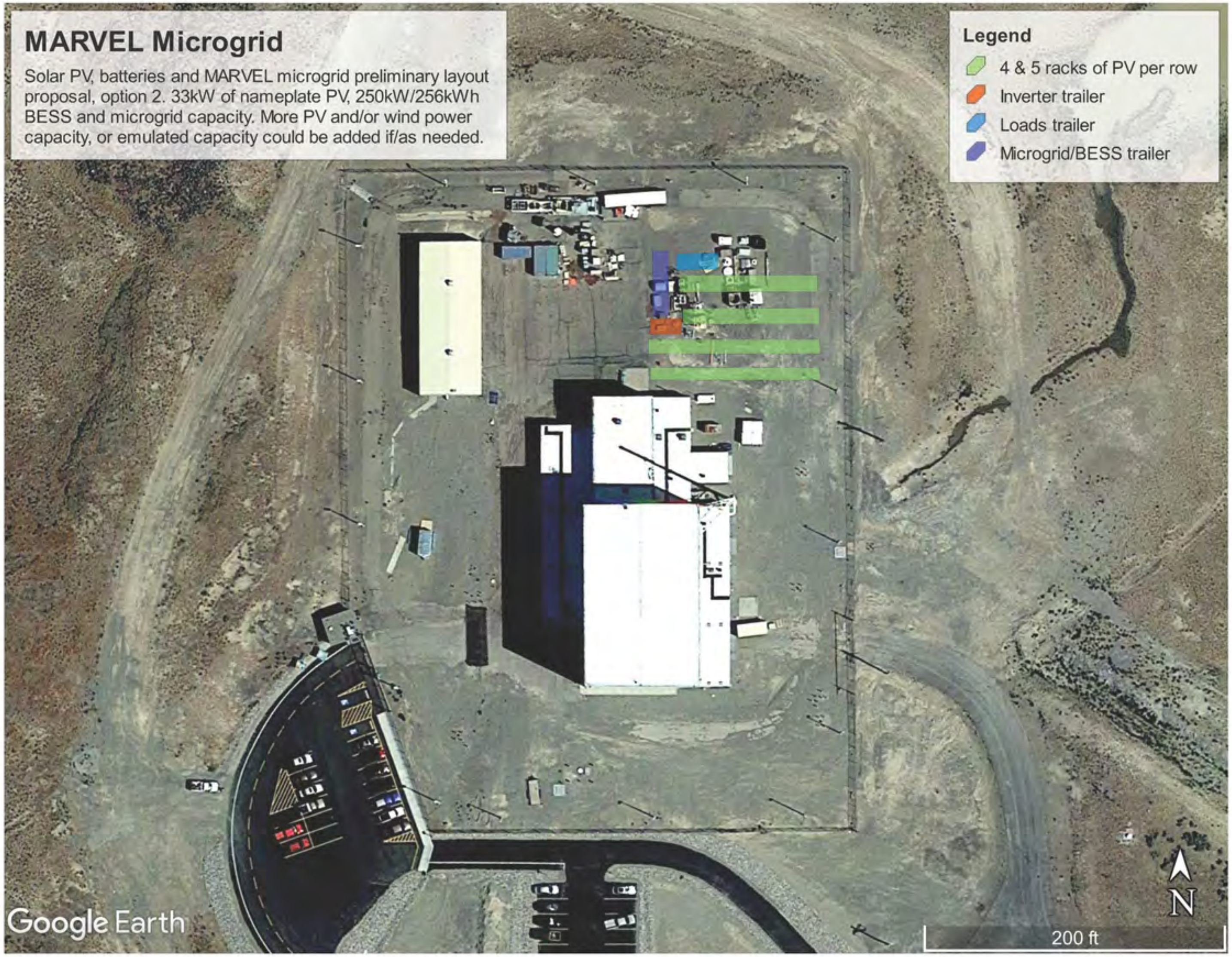
RAPID-MG High-Level One-line



Potential Area for MARVEL Microgrid Components

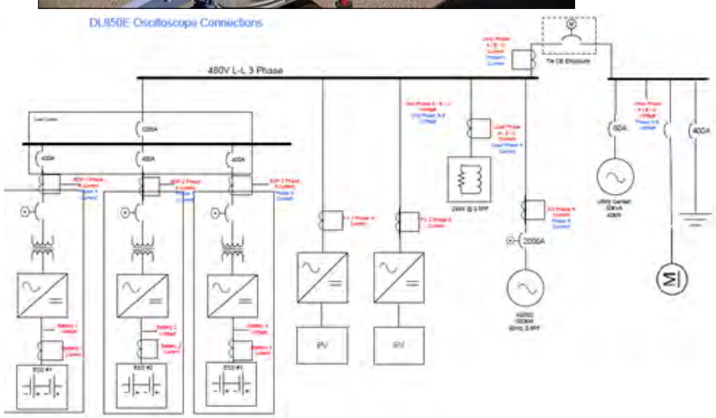


Microgrid System Architecture Optimization

- Analyze and determine desired power and energy penetration levels of variable generation (i.e., solar PV), load profiles, generation profiles, fueled generator load levels, amounts of storage and load control to enable designs for stable and optimal control, fuel use/durations and mission/energy security
  - Storage considerations may include fuel tanks, batteries, natural gas systems (pipelines, bulk storage), hydro, LPG/CNG/LNG, hydrogen, thermal, etc.
- Are you designing for times of fueled generation off, certain number of spinning generators always on, set amounts of spinning reserve, or other?
- What control functions are available in inverters, fueled gensets, secondary control systems, etc. that will allow for optimal system integration/control (i.e., droop, isochronous, advanced droop coordination, PMU-based control, etc.)
  - or what modifications need to be developed or added to the primary and secondary control systems to achieve desired results for all modes/use-cases
- Consideration of integration of other devices to improve stability, operability
  - Secondary, tertiary control loops/algorithms
  - Battery storage systems with advanced inverter functions/controls
  - Flywheels, SVAR, DVAR, and/or switched components for Volt/VAR control
- System protection and electrical power improvements
  - Considerations are somewhat different when generation is distributed closer to loads and connected within distribution panels

Microgrid System Architecture Optimization, continued

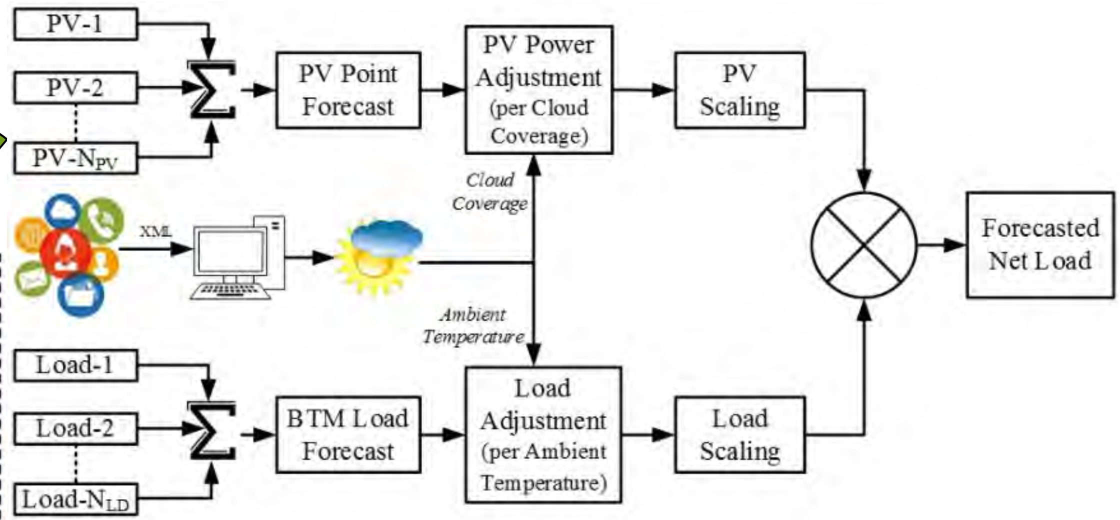
- Fueled gensets all the same sizes, or varying sizes to match up with net load profiles better?
- Make sure storage and genset combinations can pick up and manage any swings or steps in variable generation and loads. Sizing of these is critical, for both power and energy capacities, and for protection design and inrush considerations.

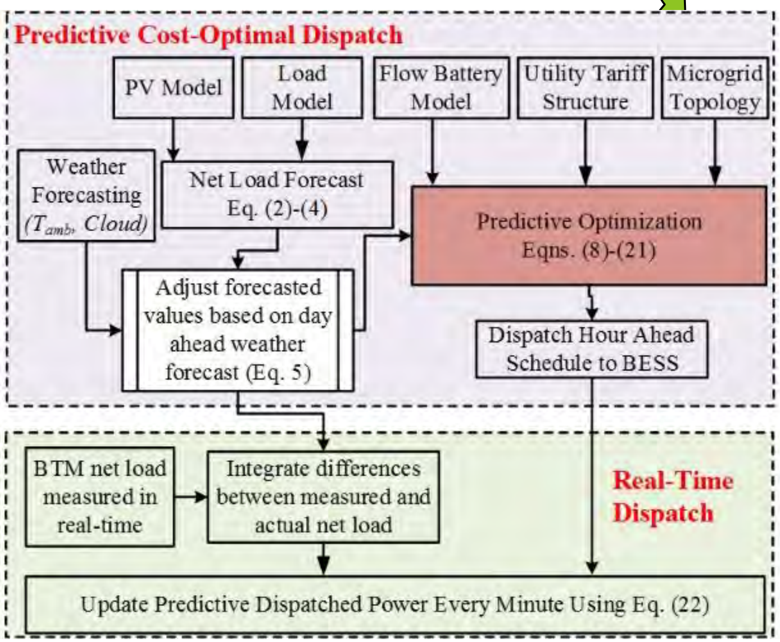


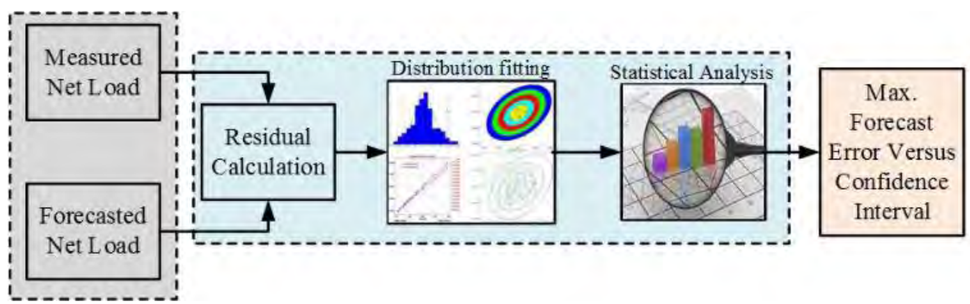
Microgrid Research and Development at INL

- **Applications:** Peak-shaving, demand or TOU management, load shifting, load-shaping/matching, Volt-var support, advanced droop coordination methods, frequency/distribution system regulations, forecasting, stacked and across-meter use cases and controls for BESS systems, and MG control techniques and interactions.

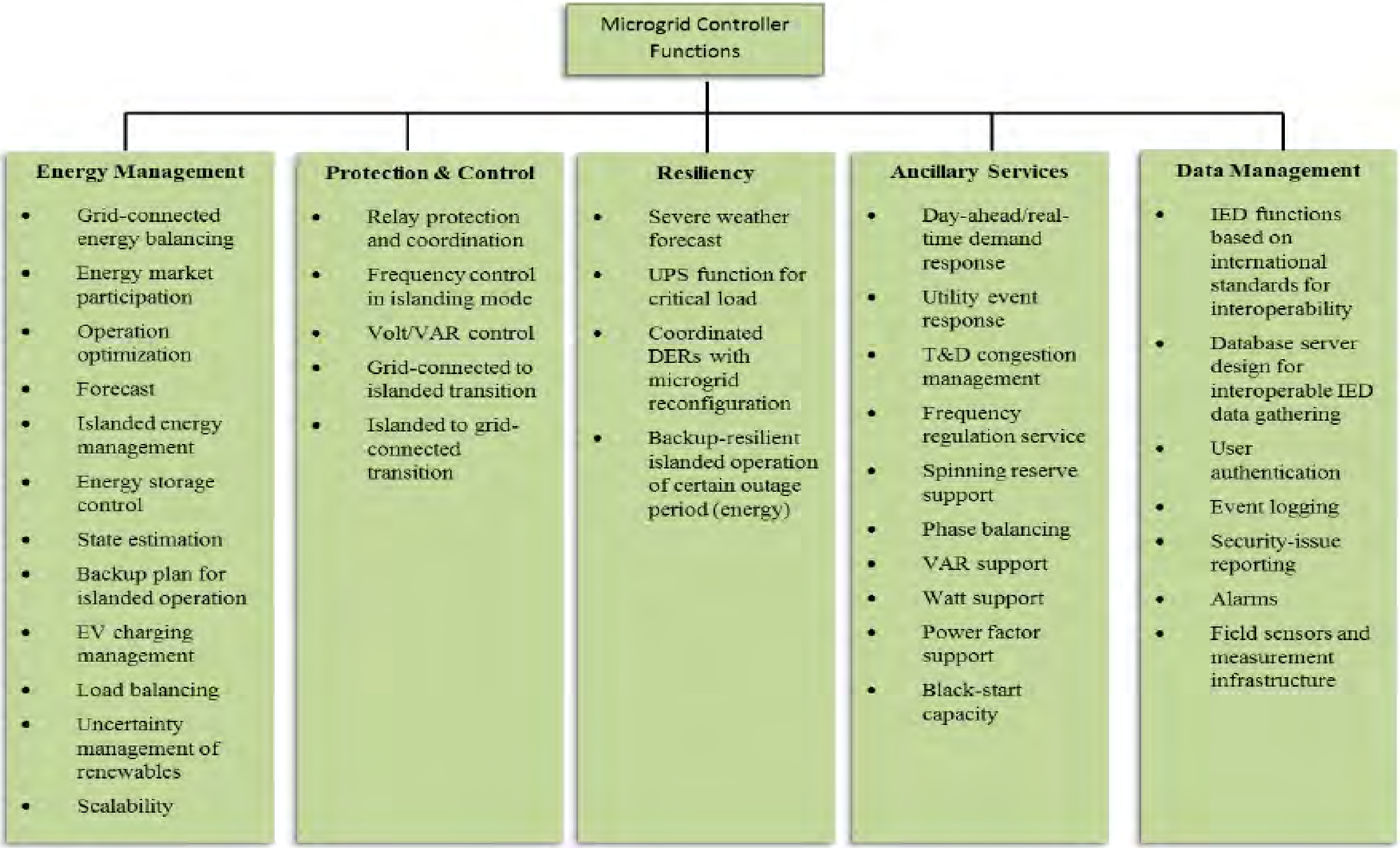
Multi-time-scale energy management



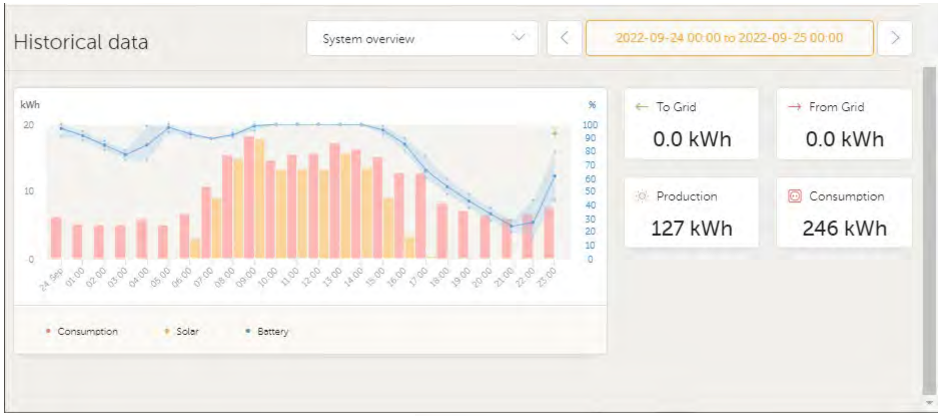




Sampling of Microgrid Control Functions



Successfully installing field implementations in Kuwait (1 of 3)



- Three projects that are part of the Operational Energy program managed through INL on behalf of the US Army Central Command (USARCENT) successfully completed their initial field implementations.
  - This occurred on two military installations in Kuwait.
  - INL team members involved include B. Turk, K. Myers, P. Hill, M. Shurtliff and J. Bush.
- The first project successfully guided the first hybrid microgrid implementation for the US in Kuwait, using advanced inverters, battery storage and specialized solar photovoltaic implementations.
  - This microgrid will operate with a higher than 60% penetration of renewable energy.
  - It will operate on battery and solar only for multiple days in a row.
- When the battery gets low, the generator will be automatically called to supply the load and recharge the battery.

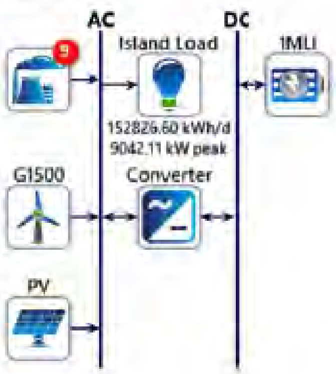
DoD Island Future Hybrid Concept Modeling: Small Nuclear, Solar PV, Wind, Batteries, Diesel

HOMER Pro

System Architecture

Component	Name	Size	Unit
Generator #1	Diesel A	2,000	kW
Generator #2	Diesel B	2,000	kW
Generator #3	Diesel C	2,000	kW
Generator #4	Diesel D	2,000	kW
Generator #5	CAT-NG-1490kW-60Hz-1	1,490	kW
Generator #6	CAT-NG-1490kW-60Hz-2	1,490	kW
Generator #7	CAT-NG-1490kW-60Hz-3	1,490	kW
Generator #8	CAT-NG-1490kW-60Hz-4	1,490	kW
Generator #9	Diesel E	2,000	kW
PV	Generic flat plate PV	8,000	kW
Storage	Generic 1MWh Li-Ion	12	strings
Wind turbine	Generic 1.5 MW	3	ea.
System converter	System Converter	8,760	kW
Dispatch strategy	HOMER Load Following		

Schematic



Production Summary

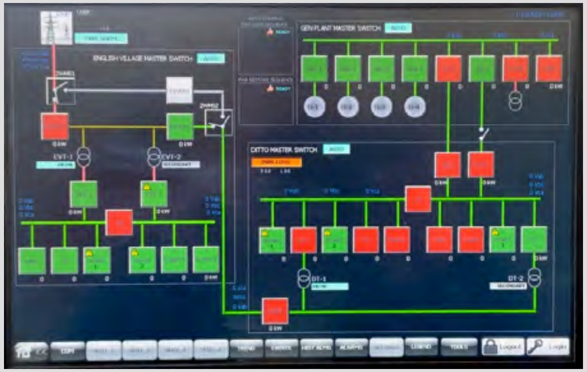
Component	Production (kWh/yr)	Percent
Generic flat plate PV	15,992,130	27.5
Diesel A	1,489,658	2.56
Diesel B	493,600	0.848
Diesel C	79,200	0.136
Diesel D	0	0
CAT-NG-1490kW-60Hz-1	9,923,894	17.1
CAT-NG-1490kW-60Hz-2	8,139,959	14.0
CAT-NG-1490kW-60Hz-3	5,834,513	10.0
CAT-NG-1490kW-60Hz-4	2,510,977	4.31
Diesel E	0	0
Generic 1.5 MW	13,734,444	23.6
Total	58,198,375	100

Small Sampling of Other Power Systems, Renewable Energy and Island-Microgrid Projects

- UT DOD Site – 2 MW PV, diesel powerplant upgrades, power studies and upgrades, multiple other energy projects, upcoming 2 MW PV+storage and wind turbine or additional PV, plus microgrid with battery storage.
- UT DOD Site – 1.5MW solar CSP, 1.5 and 1.8 MW wind turbines, power studies and upgrades, multiple other energy projects, microgrid w/ battery storage, upcoming diesel to NG genset upgrade.
- Ascension Island – Wind-diesel island power system, plus controls, desalination and PQ management systems.

Resiliency Considerations

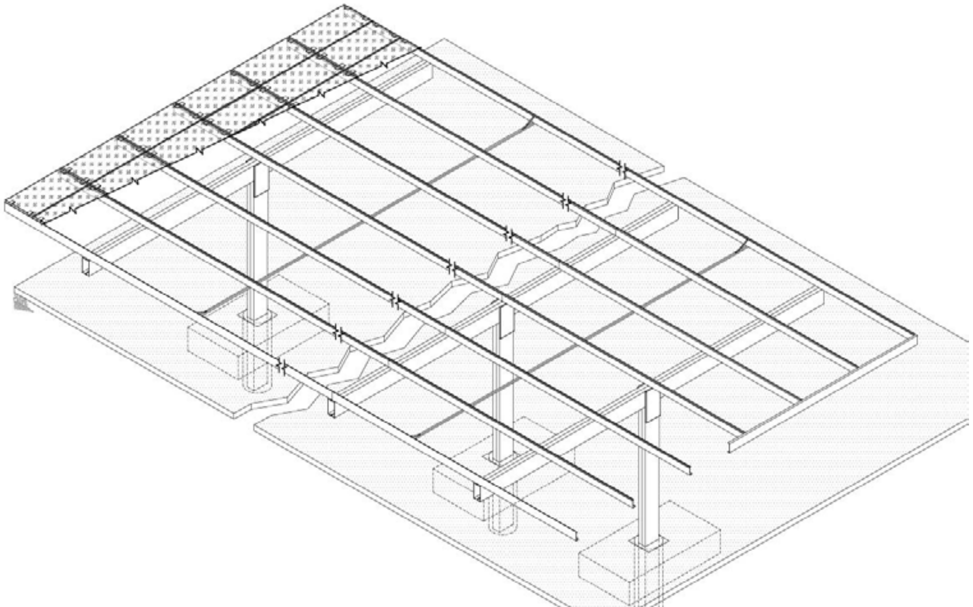
- Potentials for supply chain impacts depending on resource types and related infrastructure/systems
- Potentials for cost impacts due to outages or supply chain impacts
- Need to start valuing and funding resiliency more directly (improved resiliency and availability is typically worth 20% to 300+% more than the regular blended cost of electricity)
- Some energy resource types have significant potentials for price volatility, plus future cost impact considerations, especially for carbon-based fuels
- Increasing potential for use-cases utilizing energy storage combined with other assets and advanced controls.




ESILIENT ENERGY
INFRASTRUCTURE

Thank you!!!!!

Questions????



REPRESENTATIVE TEE SOLAR CANOPY ISOMETRIC

REFER TO PLAN AND SECTION VIEWS ON S2 FOR PROJECT SPECIFIC DETAILS

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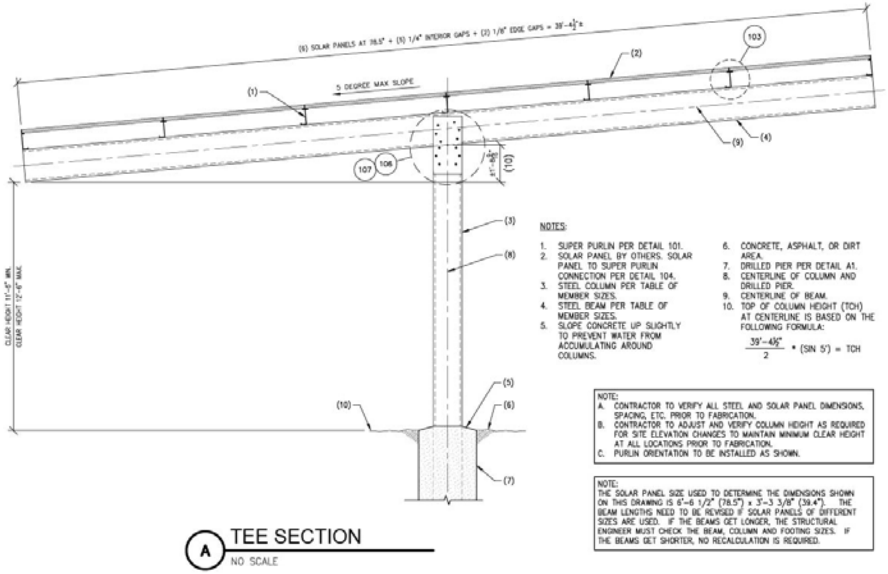

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Extra Slides

Sampling of Energy Storage Functions

- Peak/demand management (i.e., peak shaving, demand response)
- Frequency regulation
- Voltage regulation
- T&D upgrade deferment
- Capacity and reserve functions
- Solar and wind power shaping, energy shifting, curtailment reduction
- Load shaping; ramp rate control
- Black start assistance
- Hybrid with gas generation to provide more responsive and cost-effective system reserves
- Enable higher penetration of renewable energy in grids, microgrids
- Improve interaction potential with Western EIM market or other BA's?
- Can BESS systems be utilized to reduce wear and tear costs on other regulating and reserve systems (i.e. hydro turbines, NG generators, etc)?

Bulk Grid Basic Control/Services Considerations

Grid services for electric power systems are traditionally defined as ancillary services, such as power regulation and frequency response, spinning and non-spinning reserves, etc., to support the reliable and stable operations of electric power systems. These include the following essential reliability services deemed necessary for managing frequency, voltage, net area demand and dispatchability:

- Frequency support
- Ramping and balancing
- Voltage support.

Other basic services include (1) Scheduling, system control, and dispatching; (2) Reactive supply and voltage control from generation resources (3) Regulation and frequency response; (4) Energy imbalance; (5) operating (spinning) reserve; and (6) Operating (supplemental) reserve services.

Of course, must include transmission, protection (and systems responses) and power recovery considerations.

- As grids transition to more inverter-based and variable resources, large amounts of R&D related to these considerations are needed for years to come.