Performance Optimization for Power and Energy Systems in Remote and Isolated Electric Grids / Microgrids

Rob Hovsapian, Ph.D.
Department Manager / Research Scientist
Power and Energy Systems Department
Idaho National Laboratory, Idaho Falls, ID, USA

Emerging Priorities in Energy Research
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Emerging Technologies – Timeline of Expectations

Source: from Gartner, Inc. website
Power and Energy Real-Time Laboratory (PERL)

Opal RT, FPGA Development Environment (IEEE 1394 and MIL 1553)

High Performance Computing (~1800 compute nodes)

Controllers (Siemens, SEL RTAC)

100+ RISC-based programmable cards for emulating hardware devices (Electric Vehicles, Wind Turbines)

Typhoon HIL for Testing Advanced Power Electronics

Linux Servers for communication layer, Real-time Data Analytics

Real-Time Digital Simulator

Programmable V & I-Amplifiers

Micro-PMUs

Protection Relays
Co-simulation for power systems, power electronics, and communication

Integrated Power System and Data Simulation Environment

Controller HIL
Rapid Prototyping

Power Grid or Microgrid(s)
Under Test

Interface
Controls
Simulation time step 50μs

Data Acquisition

High Speed Communication Layer Emulation

Control Systems
EMS/DMS

Storage Devices

Adv. Power Electronics

Interface
Controls

Wide-bandgap Power Converter
time step ~100ns
Integrated Hybrid Energy Storage for Hydro
GMLC RADIANCE – Energy Storage Optimization

- ROR HPP Modeling – dynamic and transient evaluation in real-time simulation
- ROR HPP applications in microgrids/weak distribution grid that provide support / reliability / resiliency

Energy Storage Optimization for
- Multi-timescale (Super-Capacitor, Flywheel, Batteries) response coordination for grid support
- PHIL-based characterization of ESS under dynamic conditions

ROR HPP Modeling – dynamic and transient evaluation in Real-time Simulation

GMLC RADIANCE project outcomes from Run-of-the-river and Pumped Storage Hydro research

a) ROR as a resource for rotational inertia and regulation in coordination with microgrid controller and Energy Storage Optimization Toolbox (ESOT)
b) Coordinated operation with proximal generation as ROR or Pumped Storage Hydro (PSH)

a) Assessing rotational inertia from the existing ROR plant – resiliency enhancement
b) Modifications by removing deflector plates for rotational inertia in microgrid for regulation and frequency support
c) Upgrading hydraulic governors to digital electronic for faster, more efficient operation

Humpback Creek Run-of-the-river Hydroelectric Plant 1250kW (2 x 500 kW + 1 x 250 kW)

Power Creek Run-of-the-river Hydroelectric Plant 6278kW (2 x 3124 kW) with inflatable dams

City of Cordova 1,566 customers, 18MW One Substation

Orca Power Plant (10.8MW Diesel) Control Center

Crater Lake Dam Storage may offset 25% Diesel consumption

Siemens Energy Storage Optimization Toolbox (ESOT)

ROR HPP

a) Capacity evaluation for pumped storage hydro (PSH) as energy storage
b) Evaluation of design configurations for PSH technologies (multiple vs. single, fixed-speed vs. variable-speed)
c) Simulation-based testing of PSH as part of microgrids under dynamic seasonal conditions
d) Economic analysis of design configurations and technologies for pumped storage hydro
RADIANCE - Energy Storage Optimization Toolbox

Microgrid Control

SCADA / Existing Grid Control (PLC)

Energy Storage Optimization Control

Firmware functions (fast: only CSI)
Low-level Control

Power Converter (ABB) modular PCS

Protections

Rest of system (generators, breakers)

Power Creek

Battery Management System (SOC, CHG/DISCHG constraints: inst., continuous)

Battery modules (SAFT)
Advantages/Opportunities of Smart Meter

- Controllable EV Charging
- Reduce Hydro Spilling
- Maximizing Diesel Generation efficiency
- Optimize time of day usage
California Energy Commission’s Blue Lake Rancheria Microgrid

- First digital blueprint developed and used for HIL testing at INL
- A Red Cross Evacuation Route

“2017 FEMA Whole Community Preparedness Award”

“2018 POWERGRID International and DistribuTECH Project of the Year Award”
Blue Lake Rancheria Microgrid


https://www.osti.gov/servlets/purl/1426889
Distributed Grid Assets – $H_2$ Refueling Stations / Electrolyzer in California

- PG&E territory stretches from Northern California to central California
- Several current and future locations of the hydrogen refueling stations are generated from earlier NREL studies
- PG&E infrastructure associated with these locations is studied
- Network synthesis and modeling in real-time simulator at INL, represents the PG&E infrastructure
- It spans major distribution and coupling transmission lines (from 69 kV to 138 kV) associated with the hydrogen refueling infrastructure
- Serves as a testbed for testing grid services and stability of connecting electrolyzers in utility systems
Digital Real Time Testing for Flow Batteries

INVERTER #1 - MASTER (170)
- Analog Input P
- Analog Output P
- Analog Output Q

INVERTER #2 - SLAVE (171)
- Analog Input P
- Analog Output P
- Analog Output Q

FLOW BATTERY #1
- ViZn Z20

FLOW BATTERY #2
- ViZn Z20

Maximum Power 64 kW
Maximum Energy Storage Capacity 160 kWh
Nominal Power 22 kW
ORCA – assessment of marine hydrokinetic-based reliable and Resilient electrification in Alaska

ORCA Phase 1 – A high level schematic of assessing the feasibility of interconnecting rural grids in Western Alaska and Southeastern Alaska
Interconnection of Remote and Isolated Microgrids

- Advanced AC and DC transmission and distribution technologies for interconnecting multiple remote and isolated microgrids

Real-time Digital blueprint with AC and DC, Transmission, subsea cables

Actual power system data, profiles, topology, etc.

Field Implementation

Hardware Controller

Actual Dynamic Profiles
Thank you

Questions?

Rob Hovsapian, Ph.D.
Rob.Hovsapian@inl.gov