Smart Micro Grids – Global Pilots

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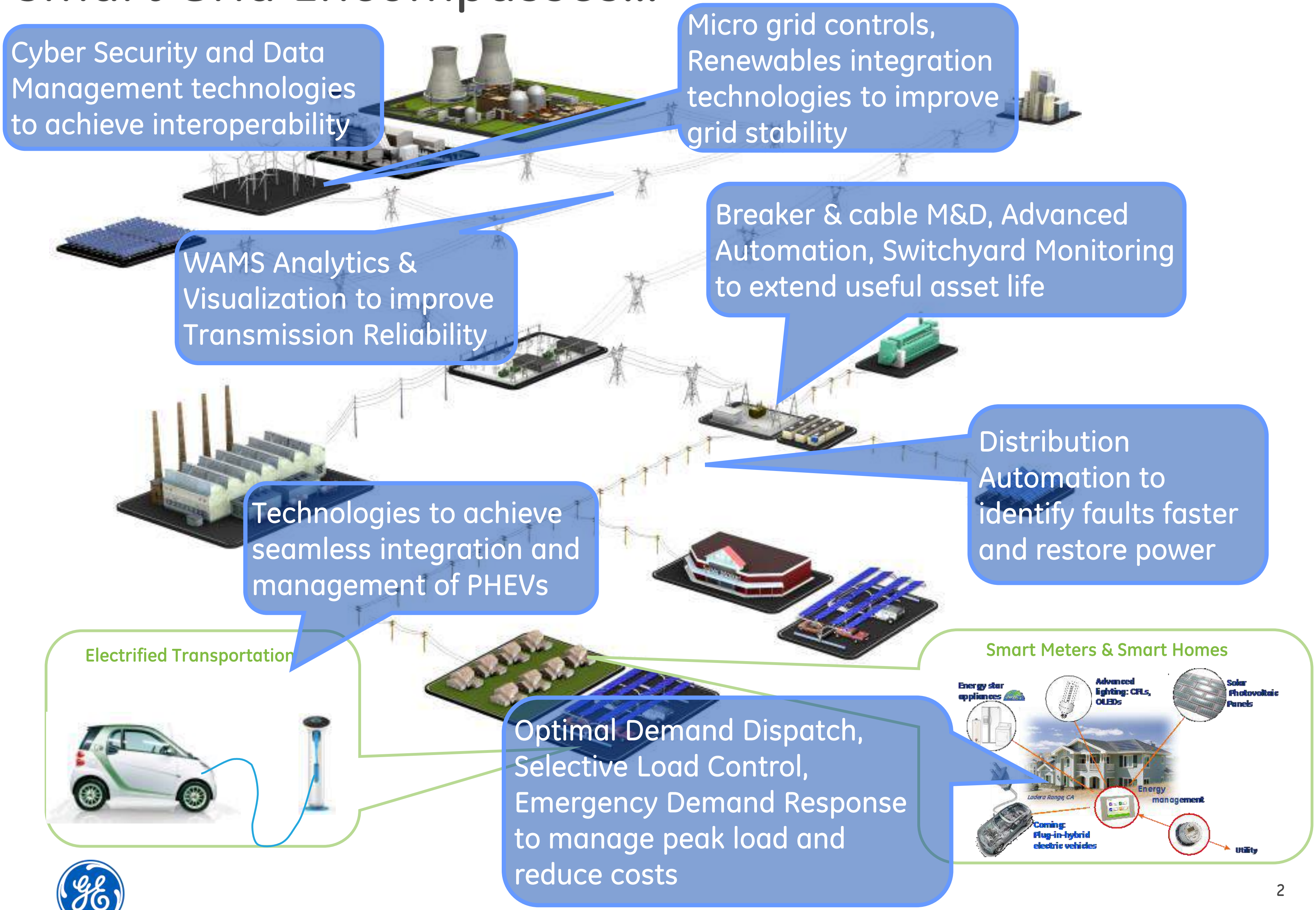
Imagination at work.

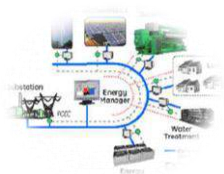
Smart Grid Encompasses…



Global Micro Grid R&D/Pilots

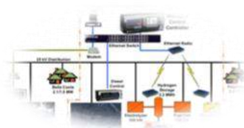
Significant R&D investment over 10+ years

10+ years of R&D transitioned to GridIQ Microgrid Control System



2005 – DOE MG Project

- Preliminary economic dispatch
- POI tie line controls

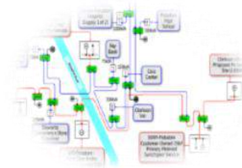


2007 – Bella Coola MG

- Fuel cell integration
- Hydro integration
- Diesel offset controls

2011 – DOD 29 Palms

- Intermittency control w/PV
- CHP optimization
- Volt/VAR control
- Storage integration



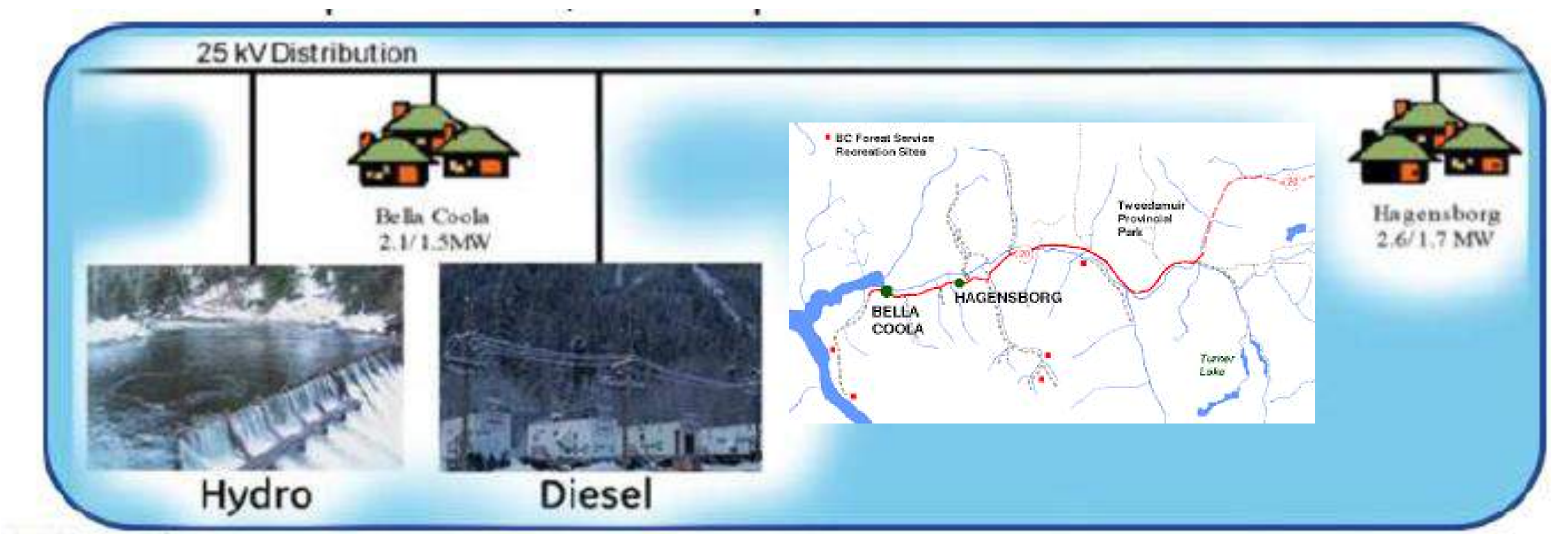
2015 – DOE MG Project

- IEEE 1547 compliance
- Frequency control
- Remote Q
- Ramp rate limit
- Black start
- Load balancing

Bella Coola – Remote Micro Grid

Bella Coola – In the Past

- Site: 430 km north of Vancouver, British Columbia
- Power Generation: 8 diesel units (6.2 MW) and 2 hydro units (2.2 MW)
- Load profile:
  - Bella Coola: 2.1 MW winter, 1.5 MW summer (peak)
  - Hagensborg: 2.6 MW winter, 1.7 MW summer (peak)
  - Total: 4.1 MW peak winter, 2.3 MW peak summer

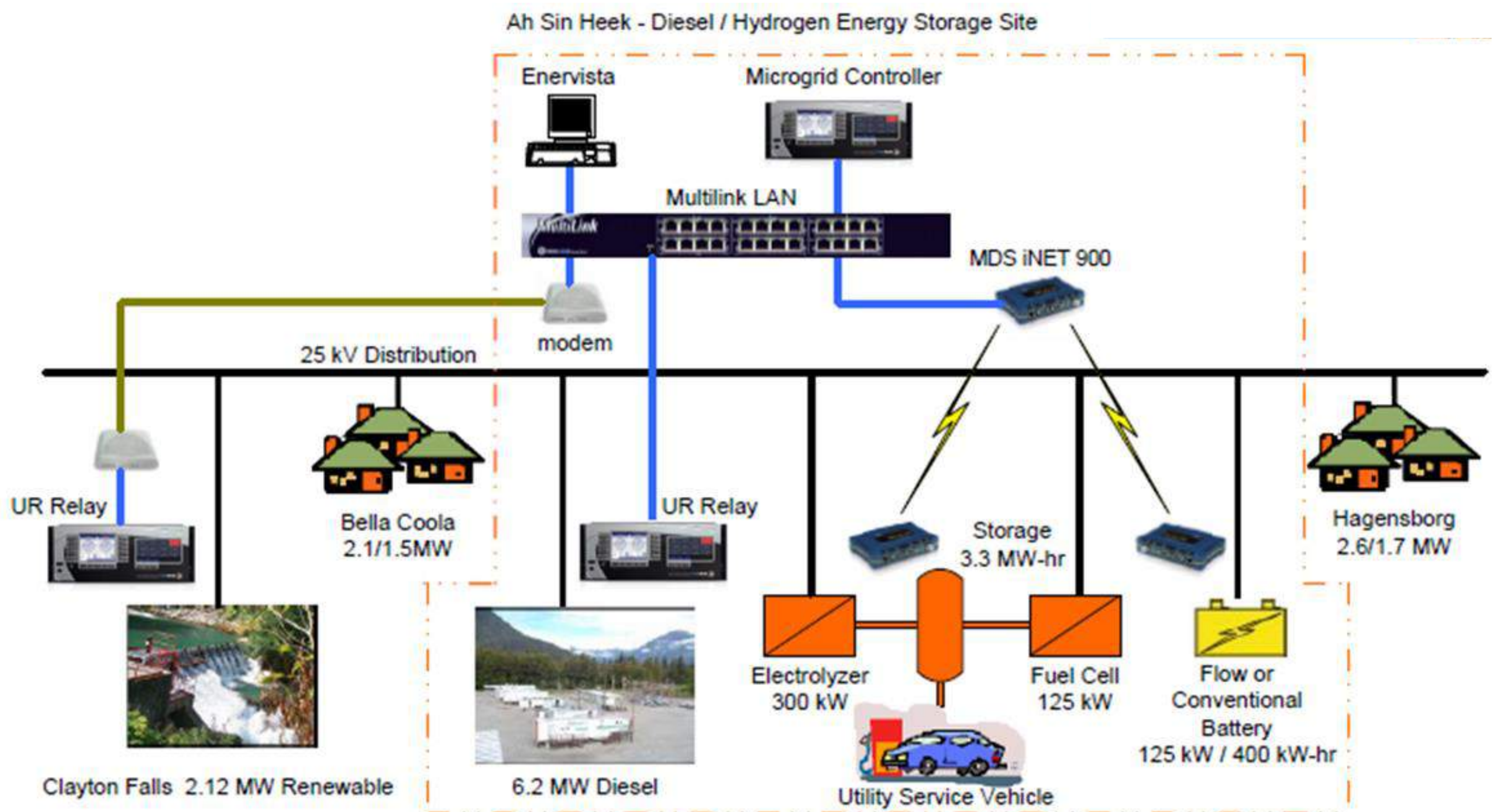


Bella Coola – drivers for micro grid

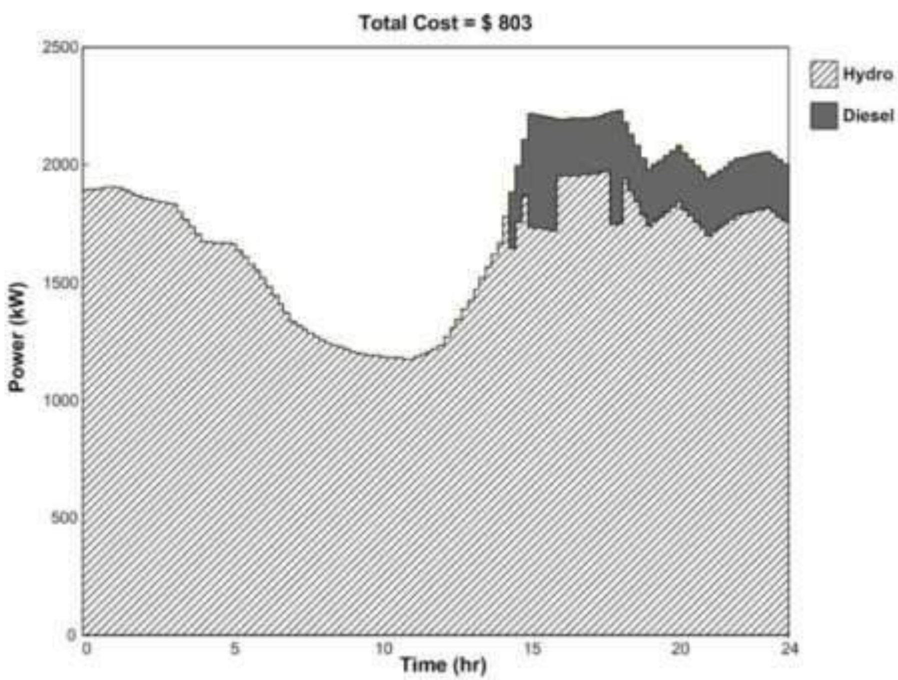
- Substantial diesel consumption
- Costly fuel transportation – terrain/harsh winters
- Inefficient system control and monitoring
- Greenhouse gas emissions
- Waste of hydro power - unavailability of storage, inefficient utilization of hydro units

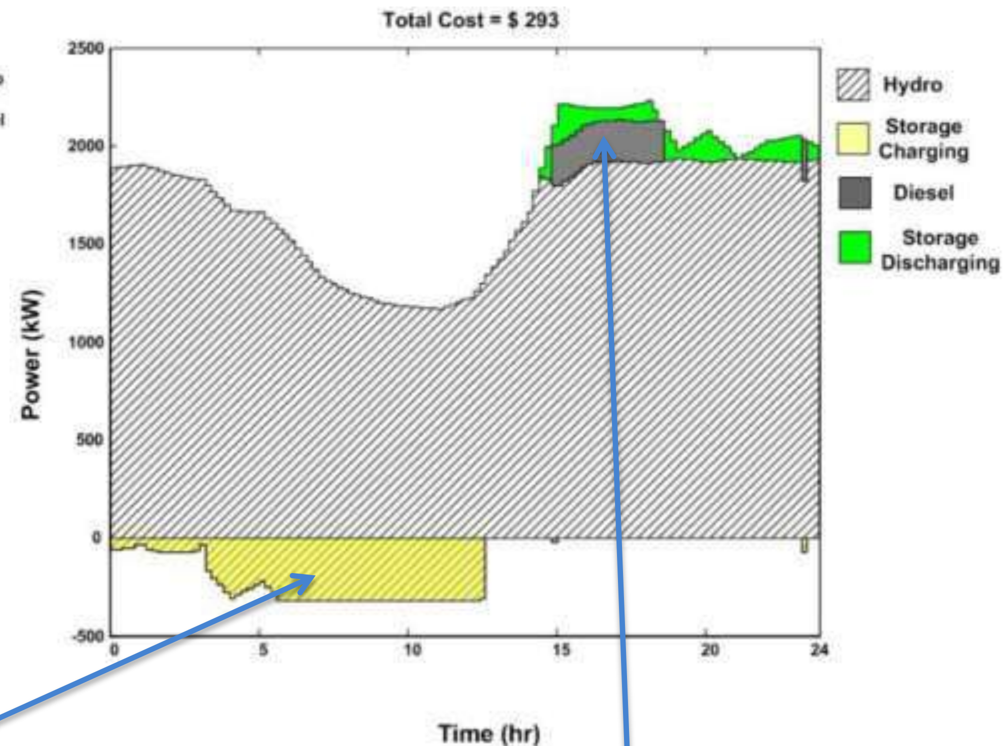
Bella Coola – Complete Solution

- Addition of the hydrogen and battery storage systems, and enhanced with smart grid technologies



Operation with Hydro in Isochronous mode





Charging the storage when surplus hydro is available

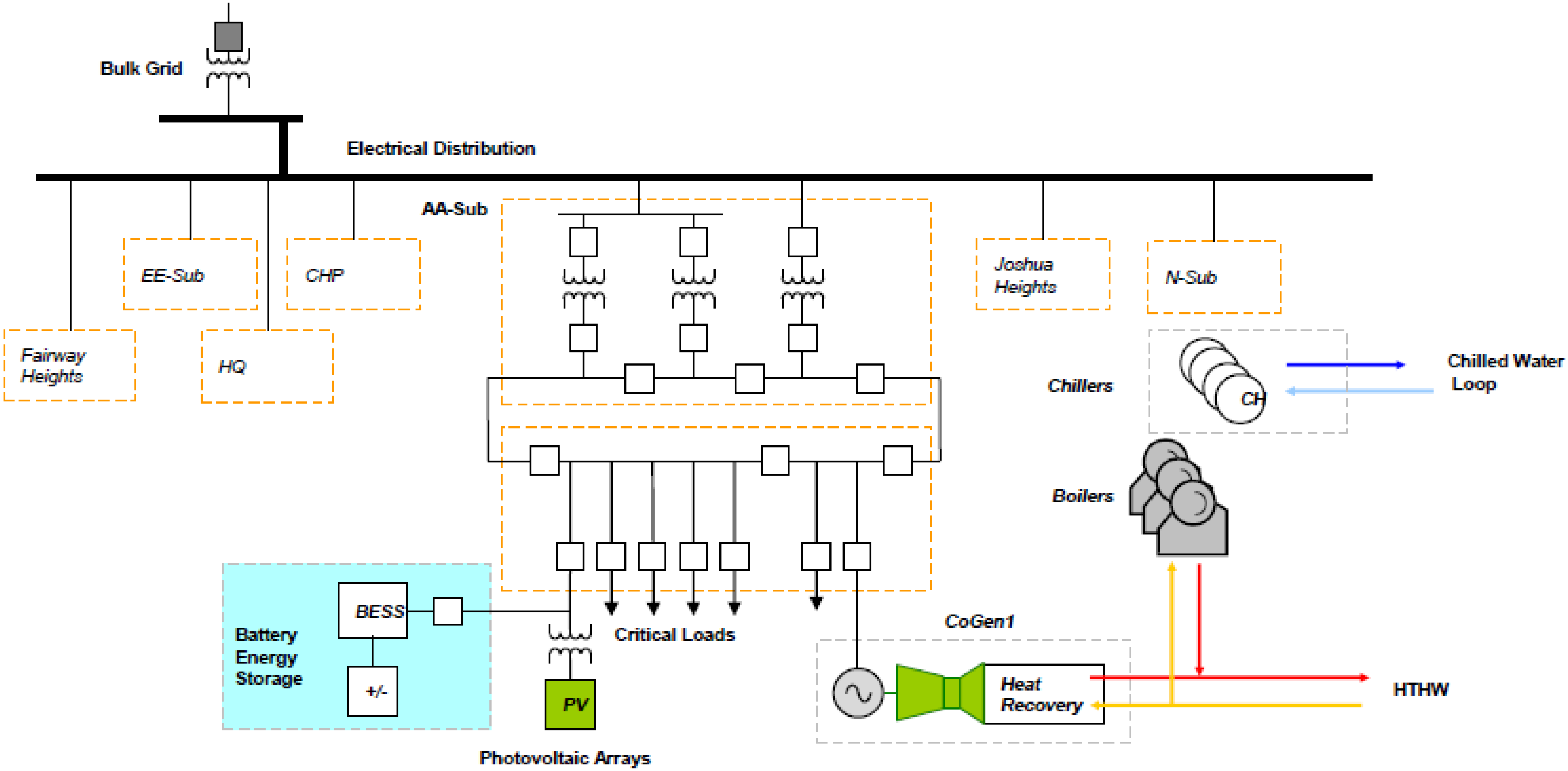
Reduced operation of diesel units and efficient utilization of storage

Bella Coola – Lessons learnt

- Served as proving grounds for key equipment and devices - hydrogen based energy storage and fuel cells
- Low short circuit capacity – stability challenges
- RTDS valuable for design, test and validation
- Need for local trained technicians/experts
- Operator acceptability
- No interference with the conventional control
- Program planning needs to consider harsh environment and access to remote communities

29 Palms – Grid Tied Micro Grid

29 Palms Military Base



~ 30% PV penetration, with electrical and thermal assets

29 Palms Micro Grid

Phased Technology Insertion

Phase 1

- Optimal Dispatch of DERs
- Co-optimization of Electrical and Thermal Loops
- Islanding Capabilities

Phase 2

- Integrated Volt/VAr Control
- Peak Load Reduction using CVR
- Manage High PV Penetration
- Voltage Flattening

Phase 3

- Integration of Energy Storage

Challenges and Lessons learnt

Instrumentation and observability

Built in hooks for future assets

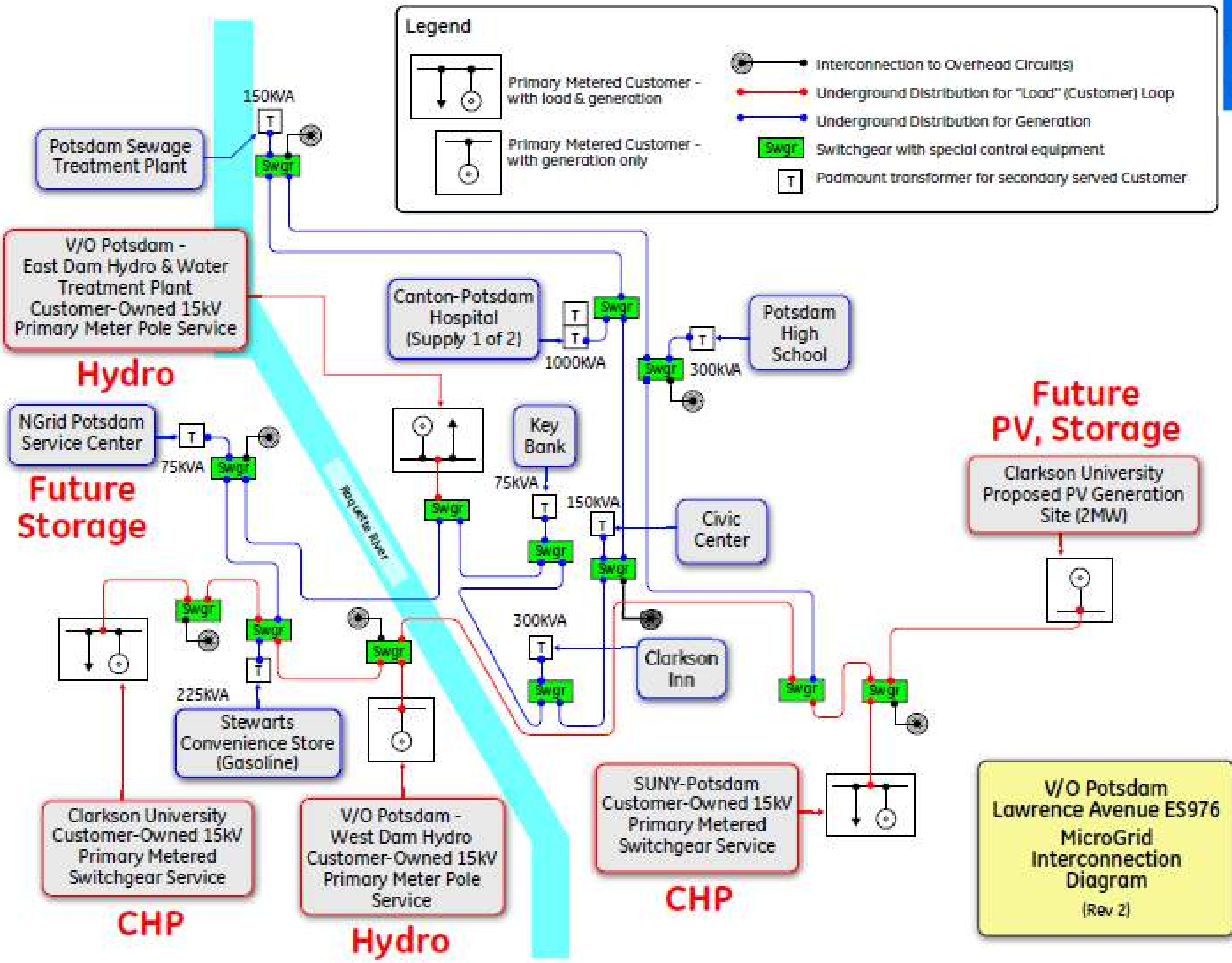
Interface with legacy systems

Handling PV intermittency

Utilize all asset features for optimization – e.g thermal and electrical

Potsdam – Community level Micro Grid

Potsdam Micro Grid



Potsdam – Objectives and Challenges

- Larger, community Micro-Grid
- IEEE 1547 compliance as an aggregate entity
- Disconnection, Resynch and Reconnection
- Protection (coordinate with utility breaker and assets)
- Steady State Frequency (utility), voltage (ANSI 84.1) and power quality (customer)
- Dispatch assets for optimized energy consumption and generation
- Provision of grid services like frequency regulation, demand response
- Community-defined resilience objectives

In Summary…

- Technology is only one piece of the puzzle
- Need to take a close look at
  - Value Proposition
  - Interoperability
  - Interconnection Requirements
  - Standards & Testing
  - Asset ownership
  - Application Engineering