ecoENERGY Innovation Initiative



SGSE116 - Development of a Utility-Grade Controller for Remote Microgrids

HATCH

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Project Motivation

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Motivation for the Project - NRCan / ecoEnergy II call for R&D Proposals

- **R&D on Smart Grid technologies, concepts and tools, including those that could advance or facilitate:**
  - Deployment and integration of distributed resources, particularly intermittent renewable Energy
  - Dynamic optimization of grid operations and resources
  - Remote microgrid control and optimization for renewable energy integration
- **R&D to address technical issues on performance and reliability, including in cold climates**
  - R&D to address the needs of rural and remote communities and cold climates in implementing renewable energy
  - R&D to support the improved integration of renewable onto the grid and into communities

300 off grid remote communities in Canada

Motivation for the Project - Remote Community Existing Power Generation Economics

- Many communities rely on diesel power
- Road/Ice road accessible communities have estimated electricity generation costs between C$0.45/kWh and C$0.95/kWh (Ontario).
- Arctic locations electricity generation costs can reach between C$1.5/kWh to C$2.5/kWh depending on the means to deliver fuel and access to other resources.
- These costs do not include risk of spillage and environmental issues with transport.

Motivation for the Project - Ontario Remote Communities

- 32 communities
- $20 M diesel
- fuel consumption

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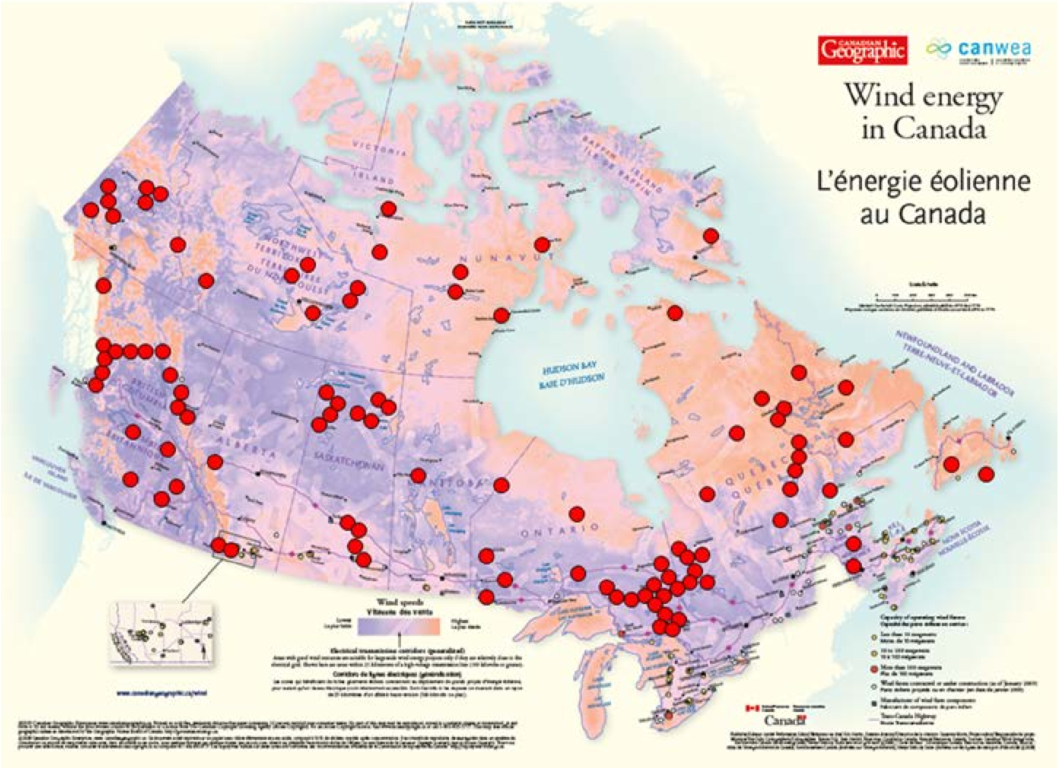
Motivation for the Project - Remote Mining Challenges

- Mining activities are increasingly occurring in more remote locations
  - High grade properties in easily accessible locations are being exhausted
  - High metal grades justify increased power and transportation costs
- Power supply is challenging
  - Many remote sites lack local hydro resources
  - High voltage transmission lines power generation cost $0.5M/km and up.
  - Diesel generators are the main power supply source
  - Fuel has to be delivered to the sites through ice highways, on barges and airplanes
  - Many environmental problems
- High energy cost
  - Cost of electricity is much higher than what major grid connected customers pay
  - The power generation cost is over $0.30/kWh and can even exceed $1.00/kWh

Motivation for the Project – Mining sites, Wind Resource and T&D Infrastructure



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Remote off-grid Renewable Microgrids

- Renewable Power to displace diesel has potential to reduce electricity costs, however, integration of significant renewable power contribution has been elusive. Technical challenges include:
  - Intermittency of renewable power
  - Constraints of diesel power plants
  - Potential impact on power system stability
- Advances in Energy Storage and users warming to the idea of allowing loads to be controlled provide new opportunities to achieve high penetration renewable power.
- Meeting the above challenges requires a utility-grade control system for managing the various power generation aspects.

Project Objectives

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Project Overall Objectives

1. To develop a commercially viable utility-grade controller for an islanded electrical grid with medium to high penetration renewable generation. The controller will manage diesel, renewable and storage assets for the most economical operation of the grid while at the same time ensuring power quality indexes remains within established tolerance bands.
2. Hardware in Loop (HIL) Controller testing on UofT RTDS.
3. Feasibility and system planning studies, in collaboration with the Kasabonika Lake First Nation (KLFN) community; these studies address technical, economical and social aspects regarding integration of higher penetration levels of Renewable Energy (RE) at KLFN being enabled by the proposed microgrid controller.

Project Evolution

Partners, Development of Scope and R&D Activities

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Partners, Contributions and Benefits

Stakeholder	Contributions	Benefits
HATCH	Project lead, Control system design, programming and testing	Commercial rights to IP
UNIVERSITY OF WATERLOO	Microgrid control and implementation research	5 PhD Graduates + Publications
UNIVERSITY OF TORONTO FACULTY OF APPLIED SCIENCE & ENGINEERING	Hardware in the loop (HIL) test facility	Graduate & Postdoctoral training
hydro One	Supporting measurement campaign and review controller development	KLFN grid field measurements results + input in controls development
KASABONIKA LAKE FIRST NATION	Allowing access for measurements at community	System planning and feasibility research for KLFN
Natural Resources Canada / Ressources naturelles Canada / Canada	To provide funding	Achieve R&D Objectives

R&D Activities by Partner

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- Activity Block 1 - Controller Development & Testing
  - Field Data Collection
  - Engineering Specs
  - Procure Hardware
  - Algorithms & Simulations
  - Programming
  - HIL Testing at UofT
- Activity Block 4 - Advanced Forecasting
  - Develop Algorithms
  - Programming
  - Testing at UofT
- Activity Block 5 – Smart Load Management
  - Develop Algorithms
  - Programming
  - Testing at UofT

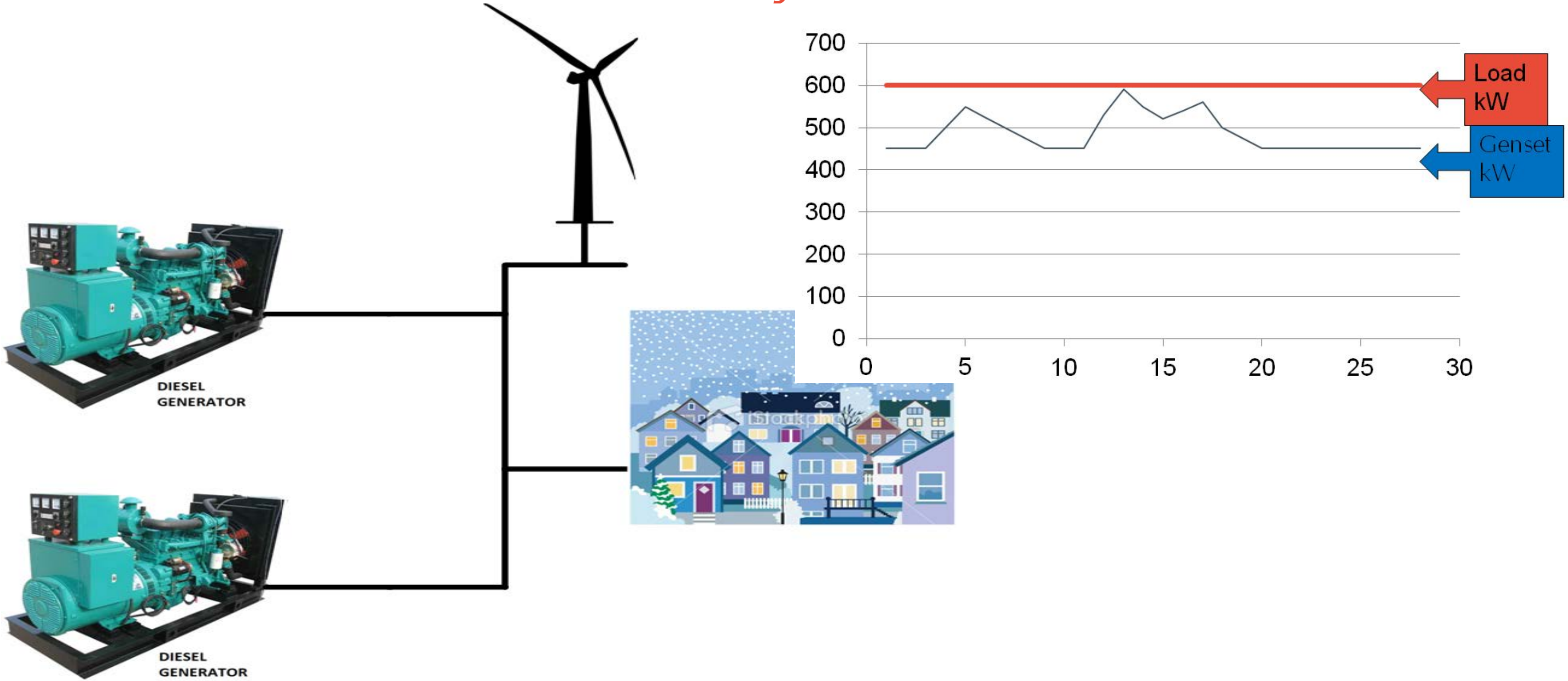
U of W

- Activity Block 2 – University of Waterloo Research
  - Project Planning
  - Project Research Activities
  - Controller Test Set-up Participation
- Activity Block 3 - KLFN Case Study by University of Waterloo
  - KLFN Community Involvement
  - KLFN Data Acquisition
  - KLFN Data processing and Analysis

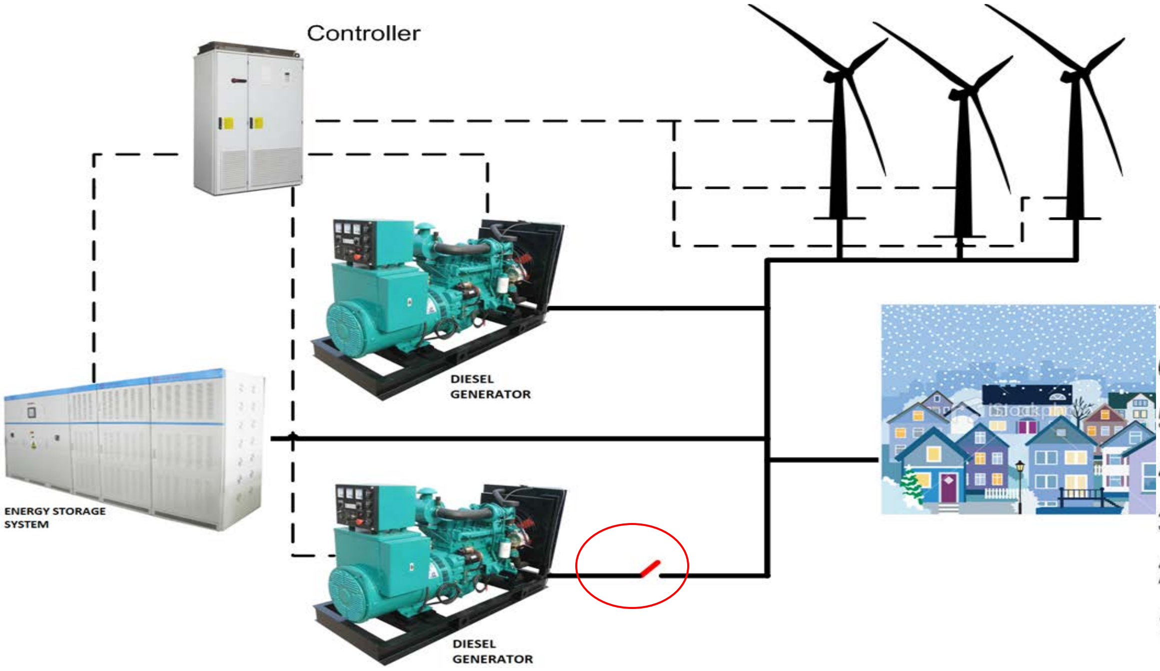
High Level Controller Specifications

- Enable medium and high penetration of renewable power and displace diesel fuel consumption
- Maintain power quality and power system stability
- Robust and reliable control system architecture, hardware, and software
- Customizable solution to specific stand-alone microgrid needs at each site, rather than claim to plug-n-play equipment packages

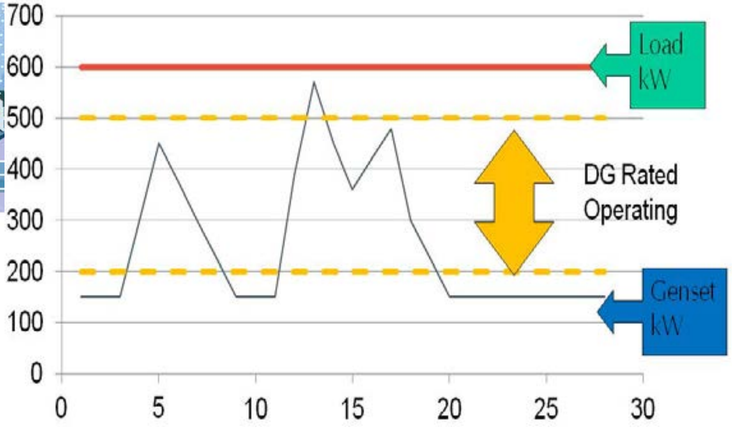
Low Penetration WDH System



Medium / High Penetration WDH System



Stability and constraint violation issues



Controller Hardware Selection Process

- Hardware cost estimate was obtained from several vendors.
- Systems with reasonable costs were considered for testing.
- Loaner units were obtained from 3 vendors.
- Hatch programmed sample routines and performed extensive testing on each unit.
- Detailed test reports prepared, shared with respective Vendors and conclusions verified.

Software, Signal Processing and Communications Development

- Software programmed by Hatch team
- Fast Measurement Layer
  - Phasor calculations with fast update (½ cycle)
  - High-speed I/O (up to 50 kS/s)
- Real-Time Layer
  - Control algorithms
  - Communication: RS232, Modbus, Ethernet, Wireless, DNP3
  - Prediction and optimization
- HMI
  - Alarming, logging and operator interface

Main Controller Modules

- Power System Measurement
- Dynamic Power Shaping (DPS)
- Energy Storage Management
- Generator Limit Management
- Supervisory Control
- Optimal Economic Dispatch (OED)
- Smart Load Management
- Output Management

KLFN Case Study – U of W

- Measurement campaign to collect data, 2014 to 2015
- Sizing of storage and renewable sources
- Social impact research

U of W Research

- Research topics by Graduate students:
  - Optimal planning of remote microgrids with renewable energy
  - Improved algorithms for optimal microgrid operation.
  - Optimization of system sizing and structure with control logic restrictions.
  - Protection and stabilizing control algorithms for DG's in isolated microgrids
  - Research on strategies for community engagement and integration

Project Evolution

Testing Phase

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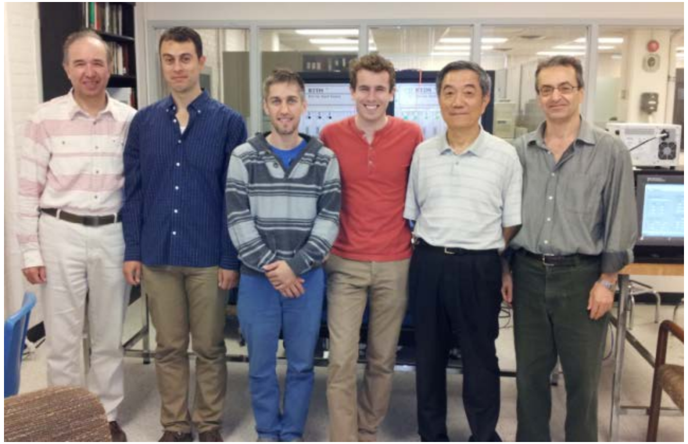
Real-time Simulation with Hardware-in-the-Loop

- Benefit over desk-top simulation:
  - Can include physical system elements, such as a physical microgrid controller
  - More powerful processing allows real-time simulation of operation
  - Can include real computation and latency of control system, as well robustness of control platform
- Benefit over field test
  - A lot less costly to simulate than to run tests in the field
  - Can simulate cases that are very difficult to do in the field

HIL Test Overview - Phase 1 and 2

- Phase 1
  - Dynamic Control (DPS) Features: Wind-Diesel-Flywheel energy storage
- Phase 2
  - Multiple Energy Storage systems (DPS) and tie line control



HIL Test Overview-Phase 3 and 4

- Phase 3
  - Initial testing of Optimal Economic Dispatch (OED) for isolated microgrids including interaction with diesel genset
- Phase 4
  - Integrated testing of OED-DPS for typical remote community with added renewable power/energy storage

Project Challenges

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Project Challenges

- Scheduling activities among multiple partners based on fiscal spending requirements.
- Finding low cost control hardware that meets performance requirements.
- Bridging academic grade research with practical engineering solutions.

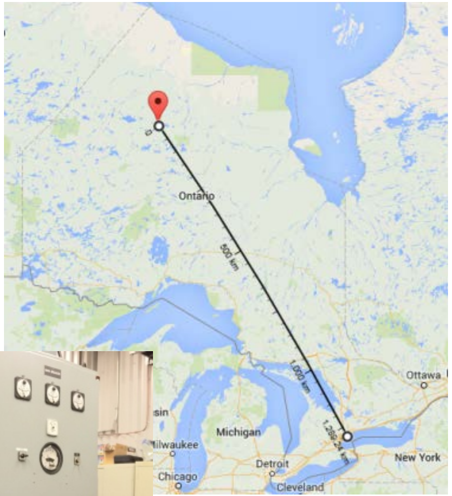
Technical Challenges

- Power stability and quality challenges:
  - Concentrated renewable integration (100 kW solar much more variable than a 10 MW solar)
  - Lower inertia with renewable sources (fewer and smaller gensets on line)
  - No grid connection
- Higher the penetration -> higher the expected fuel savings while maintaining Gensets operational constraints
- Higher the penetration-> greater issues with system reliability and stability

Project Results and Benefits

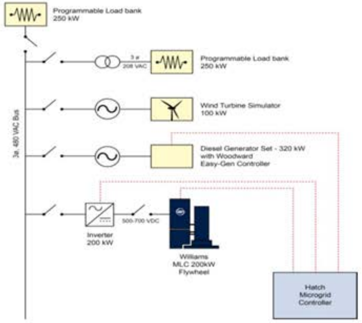
Site Applications

– KLFN Case study: measurement and analysis



Site Applications

– Testing the developed control system (HμGrid) on a separate project “Application of high-speed composite flywheels“ for the Alaska Energy Authority at the Alaska Center for Energy and Power (ACEP)



Wind-Diesel-Flywheel Test Set-up

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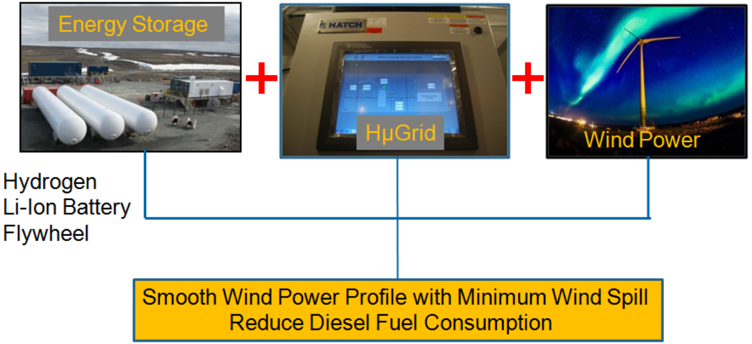
Site Applications

– Application of the developed control system (HμGrid) on a separate project “Mine 2 wind storage pilot project” for Tugliq Energy at Glencore Raglan Mine



Wind Turbine Photo Courtesy of Justin Bulota (Tugliq Energy)

Project Benefits

- Advancement of microgrid system research; several publications and research papers
- Merge advanced academic research into robust engineering solution
- Ready for deployment control system
- Specific community studies

Next Steps

Research, Commercialization and Pilot Projects

– Active ongoing effort in commercialization and export of the technology

– Pilot project implementation in select Canadian communities

– Continue R&D in expanding the technology