Research Activities at Hydro-Québec for Integrating Renewables in Remote Microgrids

Jacques Brochu

Renewables in Remote Microgrids Conference
Toronto, June 24-26, 2013

Hydro Québec

Overview of Business Unit and Research Projects

Remote Microgrids in Québec

- 14 in Nunavik
- 8 others below the 55°
- 9 out of these 22 have been identified as good prospects for wind integration
- Among them, 2 on-going projects :
  - Kangiqsualujjuaq
  - Iles de la Madeleine

Document d'information destiné aux publics concernés par le projet. Pour tout autre usage, communiquer avec : Géomatique, Hydro-Québec Équipement.

Business Unit and Research Projects

Distribution-Réseaux Autonomes

- **Kangiqsualujjuaq Project**
  - Medium penetration
  - Type-4 wind turbine (E53)
    1 x 800 kW
  - 200-kW / 5-kWh Flywheel
  - Awarded to Enercon

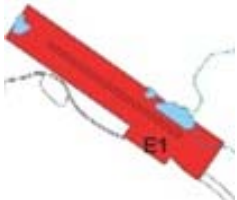
- **Iles de la Madeleine Project**
  - Low penetration
  - Type-3 wind turbines (MM82)
    3 x 1,05 MW
  - 1,5-MW / 5-kWh Flywheel
  - Awarded to PowerCorp

IREQ

- **R&D project**
  - Make available
    - Technologies
    - Tools
    - Methods

    to maximize the profitability of future projects
  - R&D team also provides expertises to the BU but is not directly involved in the field projects
  - Currently at the beginning of year 2 of a 5-year program

Kangiqsualujjuaq Village

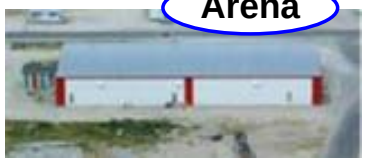


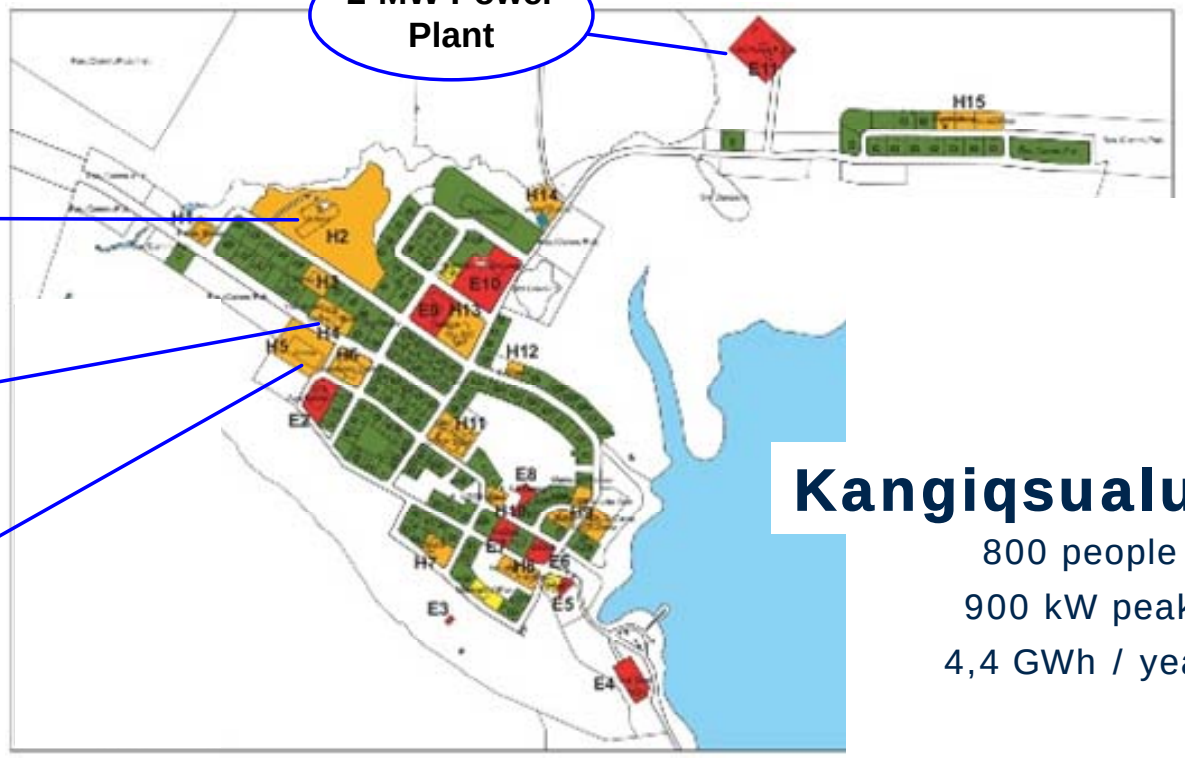
2-MW Power Plant

School

Store

Arena





Kangiqsualujjuaq

800 people

900 kW peak

4,4 GWh / year

Réseaux Autonomes Project

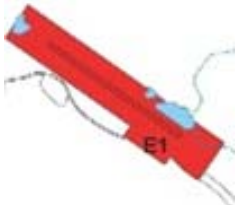
To be added

800-kW
Wind-turbine

Enercon
Technologies

200-kW / 5-kWh
Flywheel

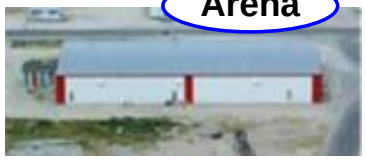
2-MW Power
Plant



School

Store

Arena



Kangiqsualujjuaq

800 people

900 kW peak

4,4 GWh / year

IREQ Project

Part 1

Characterization of Renewables
- Wind
- Solar
- Biomass
- ...

800-kW Wind-turbine

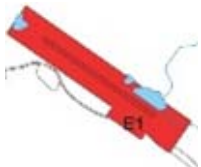
Part 2

Characterization of Storage Systems
- Flywheel
- Battery
- Thermal
- ...

200-kW / 5-kWh Flywheel

Part 4

Characterization of Diesel Motors
- Cylinder glazing
- Wet stacking
- Fuel consumption
- Wear and tear



Part 3

Dynamic Contribution of Loads
- Excess energy storage
- Frequency regulation

Space & Water heating

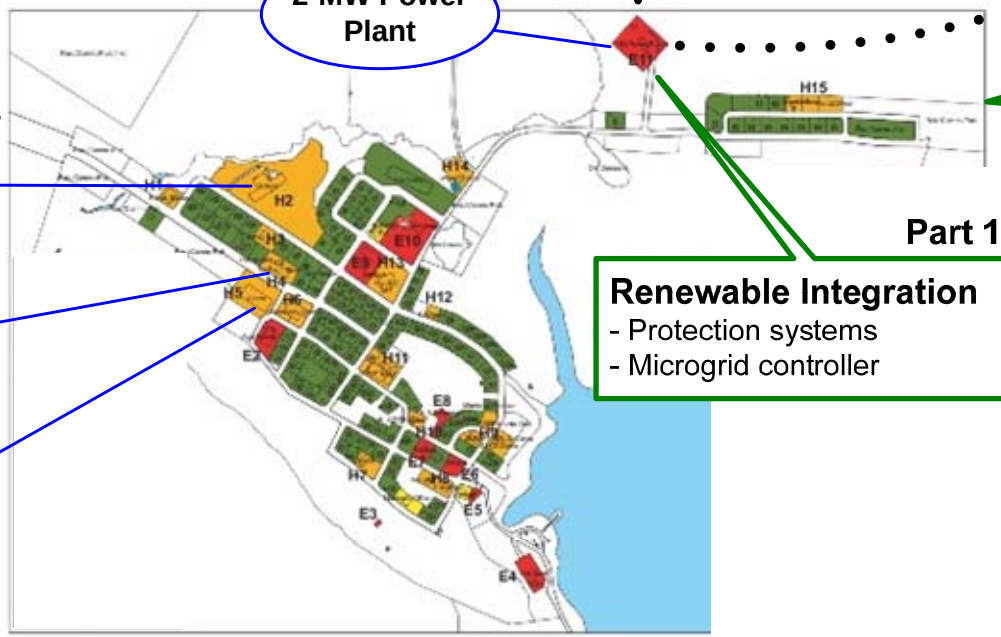
Refrigeration & Freezing

2-MW Power Plant

School

Store

Arena



Part 5

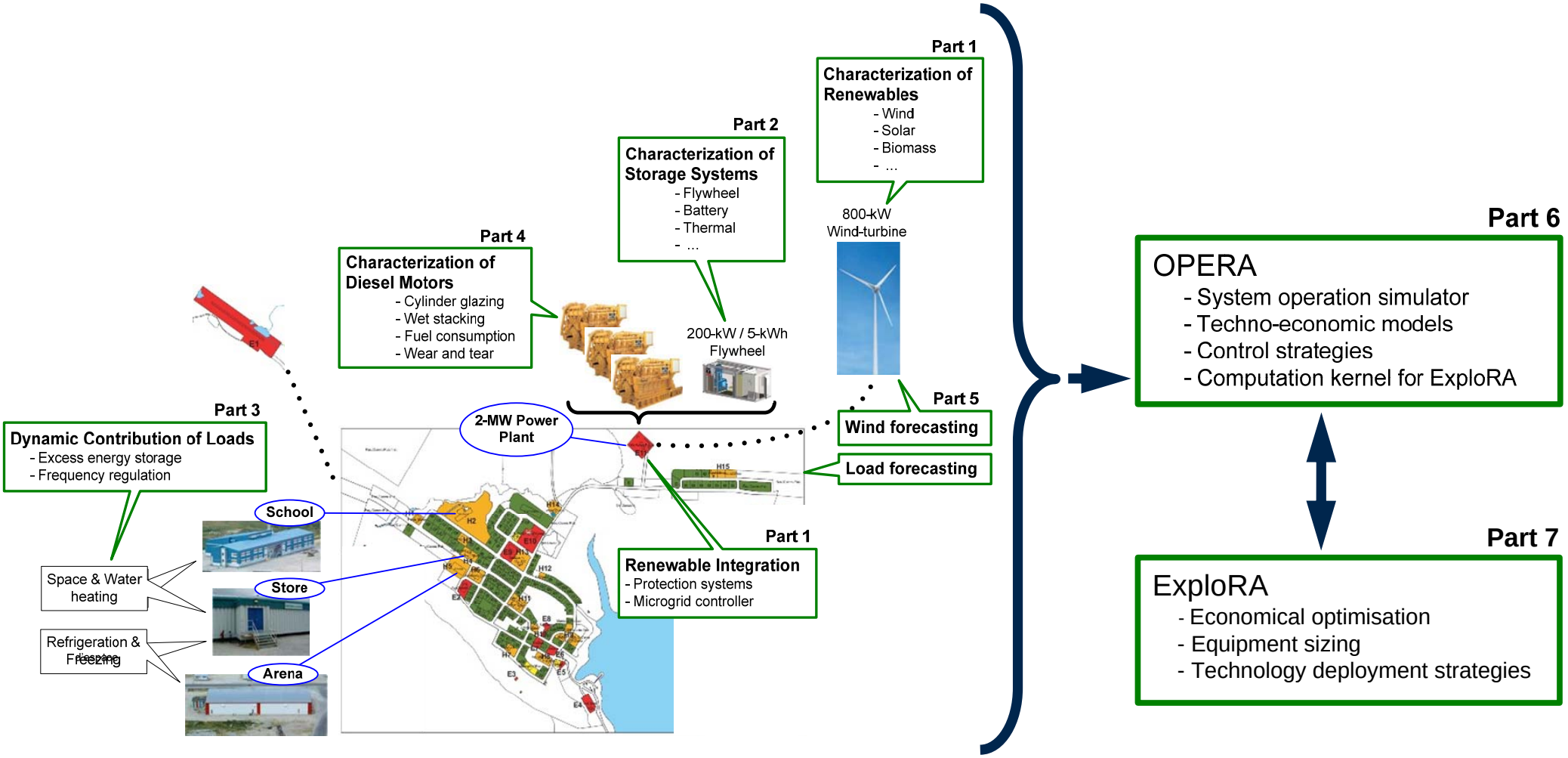
Wind forecasting

Load forecasting

Part 1

Renewable Integration
- Protection systems
- Microgrid controller

IREQ Project

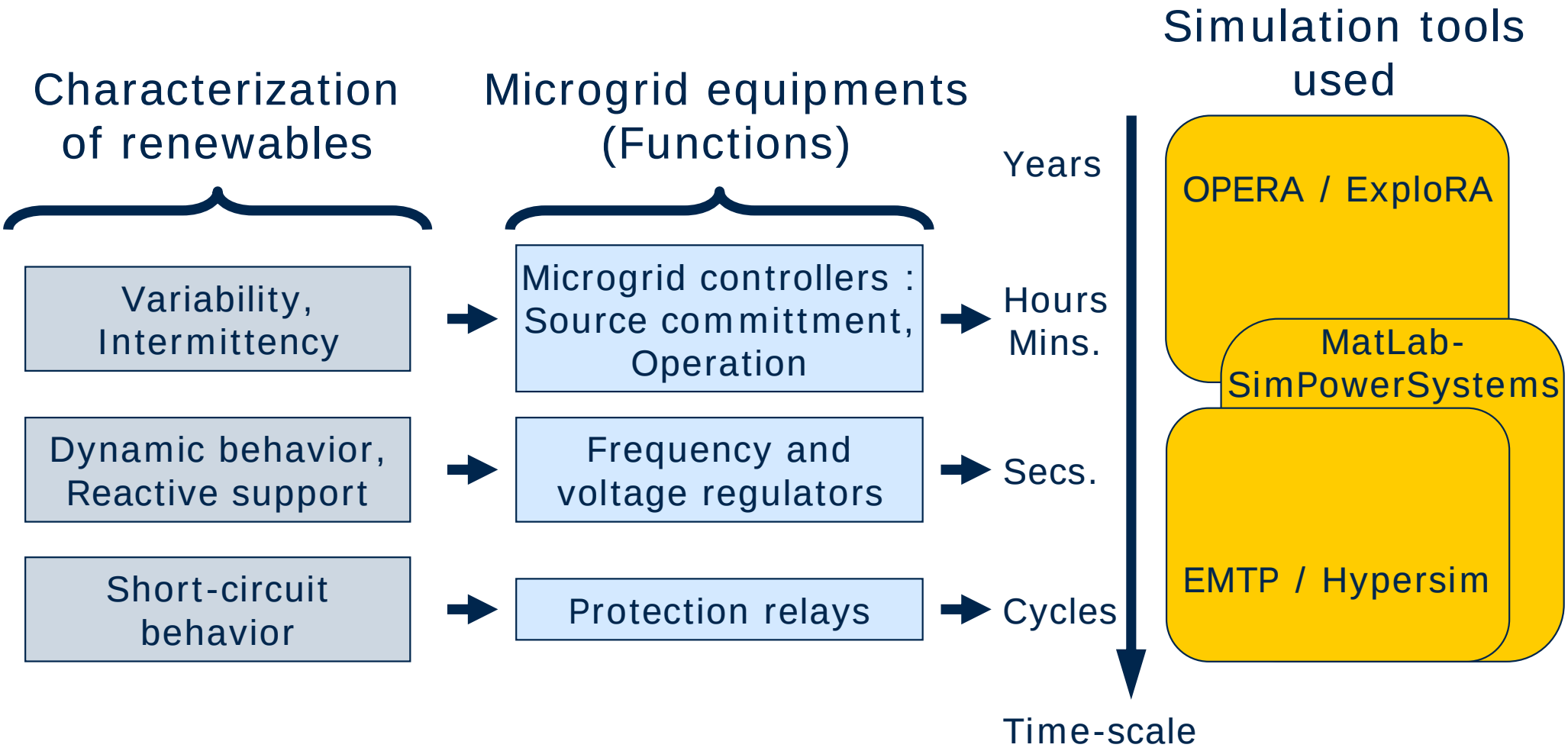


Part 1

Integration of Renewable Energies

Chad Abbey

Characterization and simulation of renewables



Main activities

- **Collect data regarding renewables (wind already done)**
  - Time-series
  - Nominal equipment parameters
- **Prepare renewable models in our tools**
- **Perform protection studies**
- **Evaluate / Improve frequency, voltage and microgrid controllers**
- **If need be, evaluate equipment performance on our experimental 25-kV microgrid**

Part 2

Analysis of Storage Systems

Jacques Brochu (Principal investigator)
Philippe Perret

State of the art

- **Large-scale storage systems of all kind are under development and testing worldwide to improve their performance and reduce their cost**
- **In integrated power systems, a number of studies indicate that**
  - Storage systems remain difficult to justify economically for storage of excess renewable energy only
  - Combination of two or more applications might be needed
- **Except for thermal storage, this seems also true for remote our microgrids**
  - High energy costs in microgrids do not seem to compensate for higher installation and operation costs
  - Anticipated cost reduction provided by mass production might not be enough to make them profitable over the next 10 years
- **However, combining the following needs seems advantageous under low and medium penetration**
  - Storage of excess renewable energy
  - Investment deferral for increasing thermal generation capacity

Main activities

- **Improve our cost evaluation of various forms of thermal storage in our remote microgrids**

- **Using lithium-ion battery as reference case**
  - Complete a life-cycle cost evaluation in the application where the above two needs have to be satisfied
  - Take into account high-penentration (all diesels shut down)
  - Learn from IREQ's 100 kWh Li-ion battery system being installed on our experimental microgrid

- **Having a better understanding of these technologies and HQ's integration costs**
  - Update our technology review to find the best options
  - If need be, proceed with testing to demonstrate the long term reliability of the selected technologies

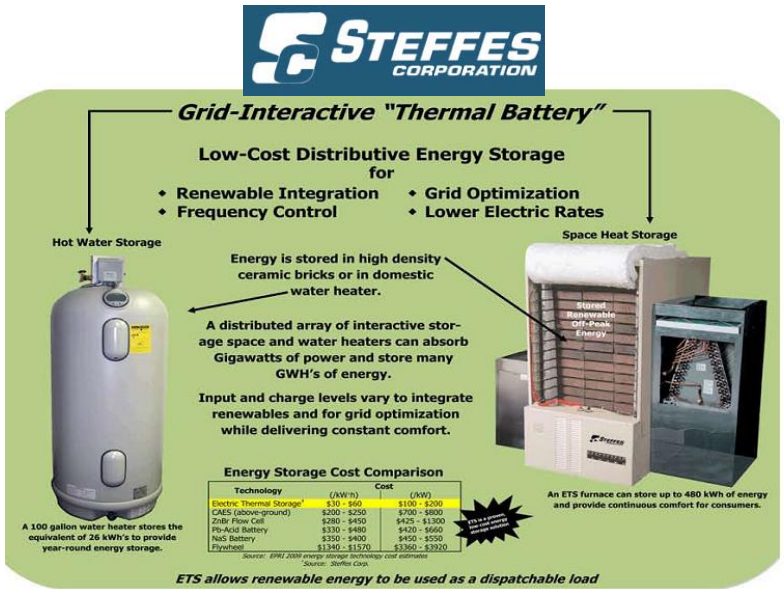
Part 3

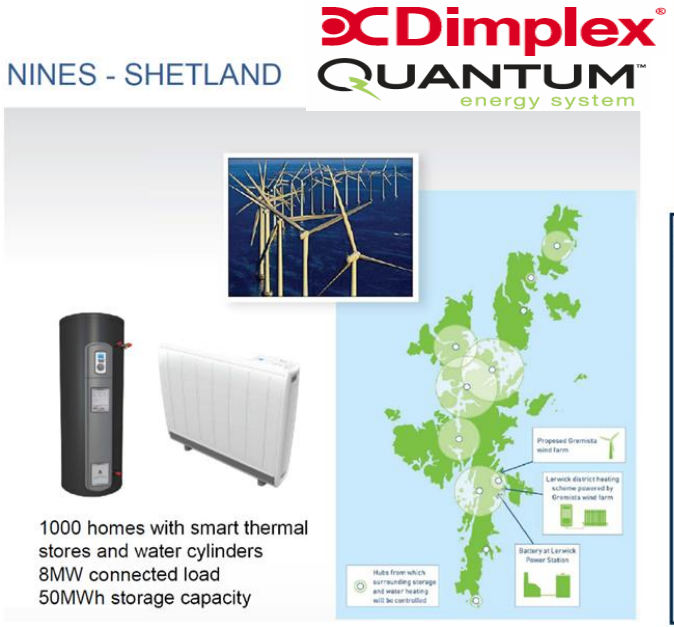
Dynamic Contribution of Loads

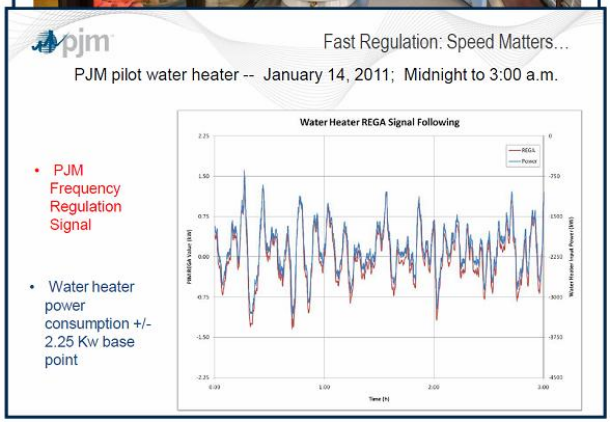
Jonathan Bouchard
Stéphane Boyer
André Charette
Éric Le Courtois (Principal investigator, stage 1)
Brice Le Lostec (Principal investigator, stage 2)

State of the art

- **Well-known and cost-effective methods are available for storing renewable energy in excess of load demand**
  - Water and ceramics are proven heat storage mediums used in remote microgrids
  - Refrigeration and freezing are other possibilities
- **Integration must be customized while taking into account possibilities and constraints specific to each site**







Main activities

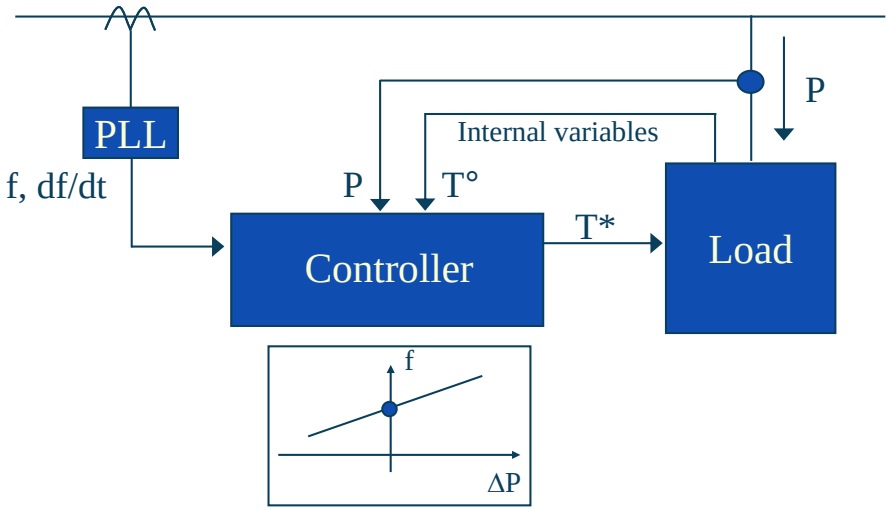
Frequency regulation

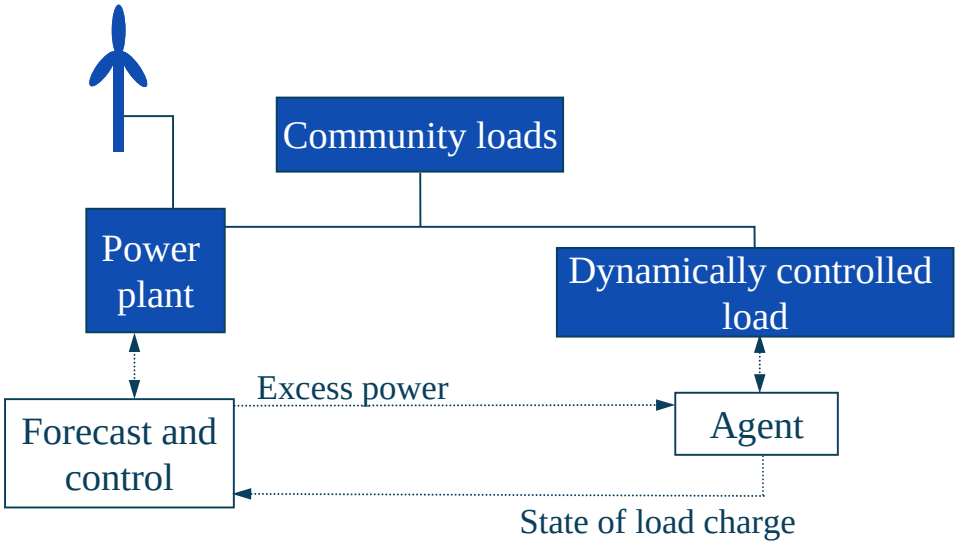
- Water and space heating
- Locally controlled
- Must not perturbate other equipments on the microgrids
- If needs be, low-cost telecommunication system with the microgrid controller

Excess energy storage

- Water and space heating + Refrigeration and freezing
- Globally controlled
- Low-cost telecommunication system with the microgrid controller needed

- A full-year field measurement is undertaken to characterize the electrical and thermal behavior of certain loads
- Low-cost retrofit into existing buildings could be difficult





Part 4

Caracterization of Diesel Gensets

Robert Adam
Normand Amyot (Principal investigator, stage 1)
Jonathan Hennessey
Luc Marcouiller (Principal investigator, stage 2)
Mathieu Soares

Need of a better understanding of genset operation in hybrid microgrids

- **Limited data on low-load diesel genset operation and reliability in microgrids**
  - To maximize renewable penetration, operation below 30% of the diesel nominal power is desirable. However, this causes
    - Cylinder Glazing
    - Wet Stacking
  - Without storage, renewables like wind can lead to a larger number of start-ups and thermal cyclings which might impact
    - Motors starters and batteries
    - Cylinder heads
    - Alternator winding insulation
    - Fuel consumption
- **Hence, benefits provided by renewables could come at the cost of:**
  - Increased maintenance
  - Fuel consumption not as low as expected
  - Fire hazard (cylinder glazing)

Main activities

- **Testings on IREQ's Caterpillar 320-kW genset**
  - Low-load conditions
    - Glazing and wet stacking
    - Fuel consumption
  - Thermal cyclings
    - Wear and tear
    - Fuel consumption
  - Model validation for power system studies

- **Definition of mitigation techniques where needed to maximize benefits provided by renewables**

Part 5

Wind and Load Forecasting

Alain Forcione (Principal investigator)
James Merleau

Need of wind and load short-term forecasts

- **Wind and load short-term forecasts are important for**
  - Sizing storage equipment
  - Avoiding useless motor startups
  - Maximizing fuel reduction

- **Wind forecast system currently in use at HQ-Distribution can easily provides part of the data needed for a remote microgrids**

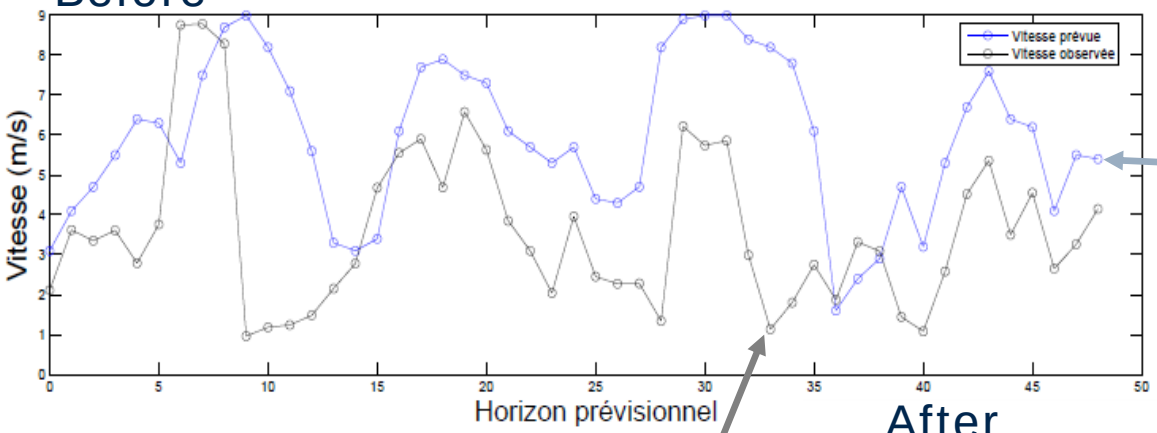
- **However, these forecast are not as good as in the Southern part of Québec due to a reduced number of weather stations in the North**

- **Also, with a small number of wind turbines (1, 2 or 3) there is no averaging effect provided by a large wind power plant (100 wind turbines over a 4 x 10 km area)**

Ex: Wind forecast

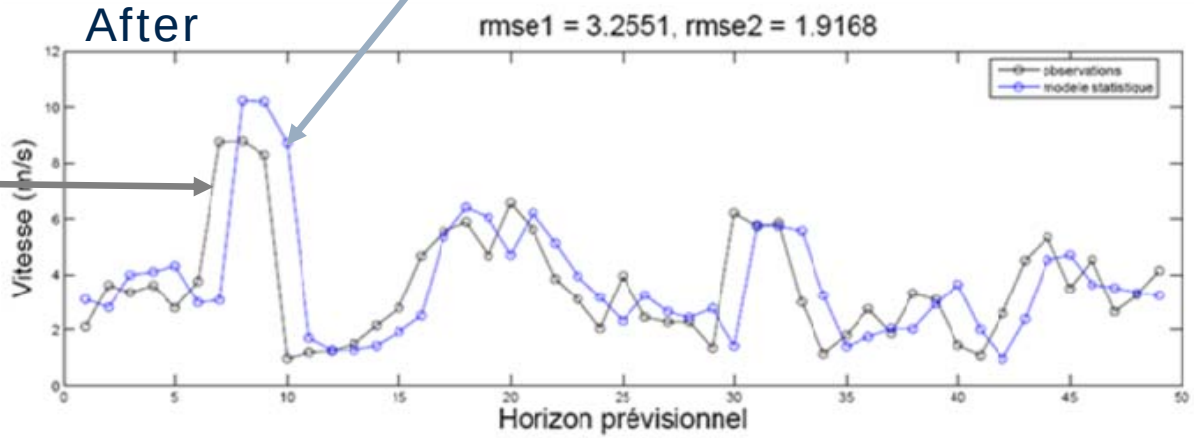
Improvement of next hour wind forecast using a stochastic model updated every hour using on-site measured wind speeds

Before



Initial and improved wind speed forecast (blue)

After



Local wind speed measurements (gray)

Part 6

OPERA – OPERAting Simulator

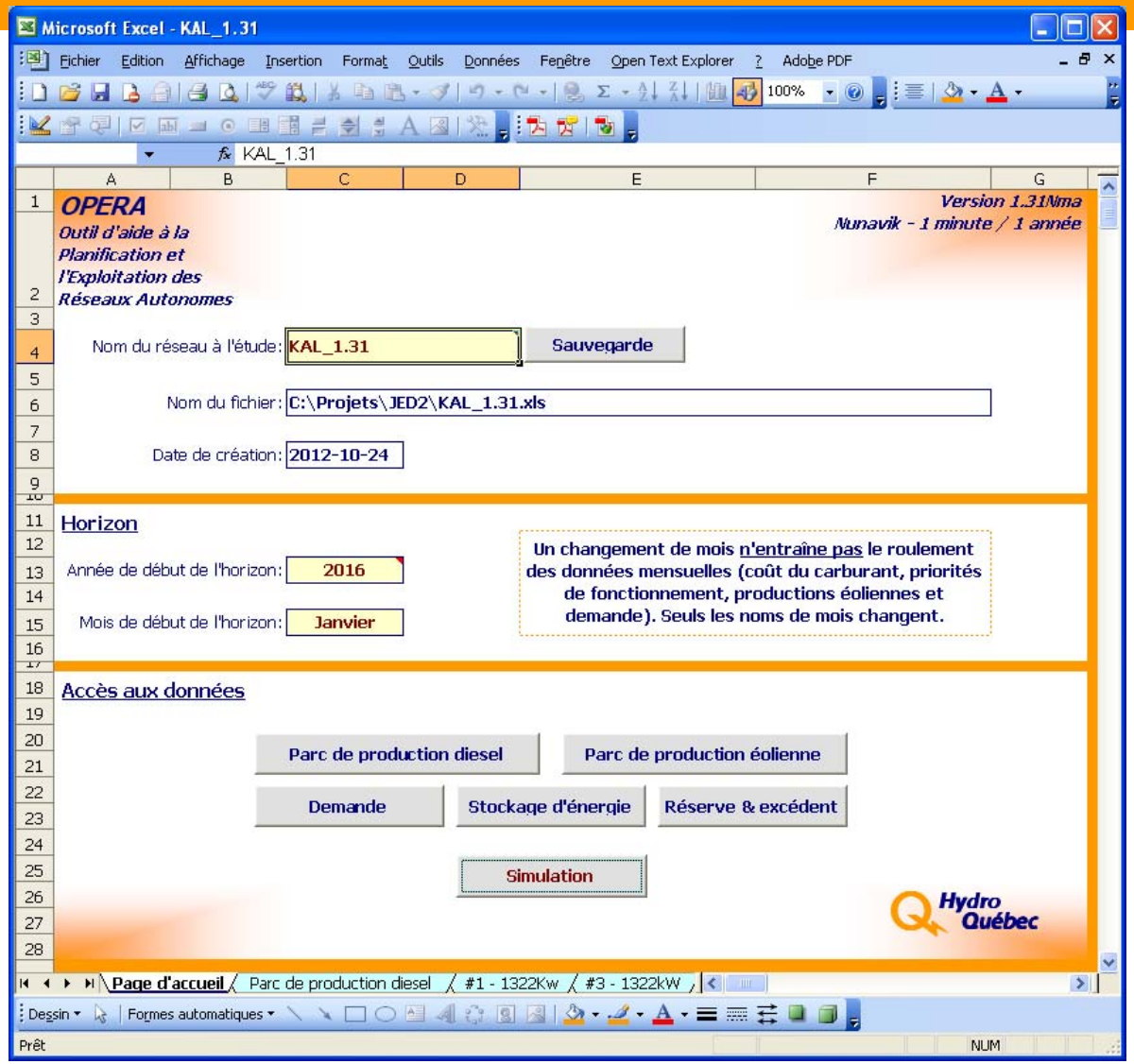
Louis Delorme

OPERA

Outil
d'aide à la **P**lanification
et à l' **E**xploitation
des **R**éseaux
Autonomes

- **Used since 2008 by HQ-Réseaux autonomes**
  - Production and maintenance plannings of diesel-gensets
  - Wind penetration evaluation study in Nunavik and Îles de la Madeleine
- **Deterministic approach based on measured wind and load time-series**
- **Hourly time-step for multi-annual simulation of wind integration**
- **Minute time-step for annual simulation when taking into account storage systems**
- **Will be enhanced during the R&D project to include**
  - Solar, biomass, hydrokinetic and other renewable sources
  - Thermal and electrical storage systems
  - Load contribution to frequency control and excess energy storage
  - Renewables and load forecasting methods
  - Diesel motor operating rules to be used under renewable generation

OPERA is implemented in visual basic using EXCEL



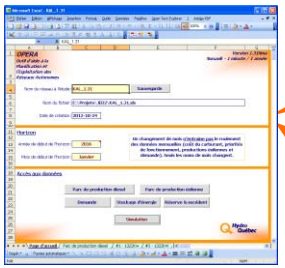
Main inputs to the current version

Thermal plant

- Genset specifications
- Efficiency curves
- Operating calendar
- Operating rules and limits
- Maintenance schedule
- …

Wind power plant

- Wind turbines specifications
- Minute-by-minute wind production (kW) over a full year
- Maintenance schedule
- …



Energy storage systems

- System specifications
- Operating rules and limits
- Operating losses
- Maintenance schedule
- …

Load demand

- Minute-by-minute load consumption (kW) over a full year
- Measured load scaled for future years

Spinning reserve

- Diesel motors
- Wind turbines

Part 7

ExploRA – Microgrids ExploRAtion

Stéphane Alarie (Principal investigator)
Louis Delorme
Louis-Alexandre Leclaire

ExploRA

des **Explo**ration **R**éseaux **A**utonomes

- **Perform microgrid optimization studies while taking into account a large number of variables**
  - Renewables sources
  - Storage systems
  - Operating strategies (forecast, diesels, loads)

- **OPERA**
  - Performs simulation based on technical and operating constraints

- **ExploRA**
  - Optimizes equipment sizing and microgrids operation based on economic constraints using OPERA as calculation kernel
  - First beta version will be set up this year

Conclusion

- **IREQ is working actively with HQ-Réseaux Autonomes for improving HQ's expertise in microgrids**
- **Given the number of remote communities in Québec, we set up a fairly exhaustive research program to address the main concerns we have regarding remote microgrids**
- **Many remote microgrids in the world are functional with low penetration of renewables**
- **However, medium and high penetration of renewables in a reliable and profitable manner remains a challenge**


Hydro
Québec