

#### Microgrids: Finally Finding Their Place

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### TISED





### What is the Trottier Institute for Sustainability in Engineering and Design (TISED)?

- An Institute that 'lives' in the Faculty of Engineering at McGill
- Institutes at McGill generally conduct research but can also offer academic programs, and frequently host events



- TISED supports the work of engineers, architects, and urban planners for sustainability advances.
- TISED is a sister to Institut de l'énergie Trottier (IET) at Polytechnique Montréal



#### Mission and Goals

- Produce innovative engineering and design solutions to protect and nurture the Earth for this generation and the next
- Catalyze inter-disciplinary and inter-institutional research providing solutions to local/global sustainability challenges
- Inform and advance policy in support of governments, industries, organizations to advance sustainable engineering and design
- Educate current and future generations of engineers, architects, and urban planners to be leaders in sustainability
- Create and participate in sustainability forums that engage with academic community, decision-makers, and the public



#### Outline

- microgrid definition
- power sector history & paradigms
- motivations for microgrids & emergence of resiliency
- N.Y. Prize
- examples: NYU, Borrego Springs, Sendai & Higashi-Matsushima
- optimizing a microgrid
- unfinished business



### Microgrid Definition

15 Feb 2017



6

# CIGRÉ C6.22 Working Group, U.S. DOE, & NYSERDA Microgrid Definitions

#### Conseil International des Grades Réseaux Électriques International Council on Large Electric Systems

Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded.

#### U.S.Department of Energy Microgrid Exchange Group

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

#### New York State Energy Research and Development Authority

Microgrids are local energy networks that are able to separate from the larger electrical grid during extreme weather events or emergencies, providing power to individual customers and crucial public services such as hospitals, first responders, and water treatment facilities.



#### Energy Independence and Security Act of 2007

Smart Grid is a three-legged stool

- 1. improved operation of the legacy centralized power supply system,
  - e.g. synchrophasor systems
- 2. improved grid-customer interaction,

e.g. smart meters and demand response

3. local control dispersed around the system,

e.g. microgrids & related technologies



EISA established that national policy supports creation of a smart grid, described as

- increased use of digital information and controls technology to improve reliability, security, and efficiency
- dynamic optimization of grid operations and resources, with full cybersecurity
- deployment and integration of distributed resources and generation, including renewables
- development and incorporation of demand response, demand-side resources, and efficiency
- deployment of smart technologies for metering, communications, and distribution automation
- integration of smart appliances and consumer devices
- deployment of peak-shaving technologies, including stationary and plug-in electric vehicle batteries, and thermal-storage
- provision to consumers of timely information and control options development of standards for communication and interoperability of appliances and grid equipment, including the infrastructure serving the grid
- identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services



#### Definitions of Reliability & Resilience

\**Reliability* by contrast focuses on the statistical expectation of power availability, and short and/or extreme events are often excluded from the calculation.

ASAI = Average Service Availability Index, e.g. 99% is "two nines" SAIDI = System Average Interruption Duration Index, min/a SAIFI = . . . . . . . . . . . . Frequency . . . , prob. of event

• *Resilience* is the "... ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions."

U.S. Presidential Policy Directive 21 (The White House, 2013)





# Power Sector History & Paradigms



15 Feb 2017

10

### Historic Landscape





#### **Central Paradigm Limitations**

- \* conflicting policy objectives generation competition (equipment stress, volatile markets) connection of intermittent renewables
- \* resiliency, security, ... (inherently insecure networks)
- \* infrastructure interdependency
- \* environmental constraints (carbon, water, etc.)
- \* load growth? (transportation electrification, heating, ...)
- \* centralized generation heat loss
- \* reliability is costly for a fundamentally insecure system
- \* restricted expansion of centralized system
- \* DC sources and sinks, heterogeneous power quality
- \* plug-in electric vehicles a potential game changer
- \* grid paradigm vs. internet paradigm



#### **Zoom on Possible Landscape**





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### Motivations for Microgrids & Emergence of Resilience



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#### Adopter Motivations (mostly true microgrids i.e. µgrids)



1600

1100

2014

- ancillary services,...)
- independence & surety

15

2020

2018

-Low Case, 2015 - Base Case, 2015 - High Case, 2015 - New Base Case, QZ 2016

US Microgrid growth beats past

estimates; On pace to exceed 3.7 GW by

2019

source: Omar Saadeh

2020



#### History of Microgrid R&D (Kyoto to Fukushima)

 $EU \rightarrow Japan \rightarrow US$  (RDSI, SPIDERS)  $\rightarrow Asia$  (China, Korea, Singapore)



16



#### Japan's Pivot to Resilience

- long and notable history in microgrid research
- outstanding performance of Sendai (and Roppongi Hills) microgrids during Mar 2011 earthquake and tsunami was noticed in policy circles
- move towards greater dependency on microgrids
- interest in microgrids moved beyond NEDO, to Ministry of Environment, and others, as well as the private sector
- Jun Matsumoto, Minister in Charge of Building National Resilience
- heterogeneous power quality represents one key to resiliency





### New York Prize





### New York Prize

- followed release of Reforming the Energy Vision Staff Report, April 2014
- NY Prize announced in December 2014
- organized by NYSERDA & New York Governor's Office of Storm Recovery
- availability of up to US\$40M, under the NY Prize Community Grid Competition
- to support the development of community microgrids
- the NY Prize competition is comprised of three (3) stages:
- Stage 1: Feasibility Assessment (~100 pages)
  - 83 projects received 100 k\$ to conduct Feasibility Assessments
  - (i) preliminary assessment of the technical design and system configuration
  - (ii) assessment of commercial, financial and legal viability, and
  - (iii) benefit-cost analysis of the proposed project.
- Stage 2: Audit-Grade Detailed Engineering Design and Financial /Business Plan
  - RFP deadline was 12 Oct 2016
  - ~8 projects will receive 1 M\$ each
  - detailed engineering design, financial and business plan assessment
- Stage 3: Microgrid Build-out and Operation

#### https://www.nyserda.ny.gov/ny-prize



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## New York University



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#### NYU CHP Facility: Sandy Success Story

- major 2011 update to US\$125M CHP switch from oil to NG
- saves US\$5-8M/a, 23% less GHG, 65% less criteria
- doubled capacity to 13.4 MW
- powers 22 buildings, HW & cooling & heating to 37
- ran islanded for six days in Sandy aftermath
- note firm NG supply



Section Content of Engineering

#### All Below Grade Power Station



15 Feb 2017



22

# **Borrego Springs**





in Anza-Borrego State Park summer population 3,500 winter population reaches 5,000 large retired population Ricardo Breceda sculptures

### **Borrego** Springs



24



#### BS1: RDSI Project 2008-13

- San Diego Gas & Electric a progressive distribution company
- classic milligrid
- renewable and Distributed Systems Integration a program of U.S. DOE
- 9 "microgrid" projects 2008-2013, incl. Santa Rita & Borrego Springs
- goal was 15% peak load reduction
- Borrego Springs depends on single vulnerable 28 MW 32 km 69 kV tie
- 26 & 5 MW IPP PV arrays in the area
- 14 MW peak local load + 28 MW tie unable to absorb all PV output
- environmentally sensitive area and suspicious population
- relatively simple technology and unclear objectives
- example of a distribution utility embracing microgrids
- but regulatory response unclear



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#### Islanding From a Desert Substation





#### 6 September 2013

- hot morning, 38°C by 10:00 and 42°C at 13:20
- thunderstorms began to form between 12:00 and 13:00
- produced rainfall totals of 33 mm at Warners by 14:00, with similar amounts along the desert slopes west of town



- gusty outflow winds from the thunderstorms began to reach the Borrego area at 14:00.
- peak gusts of 87-105 km/h were measured between 14:20 and 14:30, though evidence supports that a microburst likely occurred near the center of the storm, producing gusts up to 113 km/h
- $\sim$  167 lightning strikes occurred in the Borrego area

source: SDG&E



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#### Restoration

- 9 transmission and 11 distribution poles were down
- all roads into/out of Borrego Springs were closed
- restoration took 25 h



#### **Outage Generation**

- At 14:20, single transmission line to Borrego trips out
- 1056 total customers restored during outage





#### Borrego Springs Microgrid 2.0 CEC: 4.7 M\$ & SDG&E: 1.75 M\$

Enhance the Borrego Springs Microgrid to be more flexible and automated in responding to a variety of potential outage situations, and leverage various new technologies and Distributed Energy Resources for increased Microgrid capabilities.



# Sendai Microgrid



#### Sendai Microgrid Demonstration



A: Photovoltaic Panels 50 kWp B: Gas Engine gen-set 350 kW X2 C: Molten Carbonate Fuel Cells 250 kW D: Dynamic Voltage Restorer #1 600 kVA E: Dynamic Voltage Restorer #2 200 kVA F: Building #1 Integrated Power Supply G: Building #2 Deck to back

Back-to-back Voltage Source Converters

(For Test Equipment)

source: NTT Facilities



32

#### Sendai Project Schematic





#### Sendai Success Story



Source: http://spectrum.ieee.org/energy/the-smarter-grid/a-microgrid-that-wouldnt-quit/0



#### Multiple Power Qualities During Outage

System	Mar 11	Mar 12	Mar 13	Mar 14
Utility Grid	Grid Connection	geCollapse 🗪 GridOutag	te Outage	GridRecover Grid Connection
Gas Engine	Grid Connection	on ect Around 12 00 Stop	operation Islanding operation	Grid Connection
DC supply	Grid Connection Supp	ly from Batt ery	Supply from Gas Engine	Grid Connecti on
A Quality	Grid Connecti on Bat	02.05 ▼Stopped Manually tery Outage	Supply from Gas Engine	Grid Connection
B1 Quality	Grid Connection Bat	t ery Outage	Supply from Gas Engine	Grid Connection
B3 Quality	Grid Connection	Outage	op chStart (because of customer's wish) Supply from Gas Engline	Grid Connection
CQuality	Grid Connection	Outage	Supply from Gas Engine	Grid Connecti on

source: NTT Facilities



#### Secure Natural Gas Supply





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### Higashi-Matsushima



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#### Higashi-Matsushima: Disaster-Resilient Eco-City





#### **Key Points**

- collaboration between the City of Higashi-Matsushima (operator) and Sekisui House Co. (building designer and operations)
- circa 460 kW of PV, at disaster prevention channel, community hall, and condominium
- 460 kWh battery bank and 500 kVA biodiesel "emergency" generator
- Eco-City can maintain services at least for 3 days without grid power, providing emergency electricity to hospitals and public facilities
- project funded by the Ministry of Environment, selected for the "Program on Building an Independent and Distributed Low-Carbon Energy Society."
- CEMS(Community Energy Management System) estimated to eliminate 256 t of CO2 emissions per year



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# **Optimizing a Microgrid**



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#### McIntyre Medical Science Building

- built 1965, remodeled 1998
- 16 storey circular tower (30 000 m<sup>2</sup>)
- sick blg. venilation fix 2003
- 2 theatres & classrooms
- office and lab. space





#### Preliminary DER-CAM Analysis

#### equipment details



- modeled total heat requirement and shape based on a Minneapolis health care blg.
- \*flat 5 ¢/kWh & 14 \$/kW
- 6.5 \$/GJ for NG & biogas
- 3.5 \$/tCO2 carbon allowance
- grid availability 99%
- outage cost 225 \$/kW (option)
- wide range of sensitivities

   \$/tCO2, 5 & 10 \$/GJ NG & biogas,
   emissions from biogas production, ....
- site vs. source emissions 500, 850, 4000 gCO2/kWh (Robert Howarth, 2015, )





#### Preliminary Findings

- inefficient building, using ≈<sup>1</sup>/<sub>3</sub> more energy than a typical Canadian medical building
- without reliability only PV and solar thermal ever chosen
- except, worse cast shale gas CH4 emissions plus 10 \$/tCO2
   2 x 500, 1 x 400, & 1 x 100 kW biogas CHP plus 75 kW solar thermal
- with reliability considered, 99% availability, NG CHP & PV dominate 1 500 & 2 x 100 kW plus 15 kW PV robust solution
- solar technologies surprisingly attractive often hit footprint constraint
- NG CHP could be attractive, as sensitive loads, but upstream emissions
- more careful look at biomass and ground source options necessary



### Unfinished Business



### What Effect Will Emergence of Microgrids Have on the Megagrid?







#### **Dispersed Vision** (distributed control & heterogeneous service )



#### **Choosing Service Quality**



### What Can Be **Gained from** Heterogeneous **Power Quality?**



15 Feb 2017

50

#### Heterogeneous PQR Requirements







#### **Relevance to Québec**

- you can probably guess
- ENEA report might help
- a more nerdy approach



http://www.enea-consulting.com/en/urban-microgrids-opportunities/



#### Want to learn more about Microgrids?

• Is There a Role for Microgrids in Québec?

workshop organized by TISED, evening of 25 April 2017 New Residence Hall, 3625 Av du Parc, Montréal

- <u>http://microgridknowledge.com/</u>
- Newcastle 2017 Symposium on Microgrids
   28-30 Nov 2017 by invitation only ask me now http://microgrid-symposiums.org/

Sunday 3 -Friday 8 Dec 2017 2017 IEEE PES Innovative Smart Grid Technologies Asia (ISGT Asia 2017) Conference, Auckland, New Zealand



# Merci de votre attention!

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### Arigatou gozaimasu! ありがとうございます。

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