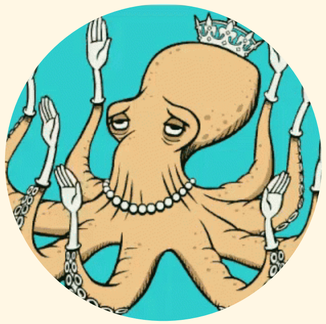
Quebec's 735kv power lines can survive the apocalypse, but can they run TCP?!

!!con 2020

#virtualbangbangcon



Nick Sweeting

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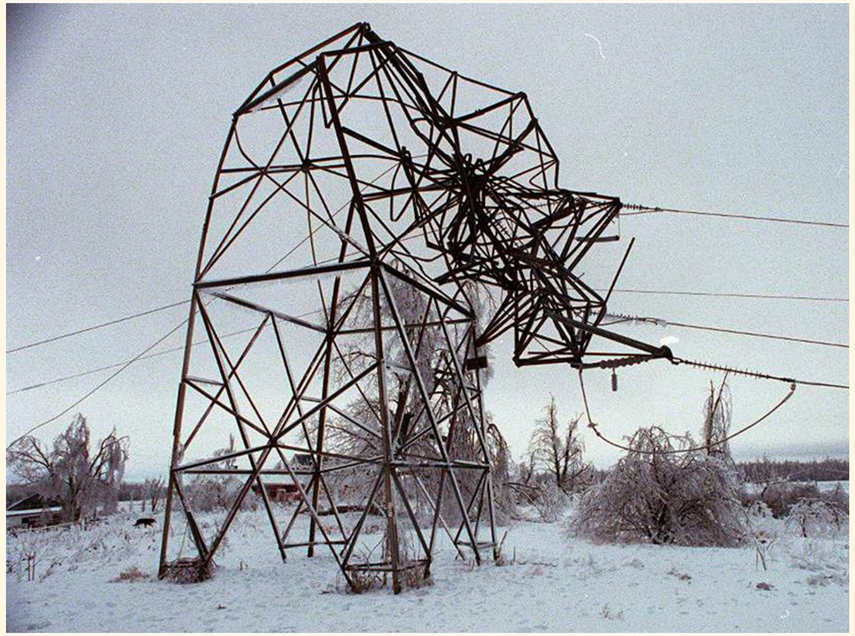
Co-Founder @ Monadical.com
(we're hiring Python devs!)

The apocalypse... x3

1961, 1986 , 1998 (the big one)

- >2.8 inches of solid ice build-up
- 17,000+ power poles replaced
- 3,400km+ of power lines rebuilt
- Over three million people affected for 5+ weeks




Hydro-Québec Main Facilities (2008)
Hydroelectric
Planned/Under construction
Thermal
Nuclear
Interconnections
High voltage substation (735 kV)
735 kV line
HVDC ±450 kV power line
International border
Provincial border
Lambert conformal conic projection - datum NAD83
Scales :
Bathymetry : 1:7 750 000 (precision : 1 937 m)
Topography : 1:5 600 000 (precision : 1 400 m)
Source : Hydro-Québec. 2008 Annual Report
Québec
Newfoundland and Labrador
Ontario
New Brunswick
UNITED STATES
James Bay
Anticosti Island
Saint Lawrence River
Jacques-Cartier Strait
Quebec City
Montreal
Saguenay
Gatineau
Sherbrooke
Trois-Rivières
Lévis
Rouyn-Noranda
Chisasibi
Radisson
Wemindji
Eastmain
Waskaganish
Nemiscau
Kuujjuarapik
Havre-Saint-Pierre
Sept-Îles
Baie-Comeau
Matane
Gaspé
Rimouski
Rivière-du-Loup
La Tuque
Shawinigan
Sorel-Tracy
Churchill Falls
Great Whale River
La Grande River
Caniapiscau Reservoir
LG-3 Reservoir
LG-4 Res.
Robert-Bourassa Res.
Sakami Lake
Opinaca Reservoir
Clarkie Lake
Nichicun Lake
Naococane Lake
Albanel Lake
Lac Mistassini
Manicouagan Reservoir
Pipmuacan Reservoir
Gouin Reservoir
Caboga Réservoir
Dozois Reservoir
Abitibi Lake
Smallwood Reservoir
Churchill
Romaine
Magpie
Petit Mecatina
Natashquan
Honguedo
Bay of Fundy
Lake Ontario
0 (km) 500
0 (mi) 300
55°
50°
45°
75°
70°
65°
60°

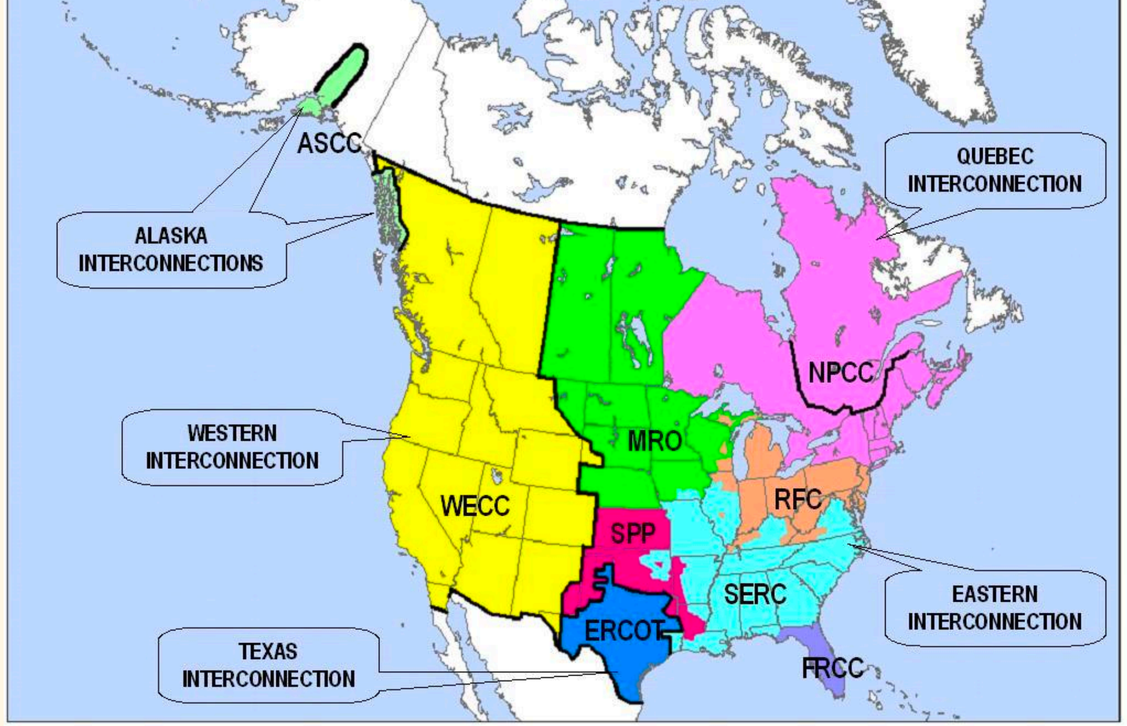
The James Bay Project

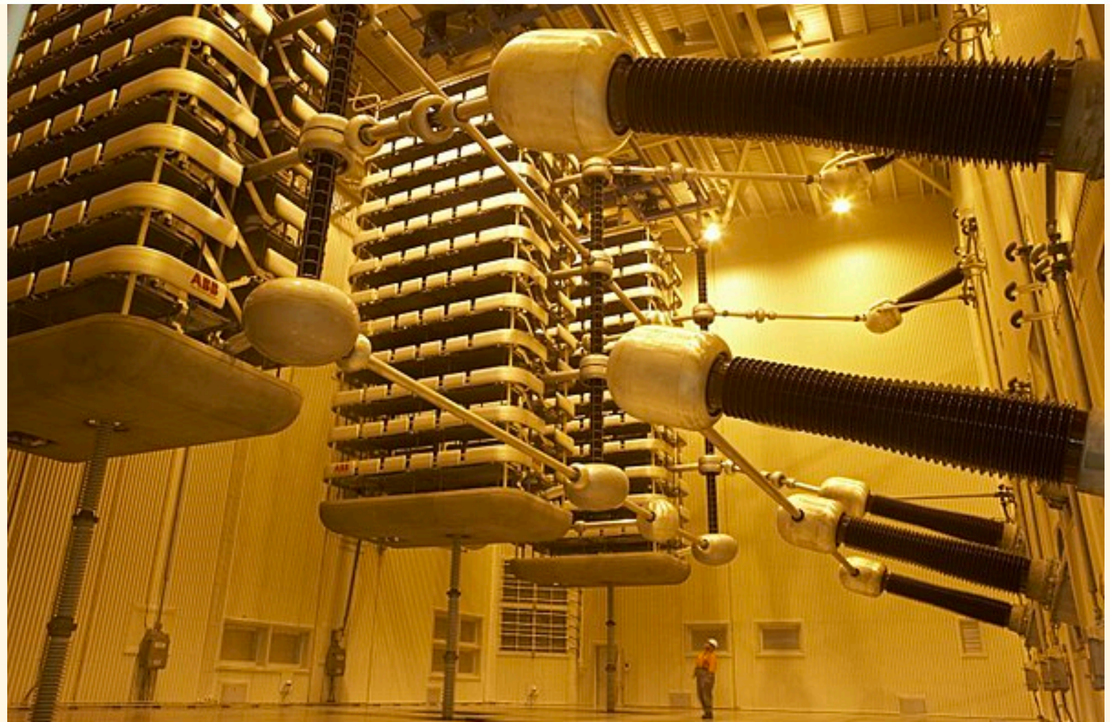
27,000 MW of awesome

- Won against nuclear power (built in the 1970's)
- Flooded 11,500km² of Cree and Inuit land (in exchange for $0.2B)
  The largest body of water ever created by humankind (largest lake in CA)
- Mega dams near the arctic circle (and lots of wires)
- Separatist at its heart, Quebec has it's own grid (just like Texas!)

So how do power grids work?

- ## High-voltage 3-phase AC
  - Easier to convert than DC
  - Old-school: Transformers + fuses
  - Modern: Capacitors + Thyristors + Optic coupling
- ## Dealing with changing load is difficult
  - Frequency synchronization
  - Phase balancing
  - Kinetic energy management
- ## Grid-scale tooling is really weird
  - Signals bounce off the ends of wires!
  - Microcontrollers cant get anywhere near >10kv!
  - The whole grid is a giant antenna!

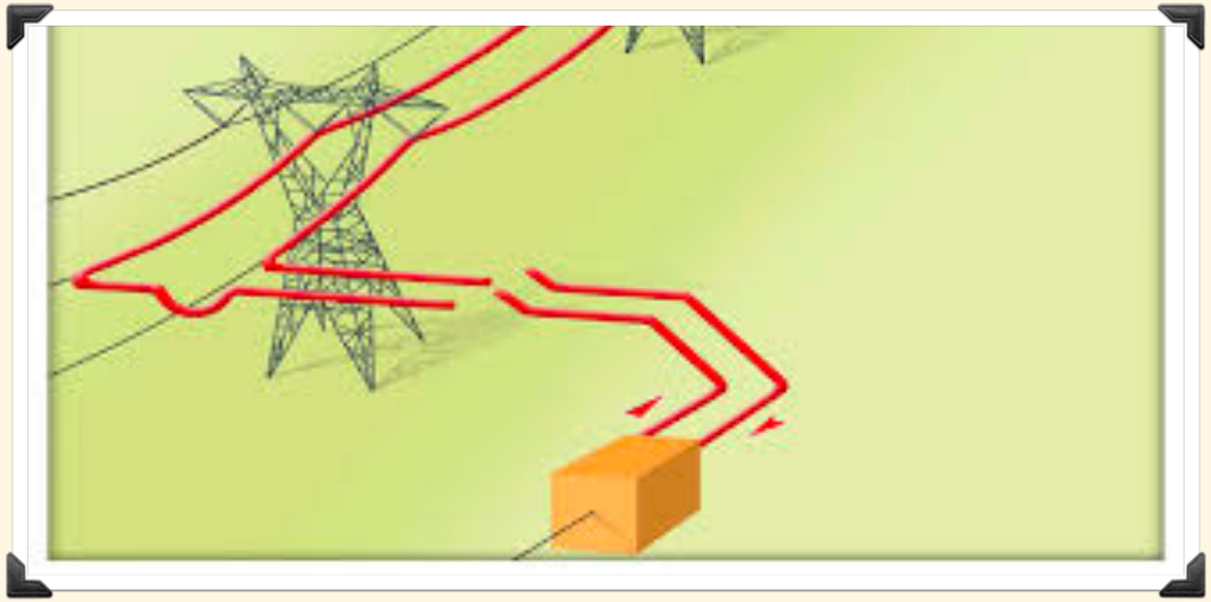




HVDC ... Edison wins after all!

It's all about long distance grid-to-grid connections.

- More efficient wiring than AC
  - No skin effect
  - Fewer conductors
- Easier to control digitally
  - Static VAR compensation
  - Simpler control circuity
- It's a rescue lifeline
  - Restarting downed power plans
  - Re-syncing drifting frequencies
  - De-Icing!



So can they run TCP?!

Theres a whole world of network chatter on power lines.

- 9 - 500kHz (DLC)

  Ethernets w/ IPv6 at 576 kbit/s for grid control / meter reading

- 100-500kHz (OSGP)

  IOT, home automation, meter reading

- ≥ 1 MHz (EoP)

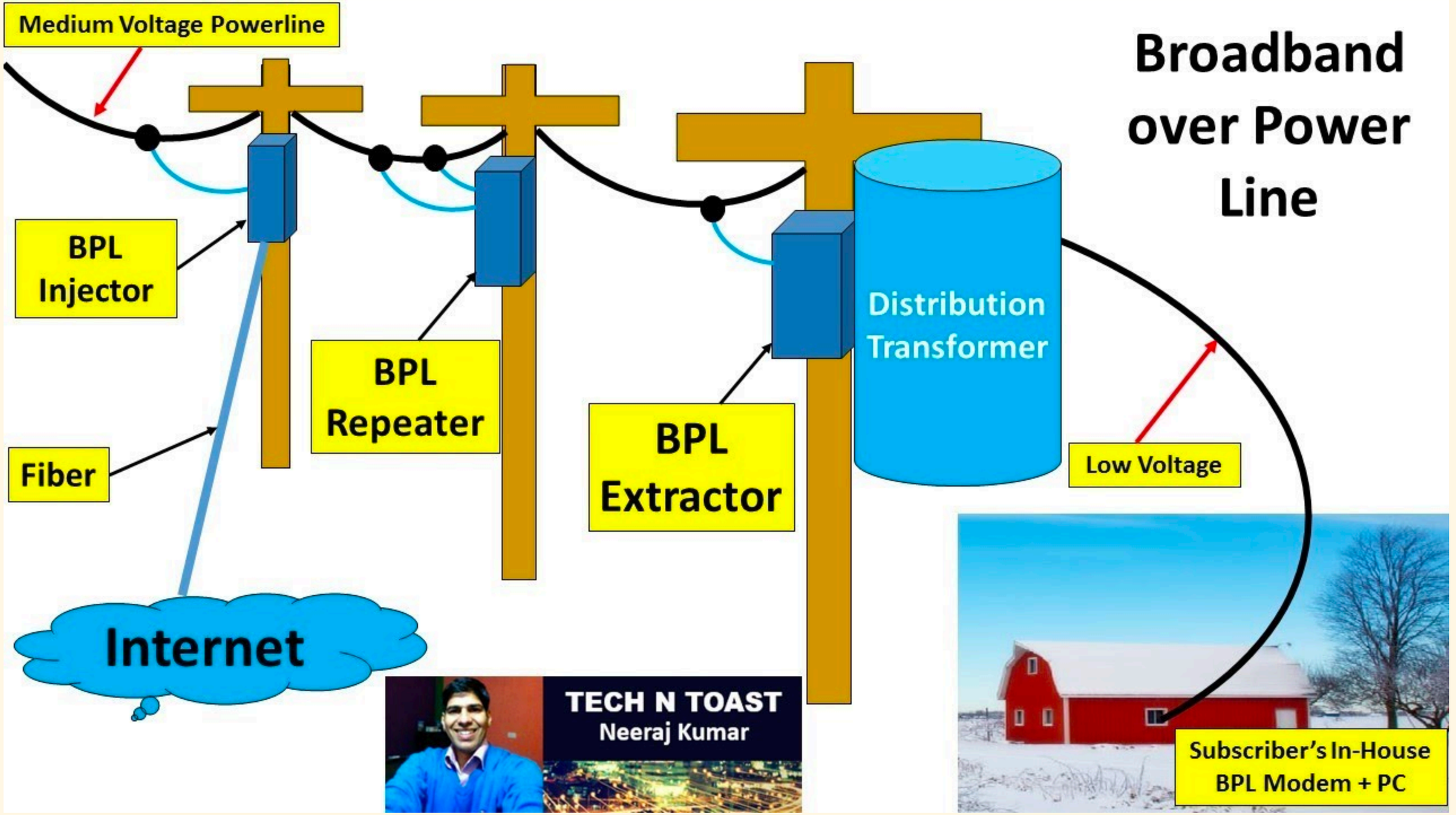
  Ethernet-over-Power AC wall wart systems

- ≥100 MHz (Transverse-mode)

  long-distance >1 Gbit/s connections (but the grid is a massive antenna)

- 2.4 - 6GHz (BPL)

  Long-distance broadband backhaul (but the grid is a massive antenna)


Broadband over Power Line
Medium Voltage Powerline
BPL Injector
BPL Repeater
BPL Extractor
Distribution Transformer
Low Voltage
Fiber
Internet
TECH N TOAST
Neeraj Kumar
Subscriber's In-House BPL Modem + PC

What does this have to do with software?

Lessons we can learn in failure engineering.

- It's a modular system
  Industry-shared common APIs
- It's a distributed system
  Time synchronization, leader election, back-pressure
- It's a critical system
  Graceful degradation (load-shedding), split brain recovery, staggered restarts
- It's a human system
  Human communication, border politics, circular dependencies

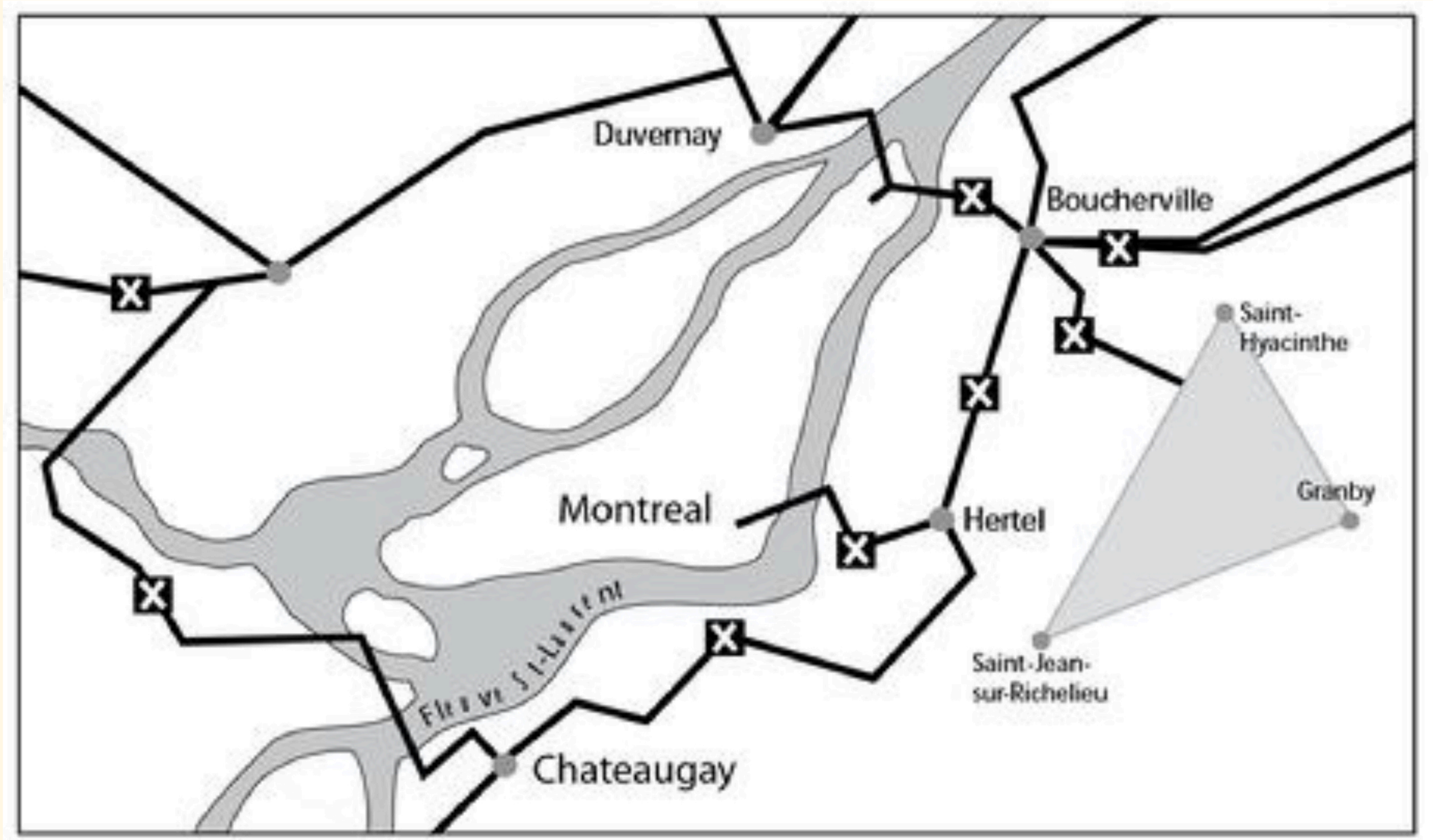
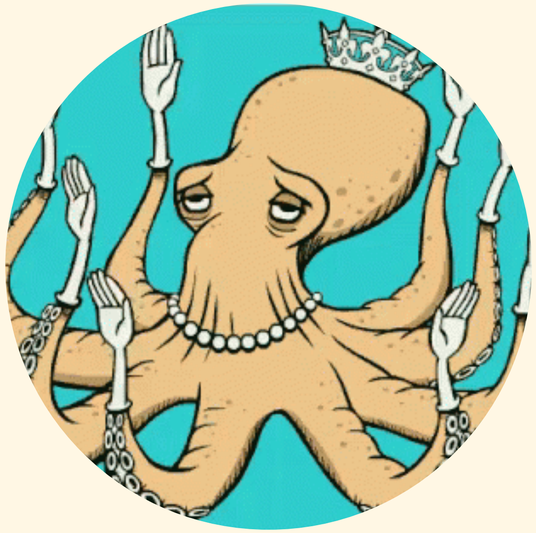


Figure 5: A map of the 'Ring of Power' around Montreal

Thank You !!con 2020 organizers, AV team, and attendees!



Q&A via Discord / Twitter:

Twitter:

@theSquashSH

Discord:

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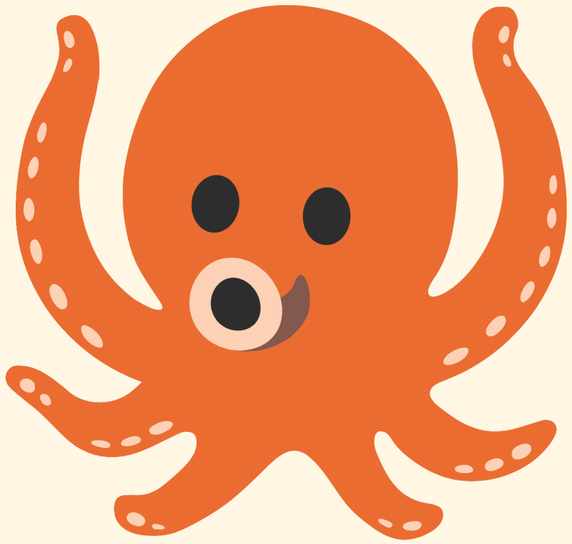

Slides & further reading links:

github.com/pirate/quebec-power-grid-talk

(P.S. Monadical.com is hiring remote Python/JS devs!)