

Human Factors of Electric Transmission, Past, Present, & Future?

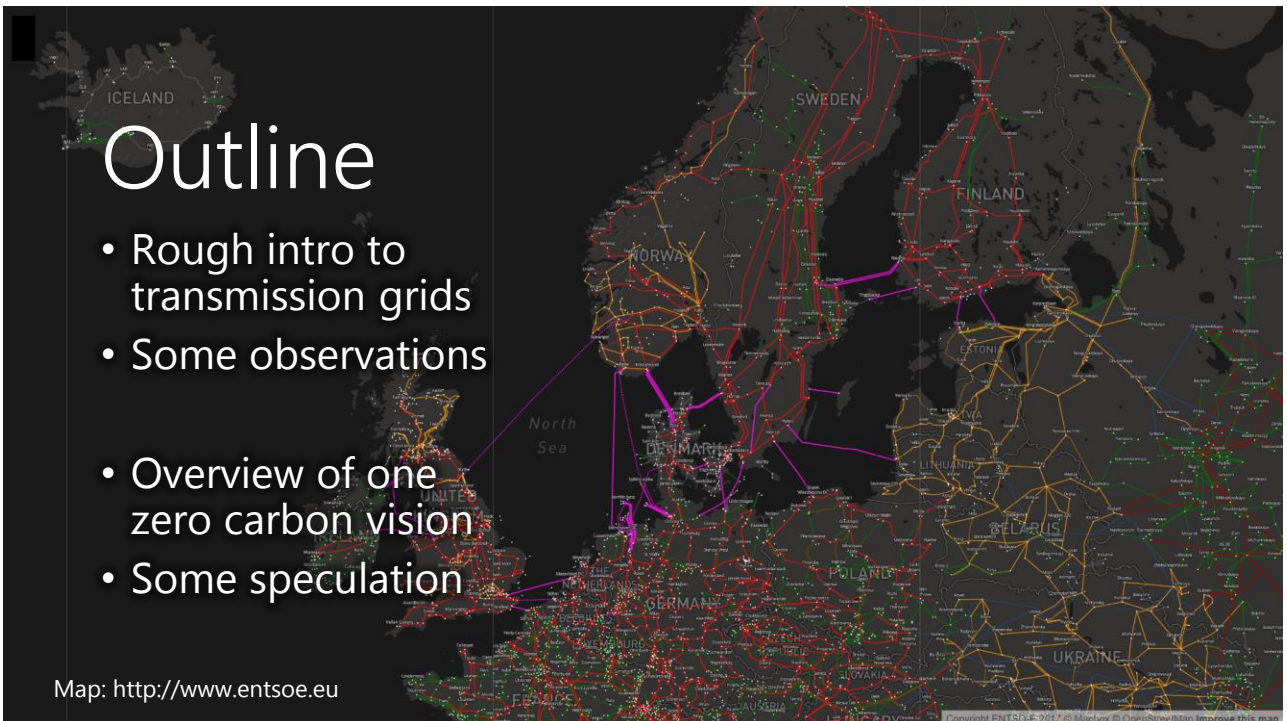
Antony Hilliard

Human Factors in Control
Spring Meeting 2018, April 18th

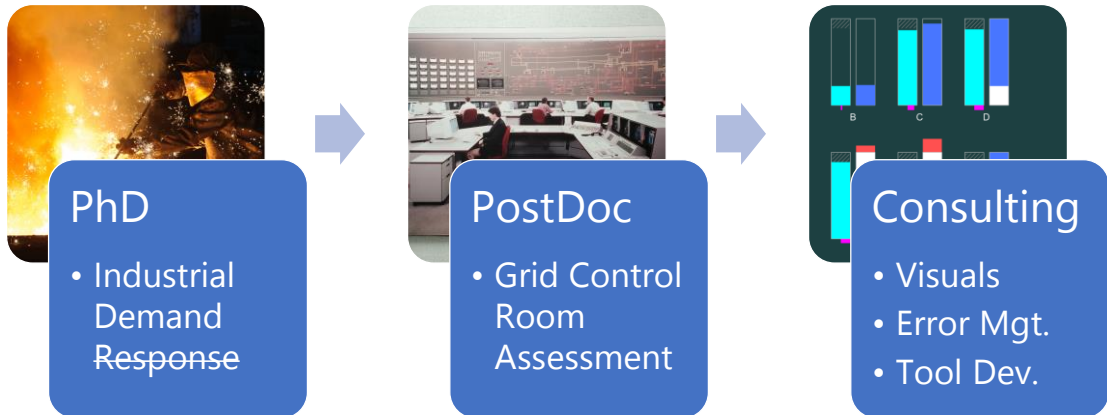
Outline

- Rough intro to transmission grids
- Some observations
- Overview of one zero carbon vision
- Some speculation

Map: <http://www.entsoe.eu>



My Background



Acknowledgements

- Operations Staff
- MITACS
- Greg Jamieson @ University of Toronto
- Richard Brath @ Uncharted Software Inc.
- ABB
- Neville Moray & Jens Rasmussen

What is Transmission Market & System Operation?

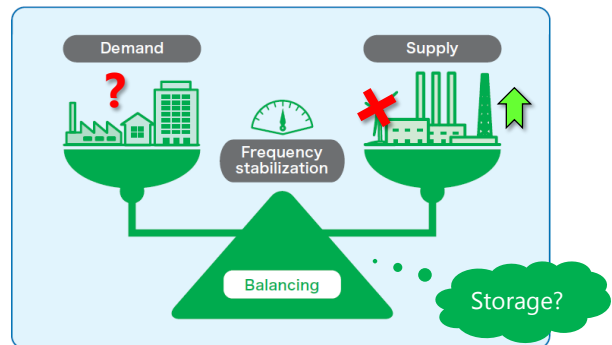
In a nutshell:

1. Match Supply and Demand (controlling supply, mostly)
2. Configure Network Securely while allowing maintenance

For 1000 pages more, see:

[EPRI Power System Dynamics Tutorial](#)

[Human Factors Review of Electric Power Dispatch Centers 1981-86](#)



https://www.occto.or.jp/en/about_occto/

What do people do in Market & System Operation?

- Plan
- Catch inconsistencies/errors
- "babysit" Automation
 - Feed it (tell it stories)
 - Monitor it
 - Clean up after it
- Anticipate situations
- **Communicate**
- Deal with situations



Framed in the control room kitchen

What I saw in Market Operation

Supervising Market Inputs

Demand-focused

- Day-ahead plan plus:
 - Generator Telemetry
 - Demand Forecast
 - Wind+Solar Supply Forecast
- = **Weather**

Garbage data,
Automation **Modes**...

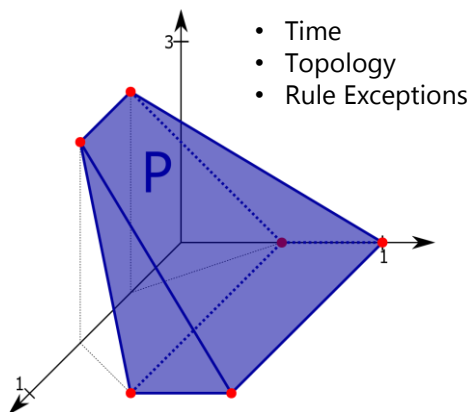
Supervising Market Outputs

Supply-focused

- Automatic dispatch (mostly)
 - Generators
 - Intermittent generators (down)
 - (very few) Loads
- New instructions every 5 min,
two minutes delay to review...

What I saw in Market Operation

Imperfect Models vs. Reality



Mechanisms of Flexibility

- 3% Load Demand Response
- ???% Industrial Peak-Dodging
- Phone the Neighbours
- 3% Emergency Procedures
 - Public appeal + Voltage shave

- Load Shedding

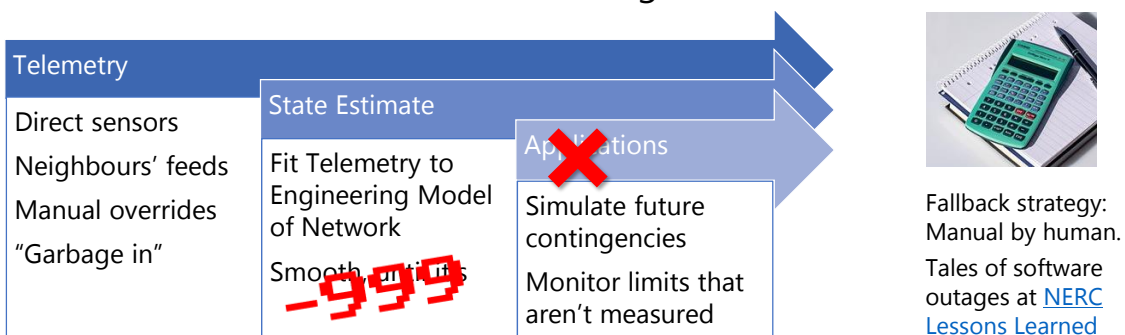
What I saw in Transmission Operation

Assessing the True State

- Automated estimate part of it
- Also: **Weather**, 24h TV news

Anticipating the future

- Always plan n-1
- Requires simulating behavior of grid *and automation*



What I saw in Transmission Operation

Control & Protection Automation

- Set & Forget?
- Arm & Dis-arm 'Special' Protections
- 'Regular' protections have ~9% mis-operation chance!
 1. Design/Programming errors
 2. Device failure/malfunction
 3. Communication failure



<https://www.nerc.com/pa/RAPA/PA/Pages/default.aspx>

Topology & Voltage Control

- Switching Lines & Equipment
- "Why is this done manually?"
 - Variety of situations
 - Coordination with field crews
 - Maintain skills post-blackout!



Cause and Prevention of Human Error in Electric Utility Operations - Terry Bilke, MISO

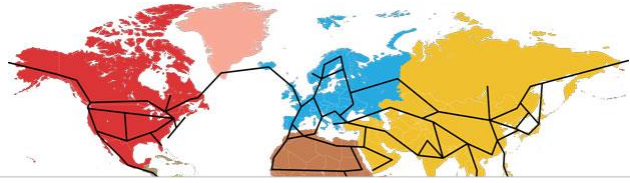


Build more Transmission?

- Interconnect to average out wind and follow the sun
- HVDC 'supergrid'?
- Small islands left out

Human Factors:

- Power lines un-liked
- Interconnection = Interdependence



[Press Release] Continuing frequency deviation in the Continental European Power System originating in Serbia/Kosovo: Political solution urgently needed in addition to technical

Brussels

Published: 06/03/2018

The Continental European (CE) Power System -a large synchronized area stretching from Spain to Turkey and from Poland to Netherlands; encompassing 25 countries- is experiencing a continuous system frequency deviation from the mean value of 50 Hz, and this since mid of January 2018.

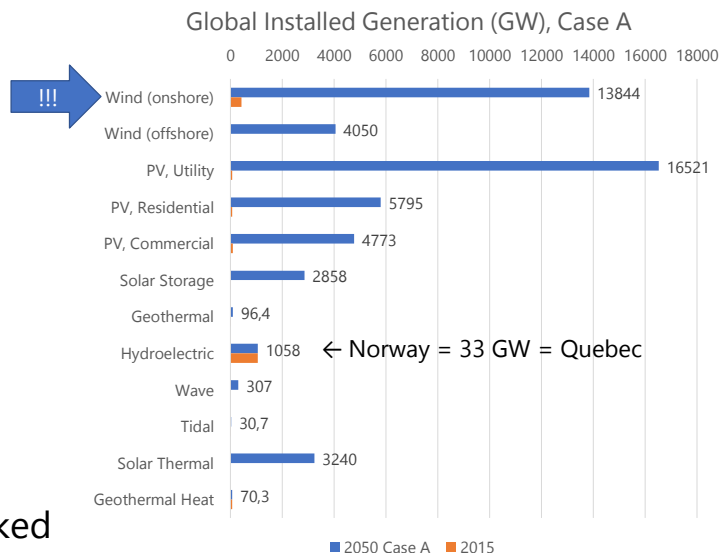
Over-generate Renewables?

Yes!

Inherent in intermittence

Human Factors:

- Wind turbines un-liked
- "Free surplus" power?



Store Energy!

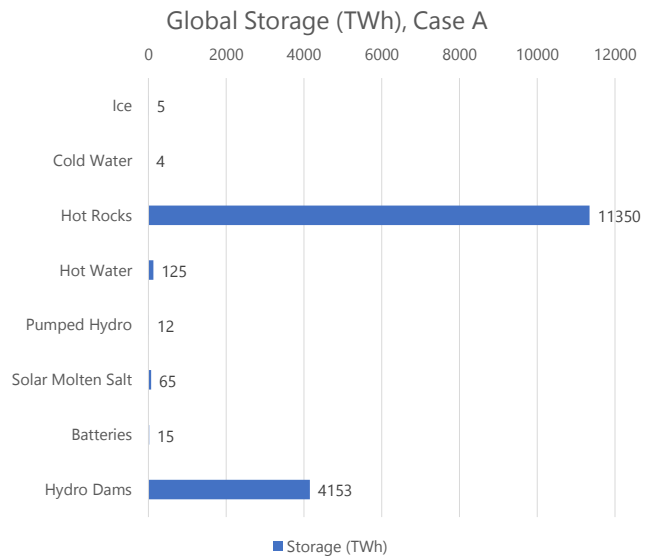
Bulk energy use scheme:

+ Surplus

- Electric Storage >
- Heat Storage >
- Cold Storage >
- Hydrogen (sink)

- Shortfall

- Heat/Cold Storage <
- Demand Response < !!!
- Electric Storage <
- Hydroelectric (precious)



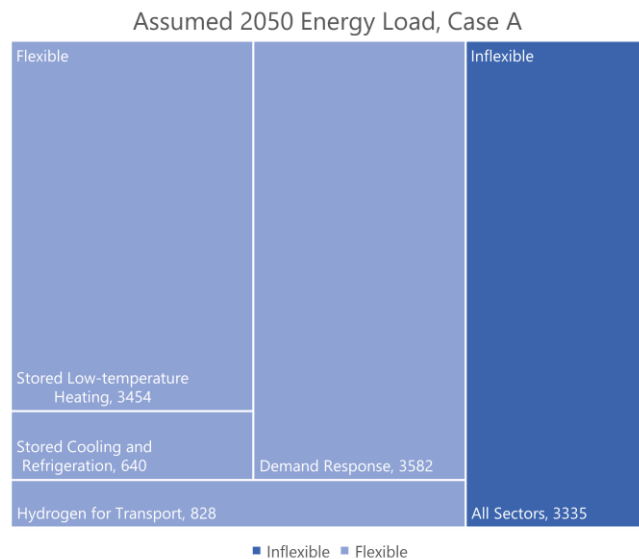
Reduce Demand to Match Supply

100% WWS estimate by 2050:

- Transport: **85%** flex-charging
- High-Temp Industry: **70%** flex
- Residential/Comm./Agri: **15%**
- "Other": **75%** flexible
- Storage for Heat/Cold, and once exhausted: **15%** flexible

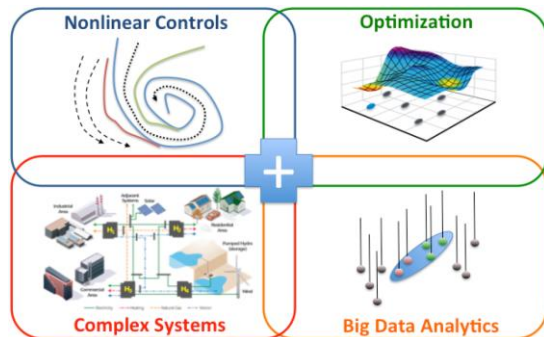
Flexible = Delay up to **8 hours!**

Massive Human Factors



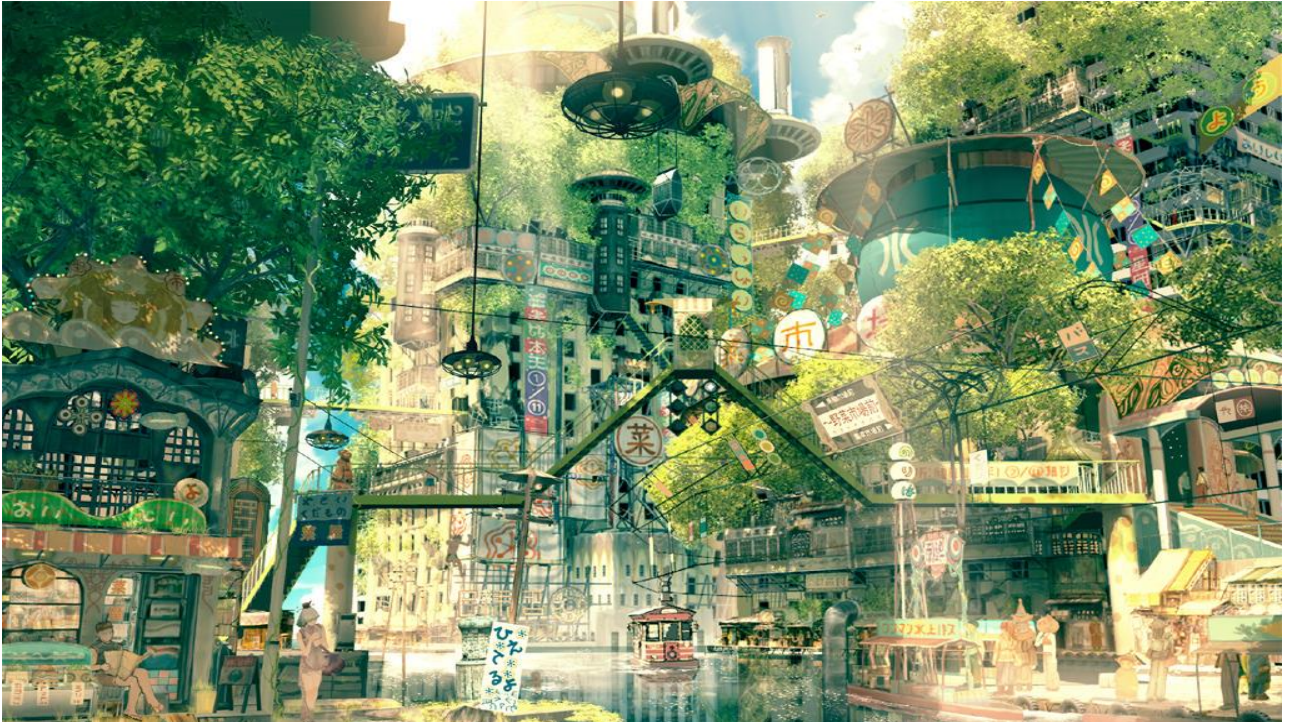
What Human Factors in this Control?

- Automated Agent Interaction (what do I want vs. grid need)
- Storage & Demand Response (lead time for planning)
- Market vs. Social Equity (what is value of energy?)
- 2nd-order effects (response!?)
- Human adaptation / Habituation
- Culture



Basic Research Needs for
Autonomous Energy Grids





Publications

- Hilliard, A., Fiona, T., & Greg A., J. (2018). Work Domain Analysis of Power Grid Operations. In N. A. Stanton, P. M. Salmon, G. Walker, & D. P. Jenkins, *Cognitive work analysis: applications, extensions and future directions* (p. 151). Retrieved from <http://dx.doi.org/10.1201/9781315572536>
- Tran, F. F., Hilliard, A., & Jamieson, G. A. (2017). Keeping the Lights On Across the Continent. *Ergonomics in Design: The Quarterly of Human Factors Applications*, 25(4), 10–22. <https://doi.org/10.1177/1064804617723781>
- Tran, F. F., Hilliard, A., & Johnson, L. (2016). *Human Factors of Transmission Operations; Summary Principles from a Collaborative Research Project*. Presented at the NERC Human Performance Conference, Atlanta, GA. Retrieved from <http://www.nerc.com/pa/rrm/hp/Pages/default.aspx>

Thank you

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Present observations

Market

- Inputs
- Outputs
- Models
- Flexibility

System

- State Estimation
- Anticipating Contingencies
- Protection Automation
- Topology & Voltage