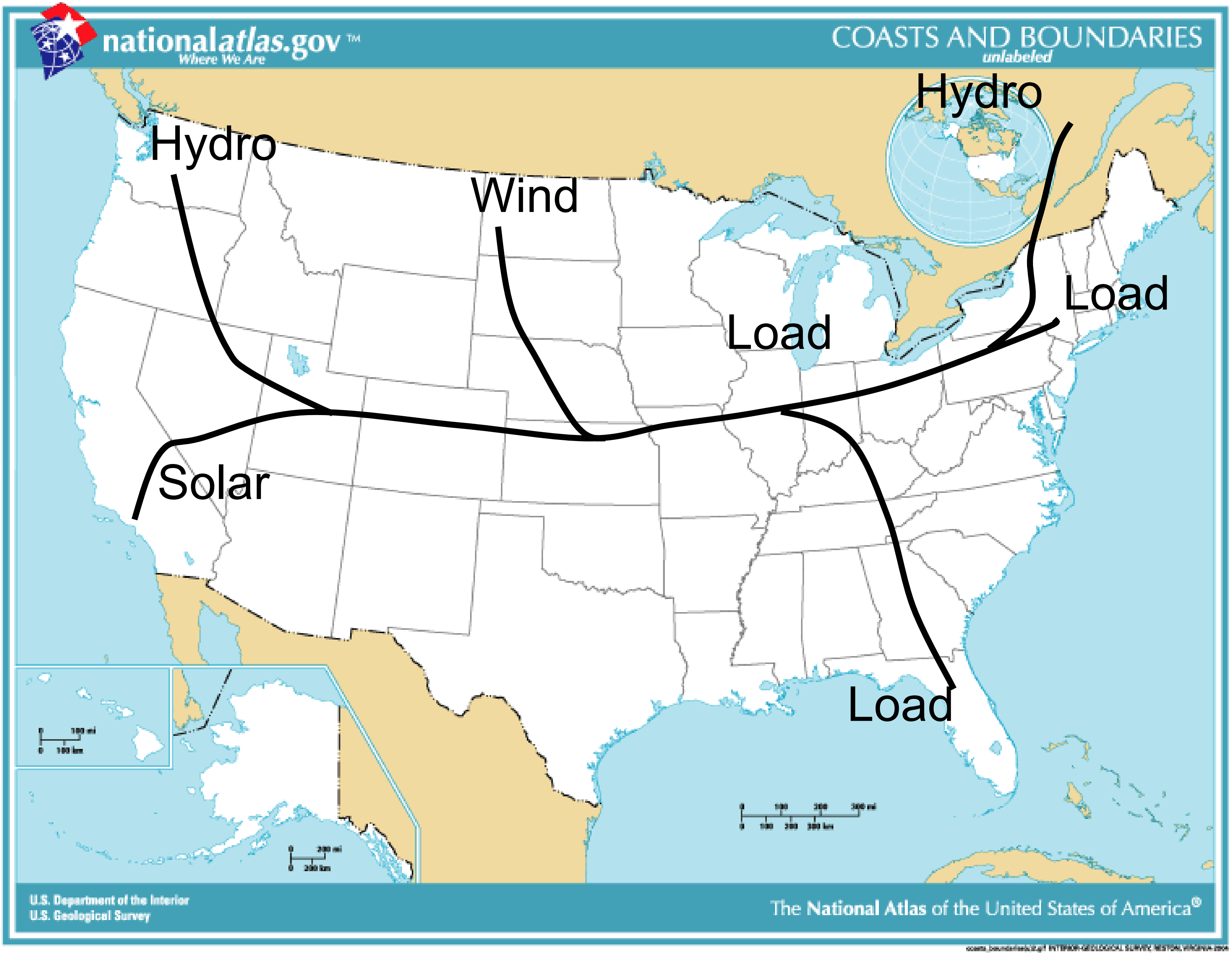
Power Control Issues in the Supergrid

ECE ILLINOIS

Functional vision of transcontinental energy exchange

- A backbone intended to deliver non-fossil energy from distant locations (often in the west) to load centers in the Midwest, east, and southwest.
- May or may not involve superconductivity and H_2, but almost surely involves electric exchange via HVDC.
- A relatively small collection of point-to-point lines, rather than a mesh


nationalatlas.gov™
Where We Are
COASTS AND BOUNDARIES
unlabeled
Hydro
Hydro
Wind
Load
Load
Solar
Load
U.S. Department of the Interior
U.S. Geological Survey
The National Atlas of the United States of America®

Control challenges

- Current vs. voltage → This is a routine power electronics issue. HVDC systems operate to maintain fixed current and adjust voltage.
- “Ocean of electrons” concept → Distributed parameter behavior and control. Large multi-tap tie based on distributed parameters.
- Impedance levels → In present systems, the impedance level and fault limits are established externally in the ac grid. The supergrid may not have this option. Higher impedance levels imply easier control.
  - 10 000 A is probably within the realm of realistic systems. 100 000 A is probably not. (Present example: 765 kV system, 10 000 A thermal limit.)
  - Higher voltage is better.
  - HVDC today is best understood for point-to-point interchange.

End use and electricity form issues

- The “best” form of electricity differs in each part of the system.
- Generation: polyphase ac (at high frequency if it is to be rectified immediately)
- Transmission: HVDC
- Distribution: ?
- End use: dc
  - Example: residential use with two-pole 48 V dc source for safety and to decrease total costs
  - Commercial at two pole 150 V dc or 250 V dc.
- End-use reliability and quality
  - Today energy storage and reliability are being provided ad hoc at the point of end use.
  - Can supergrid improve the situation?
- Load side as an energy asset
  - Providing customers with choice and ability to adjust power consumption.
  - Real-time metering and price signals to produce load elasticity.
  - This could rapidly “shave” peaks at opportune times

Research targets

- System-level simulations that allow comparison of effects and of technology penetration.
  - Control-based simulation
  - Full switch-based models
  - Tradeoffs for various distribution approaches, for sources, loads, end-use elasticity, and other issues near end use points.
  - Reliability studies
- → Suggest that about 5 research teams are needed
- HVDC grids
  - Architecture
  - Control
  - Devices
  - Operation of multiple taps
- → Suggest 4 research teams

Research targets

- Deal with extreme time scale effects → 2 research teams
- Local electrochemistry
  - Fuel cells (well covered)
  - Liquid fuel formation
- → 1 research team
- Detailed multi-source interactive control systems. This is a full distributed system paradigm. → 4 research teams
- Fault protection and management → 2 research teams
- Converter-optimized generation → 2 research teams
- Control for ripple reduction → 1 research team
- Intelligent control and system-level wide-area sensor integration → 3 research teams

Research Targets

- Suggested total:
- 24 academic research teams, $300k/yr/ea → $7.2 M/yr
- Matched with similar industry commitment → $7.2 M/yr
- (SBIR/STTR possibilities)

Wish List

- Full-blown demonstration project, MW level.
- Consistent, adequate research funding for HVDC and related topics.
- Leverage program with electric ship and other sources that have related interests.
- Sustainability as the ultimate driver.
- Public understanding of the opportunity and the vision

Final Point

- Need a hierarchical decision tree to establish an “optimum” mix of
  protons and *electrons*
  at each level in the system.