Supergrid Construction Challenges

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Assumptions

- Nuclear power plant technology established
- Hydrogen production technology established on industrial scale
- Superconductor technology demonstrated on prototype scale (meters but not km)
- Switching, dc/ac conversion and controls established technologies
- Use low voltage (20-50kV)DC at constant current (reduce line losses and 2 sets of transformers)

Objective: Construction Demonstration Project

- Site: typical congested urban area vs existing transmission right-of-way?
- Size/scale: 20-30 kilometers (12-18 miles)
- Elements: Underground generation plant, hydrogen production facility, vacuum and refrigeration stations, dc/ac conversion, substation, control room, monitoring instrumentation and data acquisition system
- Load: interconnect to existing utility system

Demonstration Project Concept Design

- Length: 20-30 km
- Electrical: 500 MW, 25kV, 20 kA
- LH2 Capacity: TBD
- Segments: superconductor, 10-15, insulated conduit, 200-300 (?)
- Components: Power, 1, LH2, 1, vacuum, 20-30, cooling, 2-3, others TBD
- Cost (?): $50-150 M ($2-5M/km ?)

Purpose

- Build a section of the supergrid on a scale sufficient to demonstrate constructability.
- Confirm permitting requirements and timelines
- Identify construction obstacles, need for specialized equipment or methods, train builders
- Benchmark cost estimates
- Benchmark critical path schedule analyses

Options

- Option 1: Above ground, existing utility transmission line right-o-way (Advantage: simplify construction, facilitate permitting, cheaper—but not best test)
- Option 2: Underground (UG) (Advantage: better test of construction issues, but probably more expensive)

Challenge No. 1: UG Right-of-Way

- Use existing utility easement?
  – Need to locate existing underground utilities
  – Assume subsurface data exists
- New location?
  – Need survey
  – Locate existing underground utilities
  – Subsurface (geophysical) exploration

Right-of Way, cont’d

- Subsurface acceptance criteria:
  - Ground water
  - Thermal properties
  - Corrosion
  - Electrical resistivity
- Design criteria
  - Seismic (especially displacement)
  - Bedding (longitudinal support)
  - Thermal insulation
  - Overburden required
  - Sabotage
  - Other

Public Acceptance/Opposition

- Need to start public information campaign early in right-of-way selection process
- Construction contract should include public information element (web site, visitor’s center with models, description of benefits, safety measures, etc.)

Permitting and Entitlements

- Multiple jurisdictions (local, states, federal)—potentially 100s of agencies
- Regulatory conflicts
- Early determination of environmental permit requirements
- New technology—no accepted standards
- Need to educate building officials

Underground Conduit Concepts

- Single purpose: dedicated to supergrid
- Utility Corridor: multi-purpose (fiber optics, water, gas/oil, etc,)
- Combine with transit (rail, subway)
- Considerations:
  - Access for maintenance and inspection
  - Safety: impact of leak on other utilities, transit passenger traffic

Excavation/trenching

- Is undergrounding mandatory?
  - Place above ground in precast concrete continuous vault (“freeway divider”)?
- Is trenching acceptable? (most cost-effective method)
  - Provides vertical access for placing conductor
  - No entry: repair requires excavation
  - Visual inspection possible by remote video
- Minimum size requirements for trench or tunnel?

Tunneling

- Most expensive, order of magnitude(s) more than trenching
- Can provide for entry and inspection
- Can be designed for multiple uses
- Costs could be shared between users
- Potential to retrofit existing tunnels (rail or vehicle)

Note:

- For demonstration project, probably want to use a tunnel to provide full access for:
  - Measurements/testing
  - Performance evaluation
  - Maintenance/Repair
  - Testing of new equipment or advanced prototypes
  - Training
- Upon proof of concept, next stage could be trenched, jacked, or drilled

Challenge: How to Place Superconductor?

- Assume superconductor has qualities between a pipe and a cable
- Relatively rigid, limited flexibility
- Must avoid crushing impacts that would damage insulation or thermal expansion joints
- How to feed into conduit or tunnel (push or pull?)
- Probably need to develop special equipment for joining and feeding conductor into excavation or conduit
- Establishing/maintaining vacuum

Superconductor Design

- Does a suitable prototype exist?
- Does manufacturing capability exist or are prototypes custom made?
- Scale-up problems from prototype to full-scale system
- Materials availability and compatibility with H_2
- Is there a need for material testing and development?

Conductor Fabrication/Assembly

- Field vs. Factory
- Can it be spooled?
- Linear segments-length determined by transportation limits (20 m?) or by fabrication limits (100 m?)
- Design for thermal expansion
- Welding/joining segments
- Couplings/connections to pump stations
- Procedure for field testing for leaks

Design/Manufacture of Subsystems

- What is available and proven, what is prototypical, and what needs to be developed?
  - Vacuum pumps
  - Hydrogen circulation pumps
  - Liquid/vapor separators
  - Compressors/refrigeration systems
- Design issues: modular, optimum size/capacity, reliability, etc.
- Power source: (supply, or extract locally?)

Undergrounding of Nuclear Power Facilities

- Nuclear power is proven technology; issue is public acceptance
- Licensing is major hurdle
- No major technical obstacles to undergrounding a nuclear power plant (costly!)
- Need to address fuel changes and other maintenance issues.
- Derivative of military experience with hardened underground facilities

Note:

- For demonstration project, consider underground modular fossil fuel generation
- Gas turbine or diesel, depending on capacity needs
- Or locate near an existing generation plant

Undergrounding of LH_2 Facility

- Is undergrounding necessary in this case?
- Can modular, packaged electrolysis plants be fabricated?
- Answer depends in part on size and capacity
- Undergrounding would have benefit of safety and reducing use of surface land.
- Maintenance issues need exploration

Construction Phasing-I

- First need to establish design parameters (size, utility requirements) for various components
- From this develop conceptual design
- Next develop master budget (rough-order-of magnitude or ROM) based on conceptual design. This will have significant contingency built in.
- Results of this budget milestone will indicate project feasibility and go-ahead for next phase

Construction Phasing-II

- Detailed design will be carried out
- Detailed cost estimates for all major activities
- Master budget will be refined as design development reduces contingencies
- Develop a critical path schedule
- Undertake contractor prequalification

Construction-Phase III

- Award contracts: Use cost plus award fee vehicle
- Develop scope of work with both fixed cost elements and unit pricing (for example on subsurface work)
- Make alternate dispute resolution (ADR) mandatory
- Provide safety incentives

Commissioning

- Develop program for start-up testing, commissioning, and training
- Validate cost and schedule models
- Collect data on system operation, performance, and reliability for first year
- Develop maintenance procedures for replacing failed line segments or minimizing system down time

Project Cost Estimate

- Let DC = ROM cost of equipment, labor and materials exclusive of land and permits
- Design cost = 0.1 DC
- Contractor OH, G&A and Profit = 0.2 DC
- Insurance and bonds = 0.01 DC
- Construction management, surveying, testing labs = 0.09 DC
- Total cost (exclusive of land and permits) is therefore 1.4 DC as first approximation

Construction Research Topics-I

- Some major issues for future study:
  - Identify permitting requirements and timelines
  - Evaluate H2 greenhouse effects
  - Optimal LH2 production technology
  - Evaluate magnitude of practical heat gains under design conditions
  - Field assembly, connection, and testing of superconductors (joints and splices)

Construction Research Topics-II

Additional Issues:

– Instrumentation and leak detection
– Power conversion and control design
– Practical/cost-effective module size and capacity
– Special tooling or equipment for handling superconductor
– Geophysical research to establish acceptable range of soil parameters for buried lines
– Design issues for maintainability

Next Steps-I

- Prepare a “pre-conceptual” design of a 10 km section of line with compressors, pumps and related equipment.
- Establish rough sizing of major components
- Create a small construction industry advisory group to review conceptual design and identify potential challenges and solutions

Next Steps-II

- Collect background information on major undergrounding projects
- Establish a dialogue between construction industry advisory group and research groups for feedback of information
- Advisory group to evaluate constructability of various equipment configurations

Last Words

- Trans-Alaska Pipeline: (heated oil, refrigeration systems to maintain pipeline supports in perma-frost, seismic design, remote location, environmental sensitivity)
- North Sea Oil: (Brutal environmental challenges, mid-ocean platform based hotels, gas-oil separation, undersea pipelines and pumping stations)
- It can be done!!
- (What can we learn about challenges and approaches from these and similar projects?)