Supergrid Construction Challenges

Craig B. Smith
DMJM H+N
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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 $\text{H}_2$
- 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 permafrost, 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?)*