SuperGrid 2 Meeting Notes

October 25, 2004

Introductory Session

Tom Overbye

98 Quads per year, 38 of which are electricity and ~30 transportation.

Petroleum ~40%; natural gas ~25%; coal ~25%

Oil production will peak in about 2015 at about 100 M barrels/day; can sustain that for only a few years.

Jesse Ausubel

Intro to Chauncy

Chauncy Starr

Regrets not being able to attend
Thanks to Professor Tom Overbye and Dr. Paul Grant for running the meeting.
Thanks to Lounsberry Foundation and to EPRI for financial support

What is the SuperGrid (SG)?

SG is a visionary concept resulting from a concatenation of technologies

- New superconductor, and developments in G2 wire, both look encouraging
- Support for hydrogen economy may benefit
- Advent in improvement in nuclear power stations (NPS)
- Concept of going underground

All these put together suggest a new, visionary technology

The problems of long-distance, above ground large-scale transmission of power are well known: magnetic fields, losses, public acceptance, etc.

How has your background influenced the birth of the SG vision?

After WW2 there was a strong urge to convert the new energy source (nuclear fission) into socially useful production of power;
Fermi discovery in 1939: a man-made source of energy, unique
I have always been influenced by that objective; the SG is a manifestation of that objective.

Scenario for next 10-15 years.

Each component of SG is a question of being applied on a large scale.
Will move in stages; each component will develop and be put in small demonstration
Perhaps first: short length superconducting cable to resolve transmission congestion

What about doing well-head generation and shipping the power by a super cable?

Very attractive option
Remote locations would become site for NGS after the fossil runs out

Hard to layout a scheme for new power 20-30 years ahead of its deployment, because circumstances change and the future is unpredictable.
What is important is to get the initial components developed and demonstrated in a feasible test.
As circumstances change then adjust for the most effective use of what you have when you have each component developed.

Major challenge of this flexibility is that growth of electricity demand in future is going to be twice what we have at present. National network problems will always be put to great strain and stress. SG concept could fill in certain places. E.g., every power system needs reserve capacity. On a national scale, a long-distance transmission line could meet these needs. Point is: we don't know how the final application of this concept will take place. We do know that the future demand for electricity will be a major objective to be filled.

Do we need any new discoveries?

The scientific basis is already well established for each component
Engineering development of high power, large scale system is the challenge
Need specific engineering programs for each component

- E.g., large scale production of hydrogen by electrolysis; superconducting cables, interconnections; undergrounding.

Undergrounding is one of the most exciting possibilities to me; raises all kind of problems in maintenance, inspection, etc.
I find that each one of these areas is exciting.
Idea of putting an NGS underground is not knew; my old colleague Ed Teller always suggested that.
There is a whole set of complex set of challenges for each area.
On behalf of my colleagues, it would be a tremendous personal gratification to know that there would be a source of power good for a millennium.

Would you be willing to take on leadership, if Doris would give permission?

I doubt Doris would give permission
If I were a half-century younger I would jump at the opportunity
I hope the younger generation will have fun.

Technical Plenary Session

Paul Grant, Supercable

Chauncy's roommate at Harvard was John Bardeen; he has a wonderful story about why Bardeen did not get tenure at Harvard and had to settle for 2 Nobel Prizes instead (BCS Theory of superconductivity and the transistor)

The Discoveries
What SC is, what it can do, what it cant do.
Zero resistance

Big difference between a superconductor and a zero resistance conductor
Pinning the lattice magnetic vortices allows a Type II superconductor to have zero resistance below the irreversibility line

LH_2 in 45 cm dia, 12-mile bipolar supercable = 1 Raccoon Mtn (1.6 GW, 20 hrs, 32 GWh)

Bob Lasseter, Power Control

Low voltage, high current DC superconducting network
Issues:

- Complexity of system control (100s or sources and 100,000s of loads
- Current control

DC transmission systems
Traditional, multi-terminal HVDC

System issues
Neg: difficult to create networks
Pos: no load-dependent voltage drop

Can create a superconductor ring and use the voltage for control

Faults
Clearing the fault
Mechanical strength of cables and vacuum system to withstand faults

Inductance of cable will determine how fast the fault builds up

Utilities may require current control.

Why are we distributing electricity? Just generate and move hydrogen and generate locally (DER)

Bob Thomas, System Integration Issues

Integration issues means planning for integrating technologies
Current planning process and where it is headed and where it might be at the point in time that we will be doing a continental supergrid.

Generation side will definitely have nuclear and renewables

Traditional expansion planning process

- Done by engineers
- Transmission planning and generation planning use different tools
- Several alternative plans created
- Have to take account of how things will look in the operations arena
    - Reliability
    - Economics

Transmission expansion planning

- Begin with load forecast and expected generation mix
- In past assumed dispatch was economical
- AC power flow and contingency analysis simulation programs are primary tools
- Substations are part of the expansion problems
- Supergrid offers alternative to adding EHV lines

Generation planning
Fuel important
Environomental concerns
Both energy and demand forecasts needed
Reliability and economic supply

Protection
Generation – not system related
Transmission – system functions

Operations
Done in control centers
Operators typically not engineers (now changing)
First job priority is reliability

In summary, in the past, planning was easy
Generation was known
Future loads known
Transmission construction accepted

Vision for supergrid network
Backbone
Primarily DC
AC might be available

Hydrogen is the coolant
Hydrogen is transported as fuel

Robert Schainker, Hydrogen

Wes Meyers, Nuclear

Undergrounding in salt could be cheaper than current day above ground construction.

Challenges and issues

- Plastic deformation
- Corrosion
- Optimum layout
- Safety issues
- Regulatory issue; no framework
- Psychological issue ("dark, dirty, dripping, dangerous")

Environmental equity satisfied

Storage in salt is ancillary benefit (e.g., CAES)

Ed Cording, Tunneling for the Supergrid

How far apart do you need to put laterals and other underground structures for the transmission system (supercable)?

- Length of line between stations
- Tunnel access for maintenance and line replacement
- Tunnel size
- Stations

Requirements

- Redundancy
- Security
- Access for maintenance, etc
- Replacement after shutdown
- Tunnel environment

Multiple use corridors: large tunnels for transportation and cable

How deep do we want the tunnel to be?

Tunnel method and lining

- Short shield tunneling in rock
- Shield tunneling
- Pipe jacking (micro-tunneling) – short distances only (up to 1000 ft.); fewer people in tunnel

Three ways to be more efficient/cost effective

- Increase advance rate
- Reduce crew size
- Reduce risk

Wayland Eheart, Environmental effects of the Supergrid

How much hydrogen to we want/need to pump?

Environmental implications of a LH2 pipeline; drawing a distinction between small and large leaks

Small hydrogen leaks (spills or normal venting)

- Flammable but not very toxic
- No disposal cost
- Fire (in forest)
- Explosion (in underground sewar)

Large hydrogen leaks (rupture)
Flammable/explosive (risk to workers
Toxic
Lake, river or wetland crossing
Ice grenades

Underground hydrogen leaks
Probably safe do to low solubility, high diffusivity

Environmental engineering

- System of isolation valves and bypass conductors
- Place valves 200-300 m apart
- Valve flanges carry full current
- Remove leaking pipe section

May disrupt wildlife migration routes
Not problem if undergrounded, but stay out of calving areas

Compromise with some trenching and some tunneling
Could be put under farm land

Location, location, location

- Interstate highway median strips (leaks a problem)
- Railroad beds
- Existing power corridors

Secondary effects (positive)
Really really cheap oxygen: more cost effective sewage treatment

Manufacturing superconductors

Humidity
- Water IS a greenhouse gas, but it condenses out quickly
- Possibly locally high humidity

Electrical field effects – not an issue if underground and DC

Water supply – needs planning, purchase of water rights in arid areas, legal problem in some areas; not large issue

Positive effects
Savings in generation from efficiency gain
Millions of household equivalents
Kyoto credits
No new power plant sources of NOx and SOx near cities

Break Out I Reports

Electrical Issues – Paul Grant

Superconductors good at carrying lots of current, as long as you don't change it.
How do you manage demand load fluctuations?
- In ac grid you change current
- In superconductor you don't want to do that

Need a device to:
- Handle current changes on the ac side
- Handle changes in power by changing voltage on the dc side

Cold dielectric cable benefits
- Outer sheath contains magnetic field
- Lower inductance

But, more complicated design, twice as much superconductor, more expensive

1% ripple on a 100kA cable is 1000A, which is the level of carrying capacity of current superconductor cables
- Natural reactance of system may filter the ripple

Cryogenics a major component (not well represented at this workshop)
- Take home problem: how do you apply current experience and technology to a 1000 km supercable?
- Cryobreaks: need to get into the system

Magnetic field forces
- Refer back to Garwin & Matisoo, first

- WD cables would have to be separated by several meters

Splices
- MRI magnets may have as many as 50-70 splices
- Splices are perfect conductors
- Issues: does the supercable need to have perfect conductor splices?

Charge/discharge cycles and faults

Power Control Issues – Phil Krein

Why and why not superconducting

Why not
- Fault management
- Line taps
- Cryogenics
- How to build mesh systems (point to point not adequate)

Transportation
- Not a logical use of hydrogen
- Power control more sensible with liquid storage
- Could a supergrid be used in road bed

Portable vs stationary applications
Portable: energy storage, energy density, conversion density
Stationary: superconductor makes more sense; fault limiting

Distance
Overhead HVDC
Underground it and cool copper in LN2
Conventional HVDC scales from existing technology

There are fundamental challenges for HVDC

System modeling
Severe problems, especially when you go to superconductors

System Integration Issues – Pete Sauer

Hydrogen R&D for SuperGrid – Robert Schainker

Seven issues
1. trade-off analyses
2. production
3. piping and distribution
4. storage

5. public acceptance
6. commercial applications
7. start-up and shut-down

Trade-offs: Gas or liquid

Producing: lot going on by DOE; but look at range of methods

Piping and distribution: not a lot being done in this country at least

Storage: lot of work from DOE; may need large storage at nodes for start-up and shut-down

Public acceptance and training:

Commercial applications: may use as magnet for commercial use of hydrogen (and oxygen)

Start-up and shut-down involving hydrogen: lot of research in this area.

Need to bring petro-chemical industry experts into the discussion of piping and distribution

Nuclear – Jim Stubbins

Most of technical issues have been identified and are starting to be addressed

- generation IV roadmap
- lead concept is high temperature reactor for electricity and H_2 production, probably He cooled – next generation nuclear plant (NGNP)
- international participation
- concepts need more transparency and better vetting

Systems and economics issues not been addressed as well as technical issues
Roadmaps good for setting goals
System scalability

- one step away on nuclear side
- need a lot of development on H_2 side (thermo-chemical processes have not been done on a large scale)

Human resources needs attention

- need to get more people going into this field (cost: $100K per person)

Very High Temperature Reactor (VHTR) - Finis Southworth, INEL

Gas cooled, graphite moderated
1000 C outlet temperature
Build by 2015 to 2017 as a demonstrator
Passively cooled in emergency

Efficiency of producing either electricity or hydrogen (SI cycle): 50-54%

$800M R&D program in US of which $400M is in hydrogen production research (very immature)

Undergrounding – Ed Cording

Goal: support and facilitate the SuperGrid

SuperGrid project will generate industry interest

Tailor R&D to specific issues on SuperGrid tunneling – focused

Environmental Engineering – Ed Herricks

SuperGrid is fundamentally "green"

- underground, out of sight, replaces a whole bunch of stuff that is harming the environment

The problem is how do we get to the future?

Public behavior is an additional research area (besides economics)

Social science research agenda

- He wont take a post modernist approach and try to deconstruct that (Post Modernist deconstructs things down to meaning rather than looking at more important aspects)

How do we make a paradigm shift that leads rather than follows stakeholder needs?

Still, there are near-term, small scale issues:

- New materials – does manufacturing, use, disposal pose environmental risk?
- Where does water come from?
- Where do waste streams from water treatment go?
- How do you maintain the grid?
- What are likely materials changes with exposure to hydrogen, temperature, pressure
- Likelihood and consequences of leakage of hydrogen
- Effect of strong electrical fields
- Byproduct management

Q&A Session

SuperGrid Construction Challenges

Craig Smith, DMJM

Assumptions

Construction of a demonstration project

- Typical congested urban area
- 20-30km
- Contain all the major elements
- Connect to grid

Design
20-30

Undergrounding of LH_2 facility

Construction Phasing – I

Need master budget (ROM) before seeking funding.

Construction Phasing – II

Break Out Group II Reporting

Summary of Benefits, Jesse Ausubel

SuperGrid is a transcontinental energy exchange
Seven areas of benefits

1. Efficiency:
    a. Minimize losses in transmission
    b. Load flattening
2. Reliability
    a. Back up for regional outages
    b. Fuel diversity
    c. But, greater chance of catastrophic failure
3. Security
    a. Undergrounding
    b. Depends on topology
4. Environmental
    a. Easier intro of nuclear, solar
    b. Footprint compact
5. Economic
    a. Improves, implements storage
    b. Higher use of capital stock
    c. Allows generators to see larger markets (larger generators – economies of scale
6. Consumer
    a. May fit the solid state world better (end of 60-cycle world?)
    b. DC devices
7. Geopolitical
    a. Every region "could" be an energy supplier (churning out hydrogen and electricity)

SuperGrid Group, Paul Grant

Group concentrated on target organizations for funding

1. SGIG – SuperGrid Interest Group
    a. volunteer organization
    b. work with other groups, like CCAS
    c. have a web site
2. Press
    a. Write up for this meeting
3. DOE
    a. very little money just now
    b. do a dc cable as a priority over hydrogen
4. BES – Basic Energy Sciences
5. NAE – National Academy Energy
    a. Get Carl Rosner to help
6. EPRI
7. EPRI/CCAS Luncheons for educating Congressional staff

The "one wish" of the working group: an energy appropriations bill passed that would restore the budget for superconductivity.

Power Control / Power Electronics Group, Phil Krein

Backbone for energy exchange

- May or may not involve superconductivity and hydrogen
- Will likely involve HVDC

Control challenges

- Current control not a problem
- Distributed parameter behavior and control
- Currents need to be < 10,000 amps over next decade or so

Research topics

1. system-level simulations that allow comparison of effects and of technology penetration (5 research teams)
2. HVDC grids (4 teams)
3. Deal with extreme time scale effects (2 teams)
4. Local electrochemistry (1 team)
5. Detailed interaction between sources and loads (4 teams)
6. Fault protection and management (2 teams)
7. Converter optimized generation (2 teams)
8. Control for ripple reduction (1 team)

Final point: need a hierarchical decision tree to establish an "optimum" mix of protons and electrons at each level in the system.

System Integration Group, Pete Sauer

Sales pitch to move forward

How to move forward

a. need to show a near-term benefit
b. better modeling methods for larger systems , multi-terminal dc systems
c. look at breaking up grid into smaller pieces
d. get DOE superconductivity and hydrogen programs together
e. simulations or prototypes, like a “table-top” system that people could experiment with or show to Congress, etc.
f. determination of functional requirements
g. short term studies looking at choice of architecture
h. society meeting presentations
i. getting DOE and DHS involved; assessment of vulnerabilities for future grid
j. credible models for simulations coupled into demonstration projects
k. intial work is mostly determining architecture, $3M/year budget
l. build industry technical committees

Potential competitors

a. GIL
b. Modular, small distributed nuclear reactors
c. Massive ethanol effort
d. Extensive HVDC links for flexible transportation and control

Hydrogen Group, Robert Schainker

1. Trade-off studie
    a. Main benefit of hydrogen in the cable – needs value proposition
    b. Liquid or gas
    c. What if global warming turns out to not be an issues?
2. Stakeholders
3. time-line vs. workscope
    a. near-term (1-2 yrs): scoping / trade-off / conceptual design
4. Ways to work together
    a. DOE appoint a lead lab

Construction Group, Ed Cording

Need for both large and small tunnels
Hold a workshop
Identify tunnel projects for demonstration
Prepare RFP for design and construct of a tunnel system

Implementation

1. bench test, 500 m, ORNL
2. component tests and demos
3. generic design
4. siting

5. site-specific design

Environmental Group, Ed Herricks

SuperGrid is fundamentally "green" so ultimately environmental issues will be site-specific. We need a social science research approach.

Wrap Up

Wishes and Actions, Jesse Ausubel

There has been very good progress, so we should feel good.

But, we have a $1 Trillion dollar idea, so we need to be diligent and clever.

I am personally committed to try to raise money for this, at least at a low level. These two days have reinforced my mind that this is a good thing to do.

1. Clarify the vision, concept development
   a. still no agreement on even things like nuclear power, hydrogen, superconductivity (doesn't need to be now –)
   b. need competing / alternate visions
   c. "SimSuperGrid"
   d. Everyone we speak to in coming years is going to ask us what the alternate visions are and we need to be able to answer
2. Get a flow of resources into the field
   a. Bankers don't fund in absence of proposals – need to develop RFPs (proposals) on specific technical questions
   b. Go to new NSF head (Arden Bement)
   c. Lobbying Congress
      i. Lobby specific issues – like decarbonization (frame project in terms of current needs)
   d. Need champions
3. Demonstrations and Prototypes
   a. "Table-top" devices for research and PR
   b. "Full-scale" demo – 400 meter cable, tunnel, etc.
4. Lift public understanding
   a. Works both ways (engineers need to "understand" the public as well)
   b. Value proposition, sales pitch; magazine articles, TV? (not enough content yet?)
5. Community building
   a. Websites
   b. Research network, working groups, university consortium
   c. Workshops, SG3? In Washington DC? With alternate visions?
      i. Should not do the SG3 until we have some alternate visions to present (maps, pictures, simulations, etc.)

6. NAE/NRC study? (National Academy of Engineering / National Research Council)
    a. Supported by EPRI, DOE, DHS, private sources
    b. This would be slow, but would address a lot of issues raised above
    c. Chair of such a study would become a natural leader of the effort as well

Final Discussion Session

1. Team formed to go to Arden Bement (Grant, Dale, etc.)
    a. Report will be done by end of November
2. Need to have a good reason for the SG, specific problem(s)
    a. Don't want a solution looking for a problem
    b. Identify places to put
3. Four main things, priority items (Steiner Dale)
    a. Mission statement, vision statement, problem statement
    b. Find a champion (someone with credentials)
    c. SuperGrid interest group
    d. Find a demonstration site, but not too soon
4. Asking for money is better done by showing Congress something tangible that is working (Vladimir Kogan)
    a. But, usually helpful to leave behind a piece of paper
        i. The reason to write a book today is to get on TV to talk about it
5. FermiLab; paradigm of a portable MRI trailer (Paul Grant)
    a. Paul to put together an appendix for report on educational facilities
6. Comments by Wes
    a. True that many elected officials don't read much, but they have science advisors; go to the advisor
    b. If I had 15 minutes with a Congressional staffer: present concept, national problem that would be solved, rough cost, something to leave behind, tangible, near-term project (but don't ask for funding at that point; have some endorsements); when asked about next step, suggest perhaps the NAE study.
        i. The study results would be used in hearings that would produce the 10s of millions needed for the demonstration
7. John Maulbetsch, Analogy
    a. Peter Glazer's orbiting solar collector – idea on the fringe of lunacy
    b. Peter Glazer got hearings and kept it alive for 40 years
    c. Sometimes you can have really power ideas whose time has come; you have to persist, but they do happen
    d. Sine qua non is a Champion
8. Tom Schneider, Alternative analogy: Arthur C. Clark's vision of orbiting communications satellites of twenty years ago using mechanical switches
    a. Now we have, but not with mechanical switches
    b. Important not to concretize the idea too early
    c. Range of variability between hydrogen and electricity; nuclear or solar
    d. Offering society a choice to make as to where to go

9. Logo: central vision of what the grid can do that nothing else can do: robustness in the face of random actions