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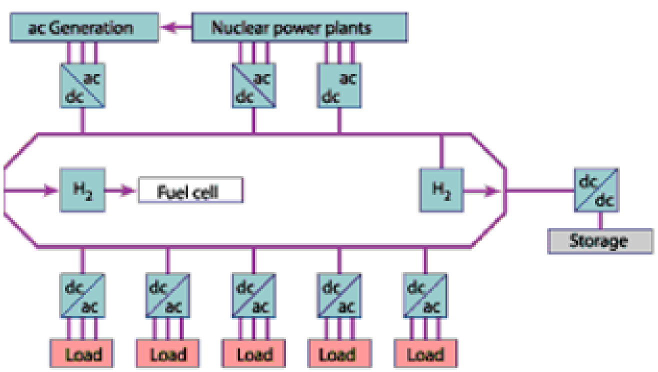
SuperGrid Concept Sparks Interest

EPRI Founder and President Emeritus Chauncey Starr's vision of a continental SuperGrid that delivers electricity and hydrogen in an integrated energy pipeline is sparking interest in the scientific and technical community. Specifically, the SuperGrid would use a high-capacity, superconducting power transmission cable cooled with liquid hydrogen produced by advanced nuclear plants, with some hydrogen ultimately used in fuel cell vehicles and generators.

Starr first proposed the SuperGrid at the November 2001 meeting of the American Nuclear Society. The concept was more recently the focus of a series of informal technical presentations and considerable discussion over three days by more than two dozen experts in various engineering fields, including energy researchers from eight major universities, scientists from three national laboratories, leading power and other industry consultants, and several EPRI staff.

The group convened in a Palo Alto hotel conference room on Nov. 6-8, 2002, with grant support from the Richard Lounsbery Foundation, obtained through the efforts of Jesse Ausubel, who directs the Program for the Human Environment at The Rockefeller University in New York City. The workshop was organized and chaired by Professor Tom Overbye of the University of Illinois at Urbana-Champaign. Overbye, one of several power transmission engineering professors who helped direct the U.S. Department of Energy's recent National Transmission Grid Study of transmission bottlenecks, was assisted in organizing the workshop by Wayland Eheart, George Gross, Ed Herricks, and Jim Stubbins of UIUC, Starr, and Paul Grant, EPRI science fellow and specialist in high temperature superconductivity (HTS).



Continental SuperGrid

"What sparked my interest in the SuperGrid concept is that it provides a solution path to simultaneously address a number of our future energy challenges," explained Overbye. "These include our need to transition to more sustainable energy resources, and our need to efficiently transport large amounts of energy in an environmentally friendly manner."

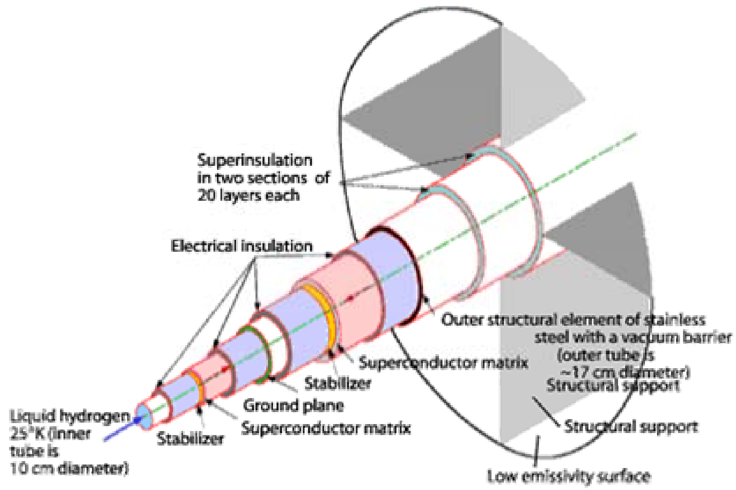
According to Grant, a former career research physicist at IBM, "the SuperGrid workshop may one day be regarded in hindsight as a seminal event, at which some bright and clever folks first began to think through the vision for an ideal system for delivering electricity and chemical energy simultaneously." Grant originated the idea of such an energy corridor for a futuristic SuperCity.

When first outlined at the 2001 ANS meeting in Reno, Nevada, Starr offered his "Continental SuperGrid" concept as an example of the kind of imaginative, "outside the box" solutions that were needed from the scientific and technical community to solve the problems of energy supply and environmental constraints anticipated with continued population growth over the next century. The past two centuries clearly demonstrate that unplanned, radical innovations can flow for as long as a century from science-stimulated R&D, such as the case with electricity, the telephone, petroleum-fueled engines, automobiles, airplanes, nuclear power, semiconductors, and biotechnology, Starr pointed out.

"All of these applied science products were initially 'outside the box' of their period, but they became powerful determinants of subsequent trends in technology, social structures, and lifestyles," Starr added. He pointed to the U.S. military's institution for preparing for the future—the Defense Advanced Research Projects Agency (DARPA), which spawned the Internet—as a model for fostering a spectrum of 'outside the box' R&D that could be emulated with respect to long-term energy strategy. "We can seek 'outside the box,' embryonic innovations, and push those that may be potential portals to new energy systems—even if only marginally feasible now," Starr suggested.

Energy superhighway

The SuperGrid nominally would be a 40-80 gigawatt (GW), high-efficiency underground energy corridor for real-time, coast-to-coast transfer of electricity as well as for powering electrolytic plants producing hydrogen, cooled to liquid form at 25 Kelvin (-248ºC/-414ºF). An even more evolved concept for the underground corridor could combine energy with transportation, in the form of high-speed electric trains or maglev systems, to spread the cost among multiple uses.



Design of an HTS DC transmission line in evacuated pipe

Liquid hydrogen would be pumped through the center of an evacuated energy pipe, both to cool the superconducting, direct current, low- or intermediate-voltage cable, which would traverse North America twice in a giant loop, and to serve as an initial, interstate pipeline for the future hydrogen-electricity energy economy. Each of about 40, 100-km long sections of the cable/pipeline would be joined by a 1-2 GW nuclear plant supplying electricity both to the SuperGrid and to hydrogen plants. High-temperature, gas-cooled reactor systems promise a particularly high-efficiency route to combined power and hydrogen production. Power electronic converters would connect the dc SuperGrid overlay at various points to existing, high-voltage alternating current transmission substations.

As conceived by Starr, the nuclear-powered SuperGrid would produce zero pollutant or greenhouse gas emissions and would have a relatively small ecological footprint, assuming underground construction, which also offers substantial security advantages. But as noted by several participants in the recent workshop, the decision to build underground is a critical determinant in the ultimate cost of the SuperGrid.

Old vision, new context

In his ANS presentation, Starr called the SuperGrid concept an old vision that dates to 1967, when IBM scientists first conceived a continental-scale transmission cable based on the low-temperature superconductor niobium-tin. But the high cost of niobium-tin wire at that time made such an application uneconomical. The more recent discovery of HTS materials operating in the temperature range of liquid nitrogen has led to advances with newer compounds, such as magnesium diboride (MgB_2) at 25 K, that hold promise for economical, large-scale power applications of superconductivity. Significant elements of the proposed SuperGrid, including superconducting cables and nuclear-powered co-production of electricity and hydrogen, have also been considered in previous engineering concepts.

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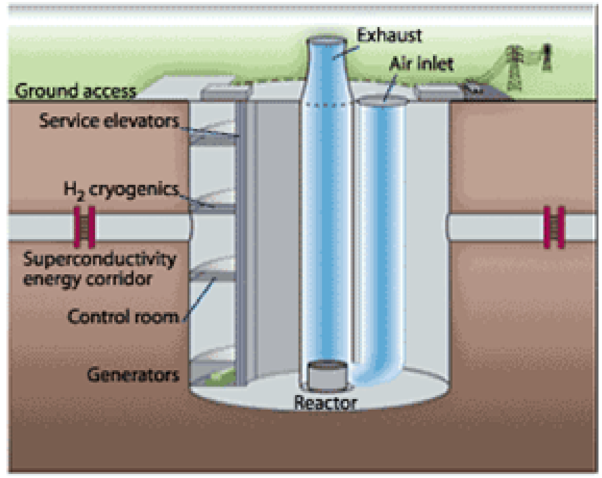
Neither the earlier scenarios nor any of the admittedly preliminary technical presentations at the recent workshop have yet turned up any clear "show-stoppers" for the Continental SuperGrid. Starr believes that such a system "would be a major contributor to our national security by connecting geographically dispersed continental fuel resources," namely the hydro power-based West with the coal-based East.

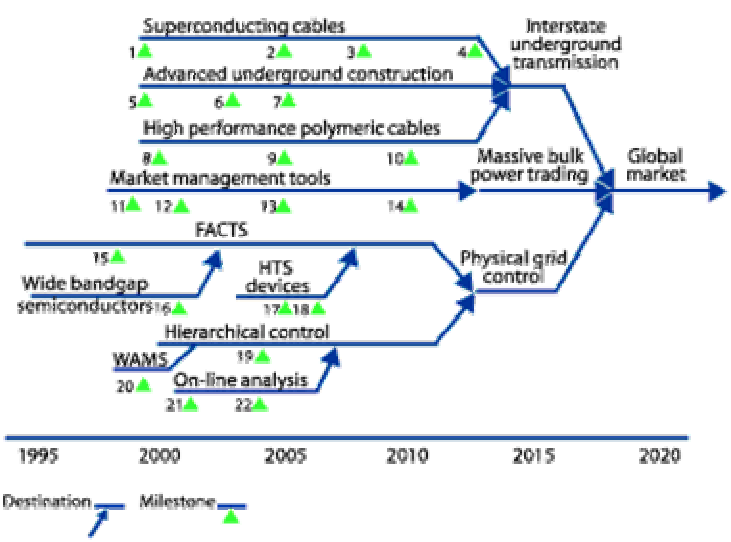


SuperGrid section

"If terrorism remains a risk, all major parts of the system could be underground," says Starr, though he concedes that aspect is not essential to the concept. "If one adds the vision of electrified transportation and fuel-cell electric autos, a picture of a futuristic all-electric energy system takes shape. If a hydrogen-fueled motor would gradually replace the internal combustion engine, the reduction of U.S. dependence on oil imports might radically change our foreign policies and commitments. Its long-term consequences might make the Continental SuperGrid a twenty-first century equivalent of the Panama Canal or the first transcontinental railroad."

Multi-decade effort

Starr envisions a long term, national project on the scale of the space missions that culminated in manned landings and exploration of the moon. "The Continental SuperGrid would be a professional challenge to both engineers and scientists for the whole century. It will take time to complete, but energy system maturation is measured in decades," he notes, underscoring the imperative of long-term thinking and planning.



Roadmap tree for power delivery technologies

At so early a conceptual stage, with virtually all important performance parameters and design features largely undetermined, estimates of the cost of the Continental SuperGrid are not yet very meaningful. Obviously, such a large system would entail a commensurately large, and presumably national, investment. Starr reckons on the order of $1 trillion at an average rate of $10 billion a year and a combination of public and private funding for a project that would take decades to complete.

Both direct and indirect benefits of a Continental SuperGrid need to be confirmed and quantified in order to create the kind of pervasive, deep national commitment that would be necessary to achieve and sustain long-term support for such a project. Starr sees

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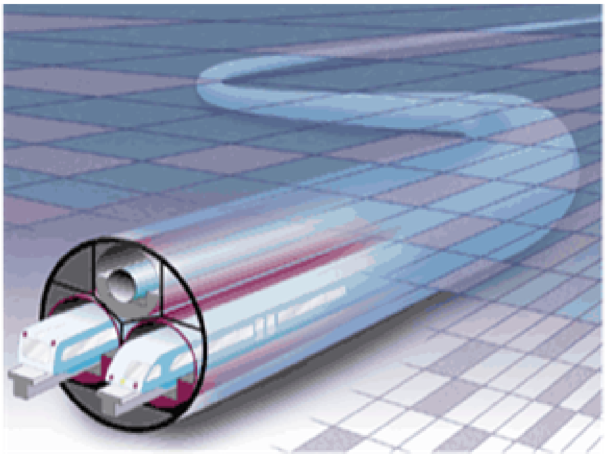
half a dozen direct benefits, not necessarily in descending order: a robust east-west electricity connection; a route to replacing imported oil as vehicles evolve to electricity and hydrogen; the nirvana vision of inexhaustible electricity and fuel energy; the stimulation toward such a total electricity-hydrogen energy system which would endure for centuries; development of technology for application on a continental scale; and the reaffirmation of national pride in technical capability and leadership, much like the Apollo Moon landings.

Studies of the potential economics of a Continental SuperGrid must also quantify and factor into account the key indirect benefits of such a system. These include the value to society of a storable, hydrogen-based clean fuel supply, which would greatly expand the potential for use of renewable energy resources. Then there is the potential for substantial flattening of utility load curves arising from the three-hour time-zone span through which bulk electricity could be moved in real time, enabling higher capacity utilization factors at every power plant in the nation. Finally, there is the less tangible, but no less significant, benefit of continuous reduction in oil imports as a percentage of total energy consumption.

Areas of focus

In a series of eight technical presentations and discussions at the Palo Alto workshop, experts outlined the likely major issues surrounding various aspects of the proposed SuperGrid. These range from possible design approaches, cost implications, environmental issues, and engineering challenges associated with the concept's superconducting, electrical, nuclear, electrolytic, and underground systems as well as overall system integration, control, and security. As neatly summarized by Starr in prefacing the talks, the SuperGrid concept appears to have no limiting scientific issues, "but numerous new engineering problems exist in every facet arising from the novelty, scale, and integration of the system."



Combined energy/transportation corridor

Starr said the workshop was primarily intended to explore the range of R&D that would be needed to design a short (perhaps 100 meters) pilot test section of the SuperGrid energy pipe, from which engineering data could be applied to a demonstration of a 100-kilometer section. EPRI's Grant suggested that near-term next steps should aim for producing a technical scoping study to support a proposal to the government and industry for the pilot-scale prototype. This would be followed in due course by a multi-megawatt scale experiment-demonstration and eventually a full-scale field demonstration of the concept over a relatively short distance to inform an ultimate decision to build a SuperGrid.

Further reading

Chauncey Starr's November 2001 ANS talk, "Energy Planning for the Next Century." Click "Download Attachment," above.

Related articles

Grant, Paul. "Energy for the City of the Future," *The Industrial Physicist*, Vol. 8, No. 1 (March/April 2002), pp. 22-25.

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