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A China-East Asia Efficient Renewable Supergrid

Executive Summary

The Supergrid represents a commitment to long-term qualitative change, a major step toward a harmonious, sustainable ecological civilization.

The Supergrid plan that follows will:

- Build the efficient renewable infrastructure and the businesses that construct, install, and maintain it;
- Dramatically reduce fossil fuel use and pollution and ecological damage;
- Slash operating fuel costs;
- Improve the competitive position of all manufacturers;
- Create many millions of jobs;
- Help facilitate the use of ecological consumption taxation to send price signals for sustainability throughout the economy;
- Help lead the world toward an effective climate change solution and the building of an ecological civilization.

This proposal considers how an Asian Supergrid can evolve:

First, from existing and under construction HVDC transmission lines serving part of China (Figure 1, Page 3).

Second, by interconnecting these power lines into a limited, but highly useful Supergrid. (Figure 2, Page 3).

Third, this logically can be developed further into a partial Asian Supergrid that extends to Northern China and Southeast Asia. (Figure 3, Page 4).

Fourth, partial Asian Supergrid can evolve over decades into an Asian Supergrid. Such a regional supergrid would eventually be connected to Europe and Africa. (Figure 4, Page 4).

A supergrid is the indispensable tool to make renewable energy practical, and it also enables sharing of other vital resources such as conventional generation, dispatchable hydropower, pumped storage, peaking turbines, new energy storage methods such as vehicle-to-grid, and spinning reserve. A supergrid enables wide area sharing of resources, and reduces the total generation capacity needed to fulfill energy needs; this factor alone can pay for a supergrid. China will likely set the world standards if it begins in earnest now: Europe is still dithering, the United States in largely immobile.

This proposal considers crucial matters in Supergrid development:

- First, the major steps needed to develop an Asian Supergrid (Pages 5-8);
- Second, discussion of key technical issues that must be addressed (Pages 9-11);
- Third, suggestions of topics and goals for a proposed meeting-conference in China in 2013 or 2014 between Chinese decision makers and experts and our team. (Pages 11-12).
- There are many technical trade-offs for an Asian Supergrid, but the map of a future supergrid ultimately depends on one technical decision: where are the existing or planned AC grid nodes to tie into? Any supergrid must powerfully link into the existing AC and DC infrastructure, which is well defined already. If the Supergrid goes from 20 nodes to one thousand, the mesh size of the grid gets much smaller, and direct ties to modest-size highly useful city micro-grids become feasible. We must consider with our Chinese partners the technical choices needed to optimize the Supergrid.
- Our team is led by Roger Faulkner, inventor of Elpipes and Ballistic Breakers and includes:

* Dr. Gregor Czisch whose pioneering work and analysis of a European Supergrid will help inform the rapid development of an Asian Supergrid;

* Joe Corbett, acting as technical envoy from Friends of the Supergrid;

* Peter Meisen, Executive Director and Founder of Global Energy Network Institute;

* Roy Morrison, Director of China International Working Groups.

- Our first meeting-conference we propose for late 2013 or 2014 is intended to:

1. Help clarify the current situation and available data;
2. Establish an orderly basis for our pursuit of agreed upon goals;
3. Form subgroups to pursue these tasks.

We suggest that the initial meeting-conference be held at the earliest convenience of our Chinese partners, as early as later in 2013 or in 2014.

We look forward to meeting and would be honored to work with our Chinese counterparts on these crucial questions.

A China-East Asia Efficient Renewable Supergrid

Introduction

by

Jennifer Wells, UC Berkeley and Roy Morrison, Director China International Working Groups

Global scientific consensus clearly holds that a climate mitigation plan including a major energy transition is necessary in every industrial society. That nations will benefit overall from transitioning in a proactive fashion is a truism, albeit one that is not fully, widely understood, at least within the USA. One region that has shown political leadership on this is the EU, which has signed binding 'climate and energy package' continent-wide legislation for a major energy transition by the year 2020.

China has taken many key steps on energy in recent years. There is currently an important political opening for China to advance quickly as a great leader in the savvy transition to the 'third industrial revolution.' An Asian Supergrid can serve as the core aspect of the overall Asian shift to a sane and sustainable energy and climate future. Chinese Premier Li Keqiang, elected by the 12th National People's Congress in 2013, supports the work of Jeremy Rifkin, the main consultant on the current energy transition plan in the EU.[1] Premier Li told his state scholars to pay close attention to Rifkin's book, *The Third Industrial Revolution: How Lateral Power is Transforming Energy, the Economy, and the World*, which has been the cornerstone of the ambitious EU laws for a major energy transition in this decade and beyond.

While efforts still are hampered in the USA, and in many places, climate mitigation leaders are of course pushing for change in the USA as well as in every region, as our hopes for the 21st century turn on major shifts by the greatest climate culprits, especially the USA, still the world's largest emitter per capita. Each nation that manages to advance will spur other countries to follow suit.

The Supergrid represents a commitment to long-term qualitative change, a major step toward a harmonious, sustainable ecological civilization. The Supergrid plan that follows will build the efficient renewable infrastructure and the businesses that construct, install, maintain it; dramatically reduce fossil fuel use and pollution and ecological damage; slash operating fuel costs; improve the competitive position of all manufacturers; create many millions of jobs; encourage the use of ecological consumption taxation to send price signals for sustainability throughout the economy; and last, but certainly not least, lead the world toward an effective climate change solution and the building of an ecological civilization.

There is an enormous multiplier effect that will follow the development of the Supergrid, not just in terms of economic activity on a two or three to one for every dollar invested, but a multiplier that will include gains from reduced costs of ecological damage, illness, loss of natural capital, and a great increase in social harmony. The efficient-renewable way is the harmonious way which will have by far the greatest long-term benefit.

Plans for A China-East Asia Efficient Renewable Supergrid

By Roger Faulkner (with input from Roy Morrison, Gregor Czisch)

I. Overview on Chinese/Asian Supergrid

A. An Asian Supergrid can evolve from existing and under construction HVDC transmission lines serving part of China (Figure I) by interconnecting these powerlines into a limited, but highly useful Supergrid (Figure 2). This design is not optimum, but it does incorporate the existing HVDC lines.

Figure 3 (next page) shows a conceptual partial Asian Supergrid that extends to Northern China and Southeast Asia. Figure 4 shows an Asian Supergrid that ties together many countries which have at times had difficult relationships; no details are shown, since if this happens it will be decades in the future, and will require political action. Such a regional supergrid would eventually be connected to Europe and Africa. China will likely set the world standards if it begins in earnest now: Europe is still dithering.

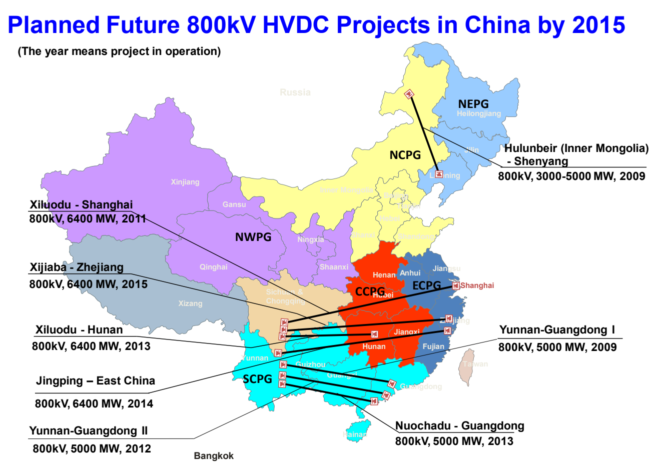


Figure 1: China's 800kV lines by 2015(source: ABB)

A robust supergrid creates a supergrid-wide market for electricity, enabling intermittent renewables to be far more practical because the aggregated reliability of many generators in different weather systems is better than for any individual wind or solar power generator.

A supergrid is the indispensable tool to make renewable energy practical, and it also enables sharing of other vital resources such as conventional generation, dispatchable hydropower, pumped storage, peaking turbines, new energy storage methods such as vehicle-to-grid, and spinning reserve. A supergrid, by enabling wide area sharing of resources, reduces the total generation capacity needed to fulfill energy needs; this factor alone can pay for a supergrid.

B. A quick look at the map in Figure 1 suggests a natural layout for the first phase of a

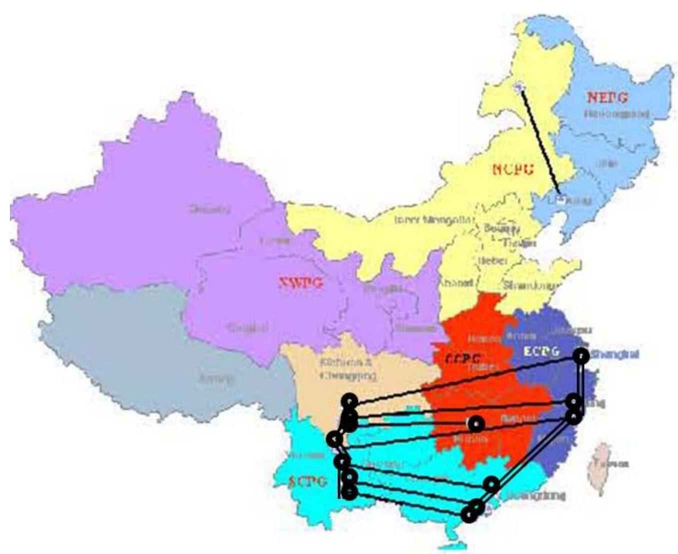
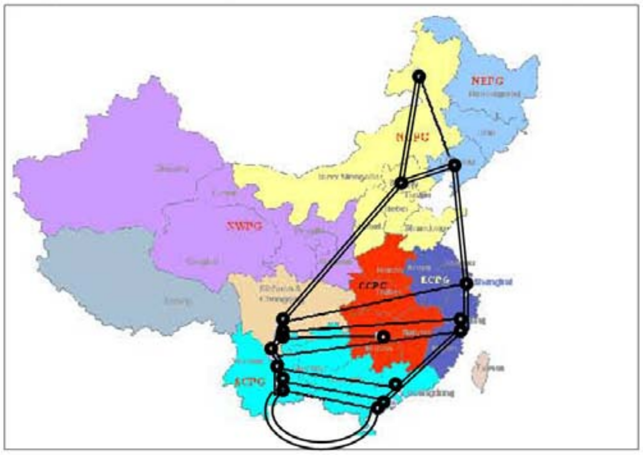


Figure 2: Phase 1: Southern China Supergrid

Chinese supergrid. There are seven existing or planned 800kV HVDC lines in southern China, and the region enclosed by these lines contains a large portion of the Chinese population and energy consumption; merely connecting the ends of these lines in the east, and the ends of these lines in the west would create a substantial supergrid covering the most industrial portion of China (Figure 2).

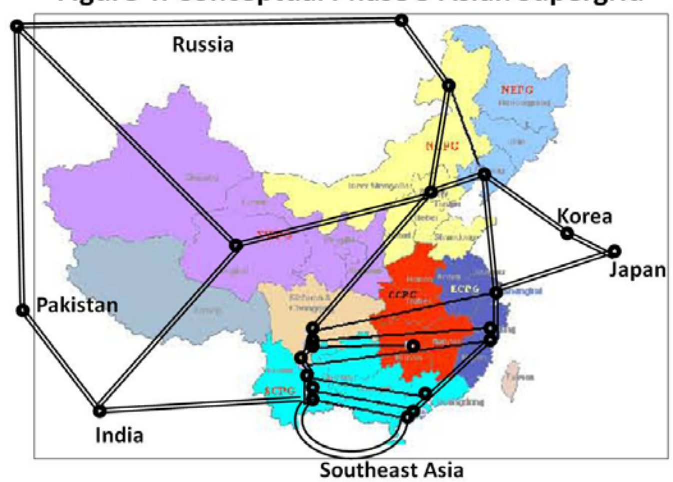
Figure 3: Conceptual Phase 2 Asian Supergrid



For economic efficiency, it is highly advantageous for the existing HVDC infrastructure to become the first part of the Asian Supergrid. That requires these eight 800kV HVDC lines that were built as point-to-point power lines based on line commutated converters "LCCs" must be incorporated into a multiple-terminal supergrid; substantial modifications of the converter stations may be needed, and the control logic must change. Insofar as not all of these lines are yet built, there may be an opportunity to modify the plans.

C. Any supergrid must powerfully link into the existing AC and DC infrastructure, which is well defined already.

Figure 4: Conceptual Phase 3 Asian Supergrid



D. Following is first, a list of major steps needed to develop an Asian Supergrid; second, some discussion of key technical issues that must be addressed; third suggestions of topics and goals for a proposed meeting-conference in China between Chinese decision makers and experts and our team led by myself, Roger Faulkner, Dr. Gregor Czisch whose pioneering work and analysis of a European Supergrid[11] will help inform the rapid development of an Asian Supergrid, Joe Corbett, acting as technical envoy from Friends of the Supergrid, Peter Meisen, Executive Director and Founder of Global Energy Network Institute, and Roy Morrison, Director of China International Working Groups.

The following list of major steps suggests the complexity of the work required. Our first meeting-conference is intended to first, help clarify the current situation and available data, second, establish an orderly basis for our pursuit of agreed upon goals, third, form subgroups to pursue these tasks. We suggest that the initial meeting-conference be held at the earliest convenience of our Chinese partners, as early as later in 2013 or in spring 2014.

II. A List of Major Steps Needed to Develop an Asian Supergrid.

- Characterization of the current grid: identification of all the current generators, energy storage sites, and transmission substations + anticipated new transmission lines & substations to bring in remote wind, solar, and renewable power. This should include phasor data and locations, including historical data showing system response during outages. This data surely exists already, but needs to be pulled into modeling software which may require some preliminary analysis.

- Analyze technical options on the highest level of supergrid operation, such as all current source converters (CSCs; this includes both line commutated converters "LCCs" and capacitor commutated converters "CCCs"), an all voltage source converter (VSC)-based system (obsoletes at least 28 large AC/DC converters, if all the planned 800kV Dc lines are built, or at least defines these converters as part of the AC grid), or a mix of both VSCs and CSCs (this is what I favor). Note that VSCs need faster circuit breakers than CSC converters.

- Consider all the options for HVDC circuit breakers and fault current limiters.

- Selection of a standard grid analysis tool for power flow and transient simulations (examples: Siemens PTI, PowerWorld, and DlgSILENT). Do the Northern and Southern Chinese Grids use the same tool? If so, then the tool they are using now should be adapted to the supergrid problem. This is a very complex system, and analysis is relatively inexpensive compared to hardware mistakes or the cost of improper control logic. This is such an important problem that I think it is justified to fund several different teams of analysts, using different software packages (for example Siemens PTI and PowerWorld software), because such complex software and such a complex problem can interact in unexpected ways. If the predictions of several different groups converge to the same optimum, then it is possible to have greater confidence in the result. This is in the domain of experts, and requires input from both outside and Chinese experts. (DlgSILENT PowerFactory can handle meshed, interconnected AC/DC grids. This includes power flow, stability, EMT, harmonics, etc. PowerFactory has recently been optimized for AC/DC grid simulation recently as it is being used in a number of projects related with the European DC super grid design. I am not sure about Siemens PTI and PowerWorld programs to model a mixed AC/DC supergrid.)

- Scenario analysis to identify how injection/removal of power at the AC grid node points will aid system stability. This is a "copper sheet" analysis on the HVDC side: no transmission constraints. The purpose is to identify which power nodes of the existing AC grid are high priority to interface with supergrid in terms of system stability.

- Combining the grid stabilization scenario analysis with renewable energy siting & power flow analysis to determine if new centralized energy storage development is needed (grid-scale energy storage includes conventional pumped storage, salt water pumped storage, compressed air energy storage, grid-scale batteries, and large dispatchable loads, like oxygen plants, as "virtual storage"), and where they should be located. (Distributed resources may be preferred, but already existing central storage & dispatchable hydro must be part of the model.)

- What to do about large scale pumped storage, including existing pumped storage + dispatchable hydro and new salt water pumped storage alternatives (Hitachi); this may also include pumped storage based on deep saline waters in Gobi Desert, for example).

- Identify new node points in a favored future grid for major renewable & energy storage projects (requires input from weather analysis).

- Lay out two alternative supergrids: one based on OHLs, max capacity = 9 GW, the other also containing elpipes, max capacity 30 GW. Consider right-of-way (ROW) direct costs; figure out how to monetize externalities (for example, overhead lines reduce the appeal of properties that may be miles away from the line, because views have been spoiled). Also consider security, reparability, technology risk, and reliability; attempt to monetize all these values.

- Route planning to tie into major regional hydro power projects (from Siberia to Vietnam & Myanmar in the south; it all depends on politics as well as engineering) consider connecting to India & Pakistan, and even all the way to Europe and Africa.

- Develop detailed estimate for the cost of proving 800kV elpipes for installation in the supergrid, and a detailed appraisal of reliability, based on modeling results with COMSOL Multiphysics.

- Develop ground-up cost analysis for several designs of elpipe. I already know that the lowest cost solution uses sodium as the main conductor; a 0.62 meter diameter steel pipe filled with sodium + an expansion bladder can transmit 60 GW with 1% loss per 1000 km. This is less expensive than aluminum extrusions, but also less flexible in terms of upgrading capacity. Compare all the feasible conductors: sodium, calcium, magnesium, and sodium on an equal resistance basis. Recommend which metal to use and where.

- Will the grid be single grounded or multiple grounded? What are the rules on a faulted bipole line operating for a while as a monopole with ground return? The rules on this are quite important for the economic cost of redundancy. I believe that use of ground return should be allowed until repairs are made (in the US, ground return is only allowed for half an hour).

- Define locations and capacities for different types of fault current limiters and circuit breakers in each supergrid scenario (this depends on the decisions made about VSCs versus CSCs in a complex way; and it makes a difference what KIND of VSC; full bridge versus half bridge; full bridge VSC can work as a DC circuit breaker as well, whereas half bridge VSCs will need to go through fast circuit breakers. Figure out which option is best economically and in terms of reliability and repairability.

- I think that CSCs + full bridge VSCs can "play together" well in a mixed technology supergrid. In combination with fast DC circuit breakers, I think half-bridge VSCs can also work. But this needs detailed modeling. One must consider that happens when a component fails: for example a half bridge VSC protected from the supergrid by a fast circuit breaker: what happens if the circuit breaker fails?

- Perform ground-up cost comparison of the different alternatives (requires getting quotes on lots of equipment). For this purpose, a simplified model that is abstracted from the real full model of the Chinese grid can be used, to save on computational time in analyzing each scenario (if this is needed). This simplified model must represent the entire coupled AC/DC system, and include representative small cities as well as major nodes.

- Use advanced methods for optimizing renewable generator locations through comprehensive weather data analysis. This will be similar to the analysis done recently by Alexander E. MacDonald of the US National Oceanic and Atmospheric Administration's Earth Science Laboratory. I have seen Sandy MacDonald's paper for Nature (not yet published), and it will be the best analysis of this issue to date. He is willing to cooperate on this aspect of the project, dependant on NOAA support. Meanwhile, Professor Sam Miller has provided some guidance, and is willing to be involved in this aspect of the project.

- System simulation modeling that includes integration and optimization of local generation and two-way energy flows at the level of residential units, industrial facilities, or community micro-grids:
    - rooftop solar PV
    - cogeneration and other biomass fuel-driven local generation (perhaps a tax on waste heat would favor cogeneration)
    - demand response: this ranges from home refrigerators and cooling units all the way up to aluminum smelters; excess industrial capacity allows the plants to be dispatched, much like gas turbines are today, to provide a valuable load balancing resource; this should be studied in full detail, since dispatchable capacity is intrinsically more efficient than energy storage (because there is always a "round-trip energy loss" with energy storage; this is missing with dispatchable load). Specific examples include:
        - cooling and thermal storage, including heat pumps that work at night;
        - oxygen and electrochemical plants (specialist team needed on aluminum smelters);
        - water pumping for irrigation.
    - local energy storage:
        - Distribution-level energy storage can improve reliability of supply for customers, and help avoid transmission upgrades, while providing ancillary services if properly interfaced with the grid.
        - Quantify the value to the grid for local storage to be grid-connected; is it enough to pay for reduced battery life? Figure out a fair incentive program that is win-win to incentivize the grid connection of local energy storage devices.
    - Electric vehicles and hybrid vehicles with their batteries as part of grid balancing and storage regime in Vehicle to Grid (V2G) and Vehicle to home (V2H) modes; Proper rate structure for fast fill electric recharging stations, reflecting real cost.
    - District heating via cogeneration (in cases where hot water can be stored) is both dispatchable generation and energy storage…capture this option in the modeling
    - New small dispatchable hydro (growing rapidly in China), needs regulatory framework: is it worth making these generators partially dispatchable? (Analysis needed).
    - Ice-maker heat pumps for off-peak cooling: how best to incentivize this?
- Consideration of solar geomagnetic storms: implications for HVDC grid layout (specialist team needed).

- A proper assessment of advanced technologies that have potentially a large impact on the future supergrid or energy supply. These are technologies "on the horizon" that should be considered because of their large potential impact:

  - LENR (low energy nuclear reactions): this is a "cold fusion" process that occurs between nickel nuclei and hydrogen that is dissolved in the nickel. Most scientists do not take it seriously, but it does not violate any thermodynamic law. I believe it is credible enough that it should be considered, as it would have a large impact on the shape of a future supergrid.

  - Ocean floor hot vents release enormous energy in a steady manner. Hot vent fields releasing ~ 30 GW (thermal) over a patch of ocean floor less than a km^2 have been documented. See http://www.marshallhydrothermal.com/ and US Patent 8,001,784, published August 23, 2011.

  - Cold cathode vacuum tubes have the potential to greatly reduce the cost and complexity of VSCs (see US patents 7,916,507 and 7,938,707 for example).

  - Modular fission energy, including ship- or barge mounted mobile power plants that use sea water for cooling. We need a review committee to thoroughly study complete fuel cycle issues involved in any new proposed fission technological system to assure it first, conforms fully to ecological norms and, second, prevent past mistakes of failing to develop a complete and ecologically sound and economical nuclear fuel cycle before proceeding with development.

The highly radioactive sent fuel pools still precariously hanging in the air at Fukushima indicate the grave dangers ecologically, economically, and politically of failing to develop a complete fuel cycle for any energy resource, non-renewable or renewable that includes all aspects of development including, extraction, construction, generation, transmission, disposal-reuse-decommissioning. An ecological civilization must be based on convergence on zero pollution, zero waste, and sustainable profit norms where the output of one process becomes the input for another. This must apply to all energy systems including solar, wind, hydro, coal, nuclear, and natural gas.

III. Discussion of Supergrid Issues

There are many trade-offs for an Asian Supergrid, but the map of a supergrid really depends on just this one decision: where are the existing or planned AC grid nodes to tie into? As one goes from say 20 nodes to one thousand, the mesh size of the supergrid gets much smaller, and direct ties to modest-size city micro-grids become feasible.

Indeed, Alstom Grid modeled IGBT-based voltage source AC/DC converter stations (VSCs) that are as small as 10 MW, but could be connected to an 800kV line. The smaller the connection points to the supergrid in terms of megawatts (MW) or gigawatts (GW) that are allowed, the more small cities would tie into the supergrid directly. I believe this would improve the ability of small cities to compete for jobs-creating businesses, and might help optimize the urbanization process in China.

A supergrid with many nodes would enable any city or local region that is connected to the supergrid to operate as an isolated micro-grid, both importing and exporting electrical energy through the supergrid; this would be highly stabilizing for the AC grid under emergency conditions, would tend to equalize the cost of power throughout China, and would also make it possible to remove many existing long-distance AC power lines. This long-term vision of a supergrid with perhaps a thousand AC/DC converters may be opposed by the China State grid (SGCC), as it potentially decreases their importance and could enable municipal utilities. This also is quite different than the vision that has so far been pursued by SGCC. This sort of DC supergrid with perhaps a thousand AC/DC converter stations is desirable eventually, but is not the logical place to begin. China already has an extensive 800kV DC investment (see Figure 1: 800kV lines to be complete by 2015; there are six more to be completed by 2018, if the entire SGCC plan is approved by the National Development and Reform Commission, NDRC). I take it as a given that this infrastructure must fit into the future supergrid. A quick look at the map in Figure 1 suggests a natural layout for the first phase of a Chinese supergrid, presuming that all of the first eight 800kV HVDC lines are completed. There are seven existing or planned 800kV HVDC lines in southern China, and the region enclosed by these lines contains a large portion of the Chinese population and energy consumption; merely connecting the ends of these lines in the east, and the ends of these lines in the west would create a substantial supergrid covering the most industrial portion of China. For economic efficiency, it is highly advantageous for the existing HVDC infrastructure to become the first part of the Asian Supergrid. That requires these eight 800kV HVDC lines that were built as point-to-point power lines based on line commutated converters "LCCs" must be incorporated into a multiple-terminal supergrid; substantial modifications of the converter stations may be needed. At the very least, changes in the way the converters are controlled will be necessary. But pulling these lines in to the first phases of the supergrid gives a huge financial and technical head start for the whole project.

The Southern Chinese Supergrid of Figure 2 shows a logical first phase Chinese Supergrid, based on maximum use of existing and planned 800kV assets, with minimal distance for new power lines. This is based on converting the seven 800kV HVDC lines in Southern China to multi-terminal HVDC operation, while connecting the eastern and western AC/DC converters with new north-south high capacity HVDC lines (the double black lines in Figure 2), which could be a pair of elpipes or multiple overhead lines. Not shown in Figure 2 are the multitude of new IGBT-based AC-DC VSC converters that could be placed as "small" (up to hundreds of MW) power taps along these 800kV DC overhead lines. This would require a mixed grid that accommodates both VSCs for small power taps and either LCCs or capacitor-commutated converters (CCCs) for large power taps. Both LCCs and CCCs rely on thyristors for switching, and are slightly more efficient than VSCs based on IGBT transistors; both LCCs and CCCs can be termed "current source converters" (CSCs) and we have used that terminology herein. IGBTs are improving faster than thyristors, and they have advantages for controlling "reactive power" and for re-starting after a black-out. The mixed technology grid concept gets into very specialized knowledge, where I personally am not an authority; it does appear desirable though to accommodate several different technologies in future supergrids; Section II of Franck's excellent review of HVDC circuit breakers[iii] provides a good review of the features of thyristor-based CSC meshed grids versus IGBT-based VSC meshed grids; both have advantages & disadvantages but to maximize the value of the prior investments in Chinese HVDC, it would be best to design a supergrid where the existing 800kV CSC converter stations can be used. This does set limitations on the designs of VSCs if they must fit into such a mixed grid.

There are several high-level design decisions that need to be made early in the supergrid project; for example what is the design voltage, and what major power nodes will be tied in? In effect, China has already set the new world standard voltage for HVDC at 800kV, by having committed to 13 major 800kV DC lines, the first 8 of which are shown in Figure 1. At present, only overhead lines can work at 800kV, and those are capable up to a maximum of about 9 GW per line (7.2 GW is the current maximum). Many more 800kV lines will be required to implement the final supergrid if the maximum capacity is 9 GW. There are underground high capacity alternatives that could be developed including my invention elpipes[iv] and gas insulated lines[v]; barge-laid cables will also eventually be capable to 800kV (600 kV is the current limit), but they are unlikely to ever reach the capacity of today's overhead lines, because of fundamental limitations that are based on the fact that cables must be flexible enough to be wrapped on a reel for transport, and because of the difficulty of shedding waste heat through the insulation layer. (Truck or rail-transportable cables have less capacity than ship-laid cables because the reels must be smaller.) Elpipes can definitely go up to a 10 GW transmission capacity per line as passively cooled power lines[vi], and up to 30 GW with special burial techniques or installation at the surface, and higher still with active cooling. Underground installation preserves views and land values, and makes the lines more secure. Compared to cables, elpipes are far more repairable (I have reproduced one of my papers on elpipes as the basis for an Asian Supergrid[vii] as Appendix A.)

A robust supergrid creates a supergrid-wide market for electricity, and enables intermittent renewables to be far more practical because the aggregated reliability of many generators in different weather systems is better than for any individual wind or solar power generator. A supergrid is the indispensable tool to make renewable energy practical, and it also enables sharing of other vital resources such as conventional generation, dispatchable hydropower, pumped storage, peaking turbines, new energy storage methods such as vehicle-to-grid, and spinning reserve. Because a supergrid enables wide area sharing of resources, it reduces the total generation capacity needed to fulfill energy needs; this factor alone can pay for a supergrid.

The shape of a supergrid is defined by the long-term and short-term list of points on the AC grid that are to be tied into the supergrid by AC/DC converters, but such a decision should be based on detailed analysis of the existing grid. I assume that the Northern China Grid and Southern China Grid have both had many detailed power flow analyses over the years. Modeling of a supergrid is quite complicated because it will strongly tie together at least the Northern and Southern Chinese grids, and will also ideally tie into other regional grids. That is already happening to a small extent with the planned 800kV DC line from Irkutsk to Beijing, and insofar as the goal of a supergrid is in part to enable a transition to a renewable or at least low carbon energy future, the bigger is the grid the better it will be for making renewable energy reliable. Figure 3 shows a conceptual partial Asian Supergrid that extends to Northern China and Southeast Asia. Figure 4 shows an Asian Supergrid that ties together many countries which have at times had difficult relationships; no details are shown, since if this happens it will be decades in the future. Such a regional supergrid would eventually be connected to Europe and Africa. China will likely set the world standards if it begins in earnest now: Europe is still dithering.

Tasks and Decisions

I am not aware of the current state of planning for a supergrid in China, so I apologize if some of this seems naïve. There is no question that technical expertise exists in China that is on a par with the leaders of the world industry (ABB, Siemens, Alstom Grid, and Mitsubishi), and I do not claim to have that sort of detailed knowledge. On the other hand, I have been able to contribute an important piece of the puzzle for a future supergrid (elpipes), and I am one of a handful of people in the world who has made the supergrid their #1 issue; others include Peter Meisen of Global Energy Network Institute (www.geni.org), Gregor Czisch of transnational renewables, and Eddie O'Connor, who founded Friends of the Supergrid and Mainstream Renewable Power. And of course, ABB and the other HVDC majors have people who have been studying the supergrid concept for many years.

What I think sets the group of advisers that we propose to bring to Beijing to discuss the Asian Supergrid apart is that they are independent, and are looking for the best solution, rather than being in the employ of for-profit companies that have an economic stake in what form the Asian Supergrid takes. You can bet that companies like ABB and Siemens will be advocates for technical approaches that maximize their profit potential, even if it is not the best solution for China. An example of this thinking is that many of those who believe the supergrid should be based strictly on VSCs would not incorporate the 13 or so 800kV CSC-based DC lines into the supergrid at all, other than indirectly, as a part of the existing AC grid.

The language barrier is a daunting problem, and there are not enough Western experts who speak Chinese.

I suggest a few steps and topics to increase understanding at a first working meeting in China:

1. Having Gregor Czisch present his research on the European Supergrid in the first kickoff meeting of the working group in China.

   I think Gregor should make two presentations: one for technical experts near the beginning of the conference; and one for policy leaders on the last day of the kickoff meeting conference.

   Gregor holds strong opinions that VSCs are not even needed for a supergrid, and he can back these opinions up. Though I do not fully agree with him, I think his presentation would engender a great and productive discussion among the technical experts as to the logical basis for the supergrid.

   Translation of Gregor Czisch's Ph.D dissertation on the European Supergrid into Chinese; hopefully with some haste; perhaps even before the kickoff meeting would be helpful. But this need not and should not delay our work.

2. Presentations by scientists at South China Grid and CEPRI about their perspectives on a supergrid, and their work so far.
3. I would like to present my ideas about moving major supergrid links underground via elpipes, and discuss why I advocate a "mixed technology" supergrid that includes both CSCs for high power nodes and VSCs for low power nodes (<~400MW).
4. Super Gird working sub-groups formed to address the major issues identified and a plan developed.
5. Last day of the conference devoted to policy issues and developing an action plan.

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ii Gregor Czisch’s dissertation on powering Europe with renewable energy has been translated into English as a book “Scenarios for a Future Electricity Supply,” published by The Institution of Engineering and Technology, ISBN 978-84919-156-2; the original German language dissertation is available as a free download from Kassel University (http://www.agenda21-treffpunkt.de/doku/sign.php?sg=Czisch-2006)

iii Christian M. Franck, “HVDC Circuit Breakers: A Review Identifying Future Research Needs,” IEEE TRANSACTIONS ON POWER DELIVERY 2011

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