High voltage direct current supergrids

Climate scientists tell us that we need urgently to reduce the concentration of greenhouse gases in the atmosphere. To do so, we have to emit less carbon dioxide than the planet absorbs. That means getting off fossil fuels fast, and saving our forests. Given the rising price of oil, gas and coal, a switch to sun, wind and water could also save us a lot of money. Yet many people assume that renewables can only supply a modest part of the world's energy in the foreseeable future. In fact, if we approach the problem on a regional scale, we could switch most of the world to clean energy within two decades or so.

If we could capture just one hour's worth of the solar radiation that reaches the Earth any year, it would power the entire world economy. There are many ways to capture that energy: directly through solar panels and solar thermal power stations, and indirectly through wind and hydro turbines which use the movements of wind and water that are driven by the sun. But to power the economy largely from clean energy, we need to be able to bring solar, wind, wave, hydro or geothermal energy to everyone from wherever these sources are abundant.

A "supergrid" linking countries within each region of the world, or simply linking all parts of large nations, using high voltage direct current (HVDC) cables, can enable us to do this. HVDC lines lose very little energy in long-distance transmission, and unlike traditional Alternating Current (AC) power lines, they work well underwater. Cheap solar power could be fed in from solar thermal power stations in the deserts and drylands. Wind power can be fed in from windy coastlines and plains, and so on.

Regional supergrids also bring another important benefit. Wind power only works when the wind is blowing, and is therefore variable. But if we harness wind power over a wide area, the supply is much more stable. When the wind drops in one place, it is still blowing in another. Furthermore, some of the wind energy generated can be stored by pumping water into uphill reservoirs in our mountain ranges. When the wind drops, 75% of that energy can be returned to the grid, to ensure 100% reliable supply.

Likewise, photovoltaic panels only work during the daytime. If some of the energy they generate can be stored in the mountains, it can be used at night to ensure a steady supply 24 hours a day.

HVDC cables currently connect the British and French national grids under the English Channel, and connect Scandinavia, Northern Germany and the Netherlands. They lose only about 3% of the electricity over every 1,000 kilometers.

The DC grid between Scandinavia and the Netherlands is already used to store surplus power until it is needed by pumping water uphill in Norwegian hydroelectric plants.

Traditional low voltage AC lines lose large amounts of electricity in long-distance transmission, because electricity is dissipated as heat due to the resistance of the conductors. High voltage lines require less surface area for transmission, which results in less heat being created, and therefore less transmission loss. Nonetheless, High Voltage Alternating Current (HVAC) lines remain inefficient over long distances.

Despite this, since AC power can easily be transformed from low to high voltage for transmission, and then converted back again for local use, AC has generally been the first choice for most utilities and transmission companies. However, with the use of modern static inverters, it is now possible to invert AC to DC and then back again with very high efficiency – making HVDC increasingly attractive. When transporting energy over large distances, the savings made due to the increased efficiency of HVDC lines more than offset the additional cost of the inverters.

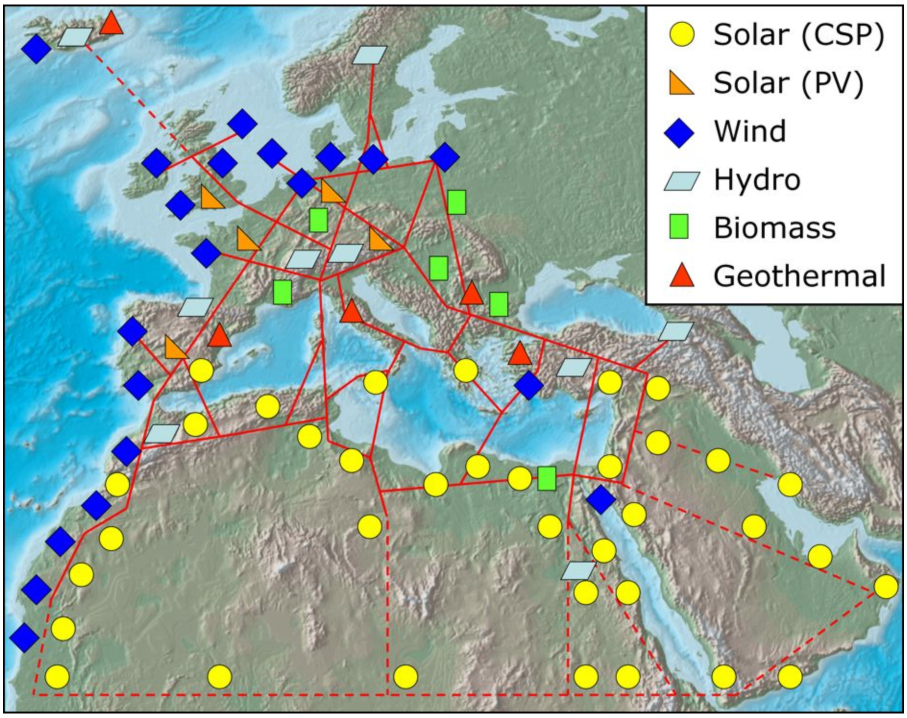
Originally developed in the 1930s, HVDC lines are now a mature and reliable technology ideally suited to transporting energy over long distances. With modern HVDC lines, for example, solar or wind electricity could be imported from North Africa to northern Europe with only about 10% loss of power.

An HVDC converter station

HVDC lines can be used to connect remote generating centres, or to connect large HVAC grids that are out of sync with each other, such as connecting national grids that run on different frequencies, for example. Increasing the interconnections between neighbouring national grids has the added benefit of increasing the stability of electricity supply across the region, even before new energy sources are added to the mix.

While HVDC lines are already economically attractive when used over long distances, costs are likely to decrease even further as the cost of static inverters and other hardware comes down.

Two studies for the German government carried out by the German Aerospace Centre (the DLR), examined in detail the possibility of creating a regional supergrid connecting the entire Europe-Mediterranean region. They proposed the construction of a system that would look something like this:



The study says:

> As a spin-off effect of this development, the import of solar electricity from the Middle East and North Africa (MENA) will become an attractive diversification of the European power generation portfolio. Solar and wind energy, hydropower, geothermal power and biomass will be generated in regions of best performance and abundance, distributed all over Europe and MENA through a highly efficient HVDC grid on the upper voltage level, and finally delivered to the consumers by the conventional interconnected AC grid on the lower voltage level. Analogue to the network of interstate highways, a future HVDC grid will have a low number of inlets and outlets to the conventional AC system as it will primarily serve long distance transfer, while the AC grid will have a function analogue to country roads and city streets. Only 10% of the generated electricity will be lost by HVDC transmission from MENA to Europe over 3000 km distance. In 2050, twenty power lines with 5000 MW capacity each could provide about 15 % of the European electricity demand by solar imports, motivated by their low cost of around 5 €-cent/kwh (not accounting for further cost reduction by carbon credits) and their high flexibility for base-, intermediate- and peak load operation.

Similar supergrids could play an equally valuable role in other parts of the world, either linking a number of countries or within large nations such as Australia, Brazil, China, India, Indonesia, Russia or the United States. In North America, in Mexico and Central America, in Southern, Central, West or East Africa, or in South America, gathering and storing renewable energy over a wider area would make it possible to supply any amount of clean energy. Linking Japan, Korea, the Philippines and Taiwan would help to ensure a steady supply of wind energy.

James Hansen, Director of NASA's Goddard Institute for Space Studies and perhaps the world's best known climate scientist, recently described a supergrid for the US as “the single most critical action” for decreasing carbon emissions. In testimony to the US Congress, he went on to say:

> The next President must make a national low-loss electric grid an imperative. It will allow dispersed renewable energies to supplant fossil fuels for power generation. Technology exists for direct-current high-voltage buried transmission lines. Trunk lines can be completed in less than a decade and expanded analogous to interstate highways.

In short, building long-distance transmission infrastructure is a crucial part of any serious effort to switch the world to renewable energy. Once we remove the barriers to energy transmission from areas of abundance to areas of high consumption, and include the potential for pumped-storage in hill and mountain country, we can clearly generate as much energy as we need in any part of the world. If we need to increase supply, we simply put more mirrors in the desert, or install more wind turbines, or more solar panels on rooftops, or more geothermal boreholes. In each part of the world, it is simply a matter of estimating what mix of these sources will deliver the energy required at the least cost, given the resources available.