SUPERGRID

Is a vast undersea grid bringing wind-generated electricity from the North Sea to Europe a feasible proposition or an overpriced fantasy?

BY COLIN MACILWAIN

North Sea energy used to mean oil and gas. Today, production of both is waning, and the rough weather that challenged the drillers has itself become a resource. In a speech last September, Alex Salmond, Scotland's first minister, estimated that the winds and waves lashing the Scottish coast could generate seven times more energy than Scotland consumes. Other countries around the North Sea hold similar potential. The problem is getting all that power from the windy edge of Europe to its populous, energy-hungry heart — the region roughly bounded by London, Berlin and Milan. "What we need above all is an efficient transmission system," Salmond says. "And the most efficient one would be a grid built across the North Sea."

On 3 December, ten northern European nations are expected to sign a memorandum of understanding spelling out how they'll build an undersea electricity 'supergrid'. The project is a major engineering and political challenge, comparable in scope, scale and ambition to the rush for oil and gas in the same waters 40 years ago. Thousands of kilometres of undersea cable would be laid, at a cost of at least €1 million (US$1.4 million) per kilometre. Unlike onshore grids, which operate on alternating current (a.c.), the subsea grid would use direct current (d.c.) and would therefore require new types of offshore and onshore substations, control systems, converters and circuit breakers in a set of projects costing billions of dollars (see 'Wiring up Europe'). The whole project has an estimated €20-billion price tag.

An even more ambitious project, called Desertec, is planned to bestride the Mediterranean Sea and North Africa, pumping electricity generated by wind and solar power from the Sahara to Europe's cities. And a group of US investors led by Google released plans in October for an undersea grid in the North Atlantic that would ship power from offshore wind farms to the eastern seaboard of the United States. But the North Sea supergrid is closest of the three to becoming reality.

Momentum for the project comes from two main sources. A 2003 European directive, updated last year, demands that European Union (EU) states open up their electricity markets to competition with each other, which will require stronger connections between their national grids. And the EU has pledged to cut carbon emissions by 20% from 1990 levels by 2020, which will require a 35% cut in emissions from electricity generation and a vast expansion of renewables. "Without these grids, there will be no meeting of emissions targets in Europe," says Georg Adamowitsch, the EU coordinator for offshore grids in northern Europe.

Wind energy is already a mainstay of clean power generation in Europe, with 74 gigawatts of capacity installed so far, and another 136 GW anticipated by 2020, according to projections released by the European Commission (EC) in August. (By comparison, just 14 GW of new nuclear generating capacity is likely to be added by then.) Analysts expect much of this capacity to be installed offshore, because it is windier and easier to get planning permission. The need to connect up those offshore farms — and future wave- and tidal-power farms — to the mainland is the first reason that a North Sea grid is inevitable, analysts say.

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The second is that it would permit the large-scale storage of electricity in the only type of 'battery' so far developed for that purpose: pumped-storage hydroelectric dams, mostly located in Norway. Wind and other renewable energy sources are intermittent, but by using the energy to pump water uphill and recapturing power as the water flows down again, these dams can store electricity at more than 85% efficiency, evening out fluctuations in supply.

The attractiveness of such storage helped to spur the completion in 2009 of a 'point-to-point' high-voltage direct-current (HVDC) link between Norway and the Netherlands, which allows surplus power from the low-lying Netherlands to be stored in the Norwegian fjords, and brought back when needed. But on their own, such links cannot tap into offshore power sources, and cannot integrate the multiple electricity markets bordering the North Sea: only an undersea grid would do that. Last December, nine EU nations (the United Kingdom, Ireland, Sweden, Denmark, France, Germany, the Netherlands, Belgium and Luxembourg), joined later by Norway, agreed to start an initiative to get such a grid built, resulting in this week's memorandum. At the same time, the EC is supporting researchers who are looking in detail at the costs and benefits of different grid configurations — and at the technical challenges of taking a power grid offshore.

EDISON RULES

A crank called Thomas Edison once expected that most electricity would move around as d.c. But almost all transmission has turned out to use a.c. instead, chiefly because it can easily be transformed from high-voltage transmission lines down to the safe 120 volts or the somewhat less safe 240 volts in the home. It is also easy to isolate parts of an a.c. grid, to deal with faults and do routine maintenance, using massive mechanical circuit breakers that slam open just as the sine wave of the alternating current hits zero.

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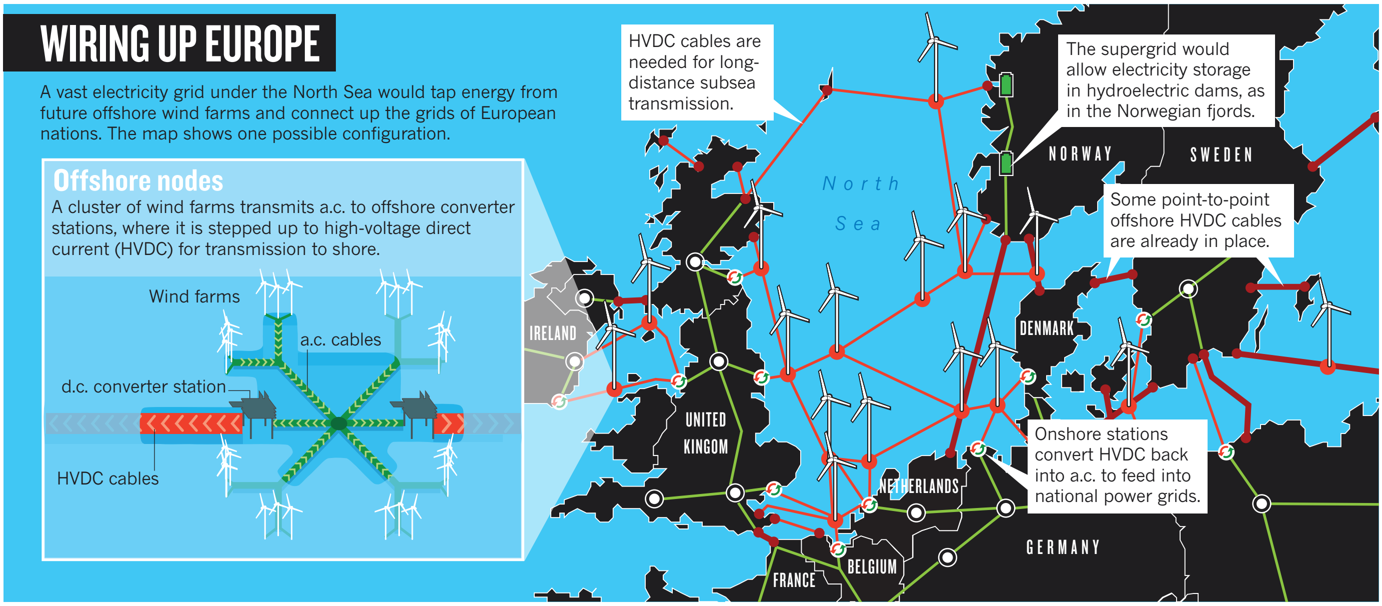

Alternating current is no good for underground or subsea transmission over more than about 80 kilometres, however, because of heavy reactive losses which arise when the aluminium or copper conductor is buried. In effect, the cable and the surrounding earth form a capacitor, draining power from the a.c. lines, and rendering them useless over long distances. So a subsea grid has to be d.c. — posing a challenge for electrical engineers who lack the technological tools they have developed for a.c. power. "There's no such thing currently as circuit breakers for high-voltage d.c.," says Paul Neilson, transmission development manager at Scottish and Southern Energy in Perth, UK. "If there was a fault in the grid, all the energy would pour straight to it, a bit like decompression in an aeroplane. You need to be able to isolate it, automatically, in milliseconds."

BREAKING THE CIRCUIT

Electrical engineers in industry and academia are addressing this and other challenges through a three-year €60-million programme called TWENTIES, a consortium of 26 academic and industrial partners supported by the EC. One TWENTIES project, led by Energinet, an agency of the Danish Climate and Energy Ministry, is seeking to design a control system that would react when storms approach. Electrical grids are designed to cope with some degree of perturbation — but a storm could make it necessary to rapidly shut down a whole cluster of wind farms. "This may develop into a system security problem, if we don't improve the present storm control algorithms," says Poul Sørensen, an electrical engineer and project partner at the Risø National Laboratory in Roskilde. "One of the solutions we're looking at is to control the turbines more, and ramp them down slowly."

It's not practical to roll out a pre-designed grid like a roll of linoleum.

Another TWENTIES project, led by transmission company RTE in France, will study the optimal configuration for a d.c. grid and test a prototype d.c. circuit breaker. Major electrical-engineering suppliers, including ABB, based in Zurich, Switzerland, and Siemens, based in Erlangen, Germany, are developing such circuit breakers, although they are not revealing details of their designs.

Dragan Jovcic, an electrical engineer at the University of Aberdeen, says that existing approaches are unlikely to yield appropriate d.c. circuit breakers, being either too slow in responding to faults, or "very high cost". Jovcic has developed and patented a new type of d.c.–d.c. converter, which involves a set of inductors and capacitors linked in a resonant circuit to step up d.c. voltage. This type of converter also doubles as a d.c. circuit breaker and, says Jovcic, could weigh five times less than some other designs that rely on conversion to a.c. and back again, because it lacks the heavy iron core transformers. Extra weight is expensive because the connection points will be mounted on platforms offshore, for maintenance access (see D. Jovcic and B. T. Ooi *IEEE Trans. Power Deliv.* **25**, 2535–2543; 2010).

In October, Jovcic won an award from the European Research Council to design new models for high-voltage d.c. converters. These have to work on microsecond timescales, rather than the millisecond timescales at which a.c. oscillates. The new model will also be able to deal with the complicated configurations in a substation that connects four or five high-voltage d.c. lines together.

But solving the technical problems will only go part-way to getting a North Sea supergrid built. The capital costs of laying grids offshore are immense. A report published in July by the EU-funded research project OffshoreGrid, based in Brussels (see go.nature.com/cssy3s), envisages, for example, that €32 billion will be invested in offshore interconnectors in northern Europe by 2020 and a further €58 billion by 2030, if wind farms are connected up individually. It suggests that €15 billion could be shaved from this if wind farms were clustered. On top of this, the opening up of electricity markets will require wholesale legal and regulatory change: at present, for example, generating companies that receive subsidies for feeding renewable energy into a German grid receive nothing if they supply power elsewhere.

Not all European countries are equally enthusiastic about the North Sea supergrid. The United Kingdom has embraced the project because it needs offshore wind capacity to meet its carbon-emissions targets. Ireland, Norway and Scotland are especially keen, because they want to build new industries that manufacture and service offshore wind and wave farms. But despite their stated intention to sign the memorandum of understanding, the French and German governments have been lukewarm, admit grid advocates, with Germany pushing instead for Desertec, which is led by German companies.

The North Sea supergrid is technically more radical than this and other proposals, and could prove almost as politically taxing — despite the theoretical commitment of EU states to get it built. And however much high-level planning goes on, the supergrid's evolution is likely to be messy, much like that of a national highway system. "Things will happen incrementally," says Neilson. "It's not practical to roll out a pre-designed grid like a roll of linoleum." ■ SEE EDITORIAL P.599

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