SOLUTION IV

Matching renewable power generation and demand over large distances with supergrids

Figure: Synergies between innovations for matching renewable energy generation and demand using supergrids

As an **enabling infrastructure**, a supergrid is a large transmission network that makes it possible to trade high volumes of electricity across great distances. Supergrids are high-voltage direct current (HVDC) power lines (greater than or equal to 500 kV) or ultra-high-voltage direct current (UHV DC) power lines (greater than or equal to 800 kV). DC technology is preferred for developing supergrids because the transmission of power over large distances using AC technology is challenging, as AC systems require reactive power support and also have 30% to 40% higher line losses than DC technology (Siemens, 2018). Supergrid networks are typically built independent of the conventional AC grid and can interact with the existing AC grid at a few or multiple nodes.

Resource-rich areas, such as geographies with high irradiation and/or wind speed, may not necessarily be in close proximity to major demand centres such as cities or industrial hubs. Supergrids are one of the solutions being explored for transporting large volumes of electricity over long distances, from resource-rich locations to demand centres. For instance, wind energy potential is much higher at offshore sites than at onshore sites (Cuffari, 2018). Geographies with high solar irradiation such as those in the African desert may be optimal for deploying solar PV generation, but may not have a high local energy demand.

AC grids prevail because DC lines so far can be used only for point-to-point transmission and do not easily form the integrated grid networks that exist today. Research and development by equipment manufacturers has been intense over the past few years for DC breakers, and products have become available that would make a meshed DC grid feasible. The EU-Project PROMOTioN seeks to address challenges to the development of meshed HVDC offshore transmission grids (PROMOTioN, 2018).

The longer the distance and the higher the power to be transmitted, the more HVDC can be economically beneficial. DC grids are potentially more efficient at connecting sources of renewable energy with demand areas located at great distance, making it possible to average out local variations in wind and solar power while bringing power to areas without much sunshine or wind.

Solar power from the Sahara could power cloudy Germany, and wind power from all over Europe could keep the lights on at night. This would enable the integration of renewable power on a bulk scale. *(Key innovation: Supergrids)*

The Internet of Things, artificial intelligence and big data can support the operation of such grids. *(Key innovations: Internet of Things; Artificial intelligence and big data)*

- Regarding **market design**, because supergrids usually enable the trading of electricity between different power systems, the harmonisation of trading rules and the creation of some type of regional market is needed. *(Key innovation: Regional markets)*

576 MW
OFFSHORE WIND INTEGRATED in the power system with HVDC line

770 KM
HVDC connection line to balance wind production and demand between UK and DK

Impact on renewable energy integration:

- **576 MW of offshore clean energy integrated in the German power system through an HVDC line.**

As a part of the German Energiewende, the HVDC HelWin1 was built to integrate offshore wind power with the German grid. It is a 130-kilometre-long, 250 kV HVDC transmission line owned and operated by TenneT to transmit power from Nordsee Ost and Meerwind Süd / Ost wind parks. It can transmit up to 576 MW of clean energy to more than 700 000 consumers (Offshorewind.biz, 2015).

- **Increased use of renewable energy and greater system reliability by connecting the UK and Denmark.**

Viking Link is a proposed offshore and onshore 1 400 MW HVDC link between the UK and Denmark, including submarine and underground cables. The 770-kilometre-long transmission line is expected to enable effective use of renewable energy and increase security of energy supply for both countries. Denmark is aiming for half of the electricity it uses to come from wind power by 2020 (Viking Link, 2018).

Being able to balance wind production and demand across countries and closer integration between electricity systems are vital for the efficient transition towards a green energy future. The project is expected to be operational by 2022 (Viking Link, 2018).

IMPLEMENTED SOLUTION

North Sea Wind Power Hub consortium

The North Sea Wind Power Hub is a proposed energy island complex to be built in the middle of the North Sea as part of a European system for sustainable electricity. The deployment estimates range from 70 GW to 150 GW of offshore wind in the North Sea in 2040 (NSWPH, 2018). A Power Link Island will be able to accommodate a large number of links to wind turbines and/or offshore wind farms and facilitate the distribution and transmission of wind-generated electricity via DC connections to the North Sea countries (the Netherlands, Belgium, the UK, Norway, Germany and Denmark). These connections – so-called Wind Connectors – will not only transmit wind power from the wind farms to the hub/island, but simultaneously serve as interconnectors between the energy markets of these countries, enabling them to trade electricity across their borders (TenneT, 2017a).

A consortium of transmission system operators is responsible for the initiative: TenneT Netherlands, TenneT Germany and Energinet from Denmark. In September 2017 the Dutch gas transmission system operator Gasunie joined the initiative with its interest in the power-to-hydrogen economy: wind power also can be converted to sustainable hydrogen for large-scale transport to shore or for storage or buffering purposes (TenneT, 2017a).

Raigarh-Pugalur 800 kV UHV DC project in India

The Powergrid Corporation of India Limited (PGCIL), a transmission network operator in India, has teamed up with ABB to build an 800 kV UHV DC network from Raipur in central India to Pugalur in southern India. Once constructed, this transmission line will be among the world's longest, at 1 830 kilometres. Serving about 80 million people, the project will transmit wind power from southern India to the demand centres in the north during periods of excess wind generation, and will transmit thermal power from the north to the south when wind generation is low (ABB, 2017).

SUMMARY TABLE: BENEFITS AND COSTS OF MATCHING RENEWABLE ENERGY GENERATION AND DEMAND OVER LARGE DISTANCES WITH SUPERGRIDS

Matching renewable energy generation and demand over large distances with supergrids	Low	Moderate	High	Very high
BENEFIT				
Potential increase in system flexibility				●
Flexibility needs addressed	from seconds to weeks (not as exclusive solution but as a valuable contribution)			
COST and COMPLEXITY				
Technology and infrastructure costs				● cost of the supergrid
Required changes in the regulation framework				● agreed regulatory frameworks between the connected regions
Required changes in the role of actors			●	
Other challenges	• International, political needed, regarding ownership, rights, revenue allocation, etc.			

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The full report and related materials are available on the IRENA website (**www.irena.org**).