Export cable system

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The export system used to transmit power from the offshore wind project to the onshore point of grid interconnection consists of an offshore substation, electrical cables, and (in some cases) onshore power conversion infrastructure. Export cables are either high voltage alternating current (HVAC) or high voltage direct current (HVDC), each of which has separate power conversion equipment needs in the offshore and onshore substations. HVAC systems (particularly the offshore substation) tend to be cheaper but result in higher electrical losses which increase with cable length. As a result, there is a ‘crossover point’ where HVDC systems become cheaper for a particular project.

We have updated the electrical system design tools in ORBIT to support both HVAC and HVDC system design. The module sizes the power conversion equipment on the offshore substation including power transformers, shunt reactors (HVAC only), switchgear (HVAC only), AC/DC converters (HVDC only), and ancillary systems. It then estimates the number of cables needed to transmit the full power capacity of the project (either HVAC or HVDC cables) and, for HVDC systems, the onshore converter cost to convert power back from DC to AC. Finally, ORBIT estimates the mass and cost for the structural elements of the offshore substation (the topside building and substructure). The export system cable cost is parametrized as a function of cable length. Our assumed cable length is a straight line from any offshore wind site to the intersection with the coastline point that is in route to the nearest point of interconnection. A grid connection cost to account for connecting the export cable to the point of interconnection was also added to the final export cable cost.

We used ORBIT to re-assess the export system cable costs, estimating the costs for both an HVAC (using 220 kV export cables) and HVDC (using 320 kV cables with monopole configuration) system for cable distances of 10-400 km. For the dynamic array cables that are required for floating offshore wind applications we assume 20% higher costs than the static array cables used for fixed-bottom offshore wind. Although HVDC cables are still not produced at a commercial scale (and therefore have uncertain costs), this cost mark-up has been informed through industry consultation with leading floating offshore wind developers. We found a crossover point at approximately 70 km cable length at which HVDC cables become less costly than HVAC cables. We then connect the HVAC cost curve for distances below the crossover point to the HVDC curve for distances greater than the crossover point to produce a single cost curve for export system costs. Our resulting cost relationship (inclusive of installation costs, offshore substation, and onshore DC converter if appropriate) shows this crossover point as part of a parametrized curve fit (Equation 1, Figure 1).

2.393\*10-6\*length3 - 0.003343\* length2 + 4.365\* length + 365.6, (1)

where length is the export cable length in km.

Chart, line chart

Description automatically generated

Figure 1: Export system cable costs and their variation by distance from landfall for floating offshore wind

The newly derived cost curves show that the export system could cost between $500 - $1,300 /kW for projects located 20 – 200 km from their point of interconnection. The substations represent significant fixed costs that do not vary with distance to shore, and the variance as a function of distance is due to the increased cable length. This cost curve is generated assuming a 1 GW project; increased project capacities could require additional cables and/or substations, which could cause project costs to depart from this cost curve. Ultimately, the design of the export system is a significant cost contributor to the capital stack of an offshore wind project and will be customized for each individual project.

The assumptions and results from the new ORBIT design module have been reviewed by industry experts to verify the new methodology. The updated cost estimates show a significant increase relative to Beiter et al. (2016) costs.