Grid-scale electricity storage
enabling renewables to power grids
affordably, reliably and resiliently

Offshore Energy Networks

The subject here is how to regulate OFTOs (cables owned by Offshore Transmission Owners) so that (for example) they can be linked together into offshore grids and/or interconnectors, or how other farms/plants can be connected to existing OFTOs, or their use can be varied in order to meet a number of challenges.

The Current Regime

In theory, under the current regime, offshore wind developers don’t build the grid connection to the onshore grid: Ofgem run a competitive tender for an independent developer to do so, with a long-duration contract to carry the energy. In practice, the offshore wind developer builds the grid connection and then hives it off into an independent company with such contracts. There is usually one OFTO per wind farm, or per phase of wind farm. Each is sized to take peak output from that farm.

Challenge 1: Utilisation

As each farm has its own OFTO, and sometimes the wind is blowing stronger for some farms than for others, so the network as a whole is under-utilised. In theory, by joining them together, more wind farms can be built onto the same grid connections.

This theory has two main shortcomings: cost, and weather. The cost is that it may be at least as expensive to connect the offshore substations together (including modifying those substations) as to build a new grid connection, so there may be few or no savings.

The weather issue is that, while it is sometimes gusty, marine weather is often fairly consistently windy, and when this happens any shared connections will be overwhelmed. This is particularly the case for neighbouring wind farms – which, of course, would be the ones connected.

Challenge 2: Offshore Network Resilience

If an OFTO develops a fault, the entire farm’s output is stopped, leading to a shortfall of generation on the grid – often multi-GW in size. By connecting the OFTOs together, then providing that the wind farms aren’t all generating maximum output, there are alternative routes for its energy to get onshore.

This would be a substantial improvement, but prevents achievement of the utilisation benefit: each farm would still require its own OFTO, or there would be inadequate capacity to take neighbouring farms’ electricity. There would still be curtailment if the farms’ output levels are high and the remaining OFTOs are swamped.

Challenge 3: Moving the Grid Connection

The onshore grid has many major congestion points, the most notable and enduring of which is near the Scotland/England boundary. If OFTOs were interconnected offshore, then the electricity could be taken down the sea bed, connecting to the onshore grid on the other side of the constraint.

While beguiling in theory, this presupposes that there is sufficient capacity in all the grid connections to carry much more electricity than they are currently designed to take, and also that the connections between the OFTOs are sufficient to take the energy from a number of wind farms. While this would simultaneously achieve challenges 1 and 2, the cost to upgrade all OFTOs sufficiently, and to put in place offshore interconnections of such size, will dwarf the cost of reinforcing the onshore grid.

There would be savings if the assumption is made (which is correct for the majority of the time) that the flows will be southwards. This means that the northernmost OFTOs and interconnections don't have to be reinforced, and that the amount of reinforcement would be greater the further south the cables are. This reins in the costs, but not to the extent whereby it's a worthwhile investment in comparison with reinforcing the onshore grid, or building north-south HVDC interconnectors.

Challenge 4: International Interconnection

It has been observed that (for example) a British wind farm is near a Norwegian one, so connecting the two together would create an interconnector with only a comparatively short length of cable.

This assumes that there is sufficient capacity on either farm's offshore connection to take both farms' output. Which requires reinforcement of both farms' cables and substations. Which covers the entire length of the interconnection. Which begs the question: what is saved?

The response is that an interconnector will only be needed when domestic output is below demand. This implies that the farms' output will be lower than capacity, which provides some spare capacity on the grid connection to carry at least some of the other farm's output, and/or some energy from the other mainland. While true, this is limited and hard to manage: contracts would be very complex unless on the "spot" market, i.e. not firm contracts on which a grid can rely in planning its grid capacity and resilience.

There is another challenge: by 2040 all Britain's neighbours apart from Norway and Iceland will be depending on imports during times of system stress, which are frequently concurrent with those in the UK. And Brexit means that we cannot rely on contracts: no longer being a "domestic" customer of an EU utility, we are now an "export market" – and it is difficult to conceive a foreign utility telling their government that a back-out in a major city was because they were exporting the energy that the city needed, giving the utility a political imperative to break the contract. This means that they will not have a surplus to export when we need to import. We need therefore to be building more domestic generation and large-scale long-duration storage rather than relying on interconnectors.

Challenge 5: Single OFTO for Multiple Farms

A number of wind farms could feed into a single offshore substation, and thence through a single OFTO to a single grid connection. This works, if it is tendered at the outset.

Challenge 6: Splitting a Grid Connection

If the grid connection is too large for a given point on the grid, the Transmission Operator may build a single new substation to take it, connecting to two or more substations – referred to as a TO owned bootstrap.

This is a valid design, but it is difficult to see why the OFTO regime needs changing to achieve it.

Challenge 7: Connecting Storage or Demand to the Offshore Side of a Connection
One particular application of this is to power electrolysis with renewable energy. This works well, removing peak output to level off the energy flows onto the grid, but at the cost of needing a huge over-build of electrolysers (as compared with the same hydrogen output from baseload electricity) to accommodate such intermittency. Electrolysis is already expensive; this makes it more so.

A second application is to store the electricity before it hits the grid.

- Firstly, it is notable that Ofgem correctly considers “storage” differently from “demand” and “generation”. So why don’t they change the regulatory definition accordingly? It would be the quickest and easiest way to solve many problems.
- Secondly, this concept differs from Challenge 6 in that the storage is “bolted on”: it doesn’t add the stability services 24/7 to the electricity feed

Challenge 8: Connecting Multiple Generation through Changed-Use Connection
At present, there are no mechanisms for changing the use of an OFTO: their contracts are tied to one single farm. There are a number of ways in which the desired use may change, such as extending the wind farm. The most notable of these is Storelectric’s proposal to connect a new wind farm through the existing grid connection of an existing wind farm, by diverting both farms’ cables through large-scale long-duration inertial storage. This has the potential to save over £1bn/GW capital costs and £100m/GW per annum operational costs relating to reinforcing the grid, as well as reducing the costs of balancing and stability services, and eliminating the costs of connecting those balancing and stability services to the grid. This proposal is replicable with all such storage technologies, wherever they can be built near wind farm grid connections – though Storelectric’s technologies deliver the best such benefits, by a big margin owing to their capital costs, configurability and exceedingly broad range of services delivered. The combined wind farm and storage can then be treated by the grid’s Control Centre as though it were a dispatchable, inertial power station. Such huge benefits for the grid make this by far the most affordable, reliable and resilient way to power a Net Zero grid, provided that there are mechanisms to share the benefits between the grid/consumer and the plant/farm.

This arrangement minimises or even avoids the need for grid reinforcement by providing the balancing and stability services before the electricity gets onto the onshore grid. North/south constraints are principally because of the intermittent nature of the flows: either too much is going southwards, or too little, due to weather patterns; this arrangement reduces or (with longer durations) removes such intermittency at source.

This use can be implemented in parallel with the others, by over-sizing the storage to take the over-sized connectors. The cost/benefit of doing so would have to be analysed case-by-case.

Summary of Challenges

In summary,

- Challenges 1-4 are benefits that appear to be good ideas as lines on paper, but when energy flows and weather patterns are considered, most of these benefits become outweighed by the costs and complexity, especially when compared with reinforcing onshore grids and/or building north/south HVDC connections. They offer the prospect of new contracts and revenue streams for developers without actually improving proportionately the system's capacity, reliability and resilience.
- Challenge 5 stands scrutiny if tendered before build.
- Challenge 6 does not need changes to the system.
- Challenge 7 is beneficial under certain circumstances, but the benefits are likely to be considerably less than currently foreseen.
- Challenge 8 stands scrutiny, and also offers the potential to alleviate north/south energy flow constraints, with benefits that will be truly transformative for the energy transition and for the electricity system as a whole.

Short-Termism

Yet again, the consultation looks at interim solutions, not at end results: at 2030 and 2040 (paragraphs 1.2, 1.5), not at 2050. This carries the risk of removing the symptoms and not the cause, of building stranded assets (like the thankfully un-consummated "second dash for gas" which would have achieved 2025 targets but built power stations made redundant by 2030-40 targets) and excess cost (like the current over-build of batteries and synchronous condensers to deliver short-duration services that are more cheaply delivered as part of the revenue stacks of long-duration storage, so the long-duration storage will have to over-charge for its long-duration services).

Early Opportunities / Anticipatory Investment (AI)

We refer Ofgem to our feedback on the Early Competition consultation. Most of the comments on on-shore early competition apply equally to off-shore early opportunities.

The entire proposal section on Early Opportunities / Anticipatory Investment (AI) omits the concept of Very Early Opportunities, i.e. projects identified and proposed by promoters. See the comments on Very Early Competition in the Early Competition consultation: in summary, to provide an incentive for developers to work on and put forward their proposals, each proposal must be analysed and contracted / remunerated on its own merits, not competed. Many and varied developers will have a greater variety of good ideas than a few TO/Ofgem planners. It would remain a level playing-field for all provided that all contractors have equal access to make proposals, and all are evaluated consistently.

AI is to be encouraged in every aspect of grid/system design and build, not just offshore. It is AI that ensured that the grid was built in the first place, and that a system designed in the 1950s would still be the backbone of the country's energy system in the 21st century. It is the lack of onshore AI that:

- Means that nearly the entire grid is saturated, preventing excellent projects even being proposed;
- Led to the black-outs of 19th August 2019, and to many near-misses since;
- Made the country over-dependent on imports, hence vulnerable, during times of system stress;
- Left the grid as largely the same design as when the majority of population industry were in the north, and that industry was heavy and energy intensive;
- Created today's network of bottlenecks, constraints and vulnerabilities.

This lack of AI has been driven by the regulatory environment, particularly its obsessions with increasing grid utilisation (sweating the assets instead of investing in them) and not "gold-plating the system" (building capacity ahead of need, so it can be built in rational and planned ways saving up to two-thirds of costs and enabling all good projects to advance).

"Highly AI" work, onshore more than offshore, is absolutely necessary: the country's demographics and industry have changed dramatically and will continue to do so; likewise its types and locations of electricity generation. These are largely predictable, and can therefore be built for in a planned and economic way. Where the forecast usage doesn't happen when anticipated, it nearly always comes later, so the investment is not wasted – that is why nearly all the grid is fully utilised now, and the planned construction is up to two-thirds cheaper than reactive reinforcement, as illustrated by the ENA (Energy Networks Association) looking at Australian grids and others.

Whatever changes are required to enable AI, onshore more than offshore, should be done. Designs of grids should be adapted pre-construction so that lines and substations are best located for proposed and future projects; these parts should be funded by the grid, only the spurs (minimised in length by such changes) being funded by the project.

Pathway to 2030: Costly Short-Termism

While the Pathway to 2030 is good as far as it goes, but aims to deliver the government's 40GW by 2030 wind generation targets. This is short-sighted. Between 80 and 120GW wind, together with a similar multiplication of solar, are needed by 2050. The grid needed for 2050 will have solutions that differ substantially from that needed for 2030, yet the assets being designed and built for 2030 will still be operational towards the end of the century: today's grid was built mainly in the 1950s to 1970s. This short (2030) planning horizon means that investment will not be future-proofed, making the future (i.e. the energy transition as a whole) tens or hundreds of billions of pounds more expensive than a policy of designing for 2050 at the outset.

For example, a new transmission line required for 2030 may be built to carry many more conductors if designed for 2050, reducing the conversion (from 2030 to 2050) to merely adding new conductors rather than modifying the entire line; likewise, its substations can be planned large enough for 2050 with suitably sized earthing etc., saving repeated and inefficient planning applications, retro-fits, modifications and construction of adjacent facilities. This is especially relevant as the locations and rough capacities of the expected future generation are known with a fair degree of certainty: most will be offshore, a large proportion being Scottish wind delivering power to England.

Moreover, such short-termism tends to lead to investments that just would not be made if a longer horizon were targeted. A classical example of this is that a few years ago both government and grid were talking up a (thankfully, un-built) “second dash for gas” to achieve 2020-30 emissions targets, regardless of the fact that these power stations would be stranded assets by 2030-40, well within their amortisation lives, thereby incurring hundreds of billions of pounds worth of wasted investment. Another example is the current over-build of short-duration storage which will cannibalise the revenue stacks of long-duration storage without providing the services that the latter would offer; the latter is needed, so they would have to increase the prices of such services and the overall cost to the consumer is increased.

The objection is made that where the demand fails to materialise as predicted, there is surplus capacity. But that surplus only lasts a while until need catches up, which is why there are almost no such surpluses in today’s grid despite the supposed “gold-plating” of the past. And building to plan is so much cheaper than building to need that the savings more than pay for any surplus.

Another hazard of such a short-termist approach is that the grid is kept near saturation throughout, preventing good projects from being put forward because their grid connection is not economically possible.

A fourth short-termist hazard is that when needs are finally acknowledged, they are too urgent for the most cost-effective (overall, in the context of the entire system’s needs) solutions to be proposed: the grid will be sustained by patches and quick fixes. Already this approach over the last 30-40 years has led to one of the world’s most reliable grids deteriorating to black-outs and near-misses, and to many other crises (most barely averted) in its operation.

A fifth short-termist hazard is that a 10-year planning horizon with a multi-year build lead time only provides for a few years’ amortisation, so only short-life, smaller-scale projects will be built. This is why, for example, since privatisation most long-life assets that have been built since privatisation (other than those planned beforehand) were under special long-duration financial instruments (e.g. ROCs, CfDs, Capacity Market, OFTOs) whose rules are market distortions and whose existence suppress market signals. Long-life assets must be built in long-term markets and subject to long-term planning.

Delivery Model
There are many shortcomings to the delivery model whereby only the System Operator can design the network, only the Transmission Operator, offshore generator and OFTO can build it, and only the OFTO can operate it. This model appears to prioritise “don’t try changing today’s system” over the best interests of the system and consumer. A few salient problems follow.

- There is no concept of other developers proposing solutions that the ESO has not proposed, which will excessively narrow the range of solutions proposed, and the imagination and the technologies applied to the grid.
- Why does an OFTO need to operate them all? I see no reason why a grid connection dedicated to a wind farm can't be considered part of that farm; adding an OFTO into the mix merely complicates and adds cost to the model. As long as access is given to others (depending on the offshore grid concepts used), there is no commercially sustainable reason to put in another company which needs to sustain another profit line.
- If a wind farm developer seeks to develop an offshore/onshore project with multiple elements (such as multiple farms feeding into the grid through large-scale long-duration inertial storage, each of which can save billions on grid connection and reinforcement), splitting out the ownership makes such consumer/system beneficial proposals well-nigh impossible.
- If the System Operator's design proposes one design and others come up with an improvement, it cannot be considered. Especially if nobody wants to build the SO's design, or if the alternative design delivers benefits that the SO hadn't considered or had under-evaluated.

Examples of other suitable arrangements include:

- Any other party (generator, TO, OFTO, developer of something else such as storage) should be able to instigate proposals from the earliest stage onwards.
- Operation of a connection supporting one developer's farms should be operable by that developer …
- … which is even more important if the whole project incorporates onshore elements, which it must frequently do in order to deliver a better-value, better-performing and more-resilient grid for consumers.
- Fossilising all offshore connections into independently owned OFTOs makes it much harder for generators and/or others to further develop their wind farms, or add other wind farms and/or other assets (e.g. storage, especially if onshore) to the grid connection.

Multi-Purpose Interconnectors

Multi-purpose interconnectors (MPIs) look very attractive as lines on a piece of paper, until one considers energy flows: then they become a futile waste of time and money with very few situations envisageable in which there would be benefit.

Considering interconnecting farm A connected to country A, with farm B connected to country B.

- Farms A and B are close to each other and therefore have very similar load (output) profiles.
- If farm A is producing, then it has no capacity to accommodate the output from farm B, unless grid connection A is suitably reinforced, and ditto in the other direction, in which case why not just lay a cable from country A to country B which would be cheaper than all those offshore reinforcements?
- If their outputs are low enough for either of their grid connections to carry both farms' output, it is rare that there will be a system need in the receiving country.

- If there is a system need in country A, that will usually occur when output from farm A and therefore also from farm B will be low or zero; therefore the interconnector adds nothing unless country B is exporting – again, why not build a cheaper cable from country A to country B?

About Storelectric

Storelectric (www.storelectric.com) is developing transmission and distribution grid-scale energy storage to enable renewables to power grids reliably and cost-effectively: the world's most cost-effective and widely implementable large-scale energy storage technology, turning locally generated renewable energy into dispatchable electricity.

- Innovative adiabatic Compressed Air Energy Storage (Green CAES) will have zero / low emissions, operate at 68-70% round trip efficiency, levelised cost significantly below that of gas-fired peaking plants, and use existing, off-the-shelf equipment.
- Hydrogen CAES technology converts & gives new economic life to gas-fired power stations, reducing emissions and adding storage revenues; hydrogen compatible.

Both technologies will operate at scales of 20MW to multi-GW and durations from 4 hours to multi-day. With the potential to store the entire continent's energy requirements for over a week, global potential is greater still. In the future, Storelectric will further develop both these and hybrid technologies, and other geologies for CAES, all of which will greatly improve storage cost, duration, efficiency and global potential.

About the Author

Mark Howitt is Chief Technical Officer, a founding director of Storelectric. He is also a United Nations expert advisor in energy transition technologies, economics, regulation and politics – invitation here.

A graduate in Physics with Electronics, he has 12 years' management and innovation consultancy experience world-wide. In a rail multinational, Mark transformed processes and developed 3 profitable and successful businesses: in commercialising a non-destructive technology he had innovated, in logistics (innovating services) and in equipment overhaul. In electronics manufacturing, he developed and introduced to the markets 5 product ranges and helped 2 businesses expand into new markets.

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