Watt-Logic

Global Warming Policy Foundation

Interconnectors and their impact on the GB power market

Kathryn Porter, Consultant, Watt-Logic

Executive summary

The GB electricity market has become increasingly reliant on interconnection with other markets. In its 2023 Future Energy Scenarios[1], NG ESO said:

> *"To manage dunkelflaute[2] periods, dispatchable thermal power plants (gas and/or hydrogen), depending on the scenario and year, are likely to be required. A combination of LDES (e.g. Compressed Air Energy Storage (CAES), Liquid Air Energy Storage (LAES), Pumped Hydro Storage (PHS)) and interconnectors will be required to manage the network during these periods."*

In other words, interconnectors are seen as key to managing periods of low wind output in an electricity system increasingly dependent on intermittent renewable generation. But what if the markets at the other end of those interconnectors are also experiencing dunkelflaute conditions? As most of them (with the exception of Norway) share similar weather to the UK, and (with the exceptions of Norway and France) share similar wind-led de-carbonisation strategies, can we really rely on interconnectors to ensure security of supply? And what about the effects of energy nationalism which has been increasing since the war in Ukraine? Can we rely on countries being willing to export at all times when GB needs to import?

Cross-border electricity trading allows resources to be used more efficiently across wide regions, but they tend to increase prices in exporting countries while lowering prices in importing countries, which may be unpopular in countries which export more than they import (such as Norway). Britain is typically an importer, so is able to benefit from (slightly) reduced power prices, but analysis of historic interconnector behaviour indicates that quite often we import when we don't need to and export when demand is high and imports would be preferable. In addition, the rules governing the behaviour of interconnectors do not guarantee they will import during times of electricity shortages – they could even export instead.

Some countries, in particular Norway, are expressing doubts about their commitment to trading electricity, and have passed laws allowing them to suspend exports under certain conditions. They are also considering imposing export taxes in order to prevent domestic prices rising too much, which may reduce the availability of exports. Other countries may take a similar stance if they face electricity shortages, but high weather correlation and many countries in northern Europe relying on wind power, means that several countries could face shortages at the same time and be unwilling to export.

There have been well-publicised acts of sabotage against cross-border gas pipelines which leads to concerns over the security of all energy infrastructure.

All of this suggests that while interconnectors may benefit Britain under normal market conditions, they may not deliver at times they are needed the most, and that relying on them could be a risky strategy.

[1] https://www.nationalgrideso.com/document/283101/download

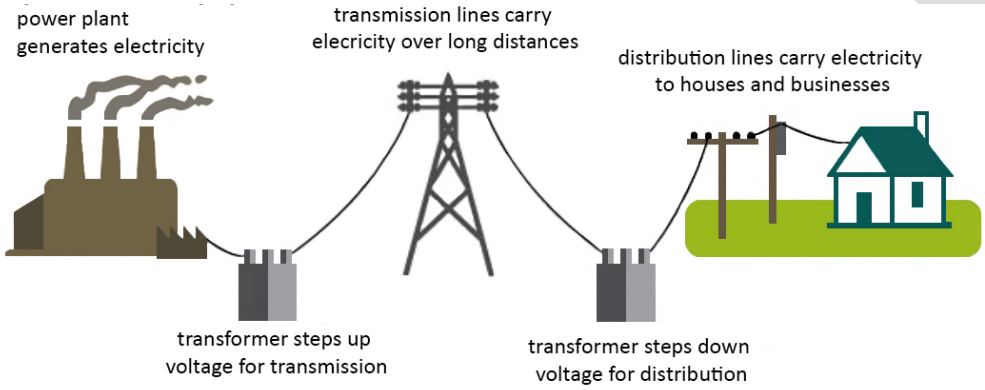
[2] "Dunkelflaute" is a German term which means "dark lull". It describes a Dunkelflaute is a meteorological phenomenon when there is little to no solar and wind power generation due to unfavourable weather conditions - see https://capital.com/dunkelflaute-what-is-definition

Background

The electricity industry is made up of four functions: generation, transmission, distribution and supply. Both generation and transmission are highly capital intensive and transmission is a natural monopoly.

The electricity system or "grid" comprises the electricity substations, transformers, and power lines that connect electricity producers and consumers. This is normally divided into two distinct sections: the high voltage transmission network and the lower voltage distribution networks. Large sources of generation (power stations) and demand (large industrial users such as factories) connect directly to the transmission network, while other users (small generators and consumers) connect to the local distribution network.

Physical electricity system



Source: adapted from the US National Energy Education Project

Once produced, electricity travels along the grid infrastructure following the path of least resistance, at the speed of light. As electricity is transmitted, energy is lost due to heating of the wires and other factors. These losses are known as "line losses" and can be reduced by transmitting the electricity at higher voltages. This is why there is a distinction between the transmission system and the local distribution networks – consumers require electricity at low voltages, but to reduce losses, transmission over large distances is done at high voltages.

Most transmission lines are high-voltage three-phase alternating current ("AC"), however over very long distances, line losses can be significant. For this reason, high-voltage direct current ("HVDC") technology is used for very long-distance transmission, particularly in submarine power cables. Interconnectors are high-voltage cables that connect the electricity systems of neighbouring countries (or states in the case of the US) to one another. Interconnectors allow electricity to be traded between countries, with flows typically moving from the lower priced market to the higher priced market.

National Grid ESO ("NG ESO"), the GB transmission system operator, say of interconnectors[3]:

> *"By sharing excess power, we can ensure renewable energy isn't wasted, and constraint payments are minimised. For example, when weather conditions mean supplies from UK wind farms and solar are lower, we can draw on carbon-free sources of electricity through the interconnectors. On windy or very sunny days in Britain, excess renewable energy can be sent via an interconnector to neighbouring countries. By connecting Great Britain to*

[3] https://www.nationalgrideso.com/news/interconnectors-role-transitioning-net-zero

broader and more diverse sources of energy, interconnectors can help overcome operability issues, which lowers costs to consumers."

Great Britain's electricity network is linked to networks in several other countries including France, Norway, Netherlands, Belgium, and Ireland via interconnectors that allow electricity to be traded and shared. These interconnectors currently have a total capacity of 8.4 GW and more are being built, potentially adding 16 GW by 2035. NG ESO modelling found that interconnectors will remain an important source of energy into GB in periods of highest need, and imports into GB are mostly expected to grow in absolute terms during periods of system stress.

Rules governing the behaviour of interconnectors

The contribution of interconnectors to energy security is laid out in the Capacity Market, a mechanism by which providers of electricity supply (including generators, batteries and interconnectors) agree to provide electricity during times of system stress, in exchange for guaranteed payments. Each contract holder must meet annual availability tests and must be available to provide the agreed electricity if National Grid ESO, the electricity system operator, declares that a system stress event is occurring.

Under Capacity Market rules, interconnectors only need to be operational during times of system stress – they do not need to be importing, and there are no mechanisms to force imports if the capacity has been sold to market participants for the purposes of exporting (although exports can be stopped). If both markets at each end of the cable have simultaneous system stress, then technically, there would be price competition between them to secure imports, but in reality it is expected that system operators would intervene to float the cable, meaning power would not flow in either direction.

"Interconnector analysis has always been challenging. Firstly, because of their nature: they are transmission links but inject energy resources into the GB network like generators. Secondly, because an assessment of their contribution under stress events is quite hypothetical as there is an absence of sufficient historical evidence on flows under stress. As a consequence, the resource contribution and derating factor analysis is essentially model-based,"
- Panel of Technical Experts: Report on the National Grid ESO Electricity Capacity Report 2023

The overall expected availability of interconnectors is captured in the Capacity Market de-rating factors. The Government took a more conservative approach[4] than had been recommended by National Grid ESO[5] and the Panel of Technical Experts[6] ("PTE") which scrutinises the annual Electricity Capacity Reports ("ECR") by National Grid ESO. The de-rating factors determined by the Government in 2023 suggest that two thirds of available interconnector capacity would be available in a time of system stress.

[4] https://www.gov.uk/government/publications/capacity-market-auction-parameters-letter-from-desnz-to-national-grid-eso-july-2023

[5] https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Electricity%20Capacity%20Report%202023.pdf#search=Electricity%20Capacity%20Report%202023

[6] https://assets.publishing.service.gov.uk/media/64b5d6100ea2cb001315e436/panel-of-technical-experts-2023-report.pdf

Capacity market interconnector de-rating factors

Interconnector	Country	Capacity	De-rating factor
IFA-1	France	2 GW	59%
IFA-2	France	1.1 GW	60%
Eleclink	France	1 GW	64%
BritNed	Belgium	1.2 GW	61%
Nemo	Netherlands	1 GW	64%
NSL	Norway	1.4 GW	83%
Viking	Denmark	1.5 GW	55%

Source: DESNZ

However, as the Panel of Technical Experts notes, this is purely hypothetical, and based on National Grid ESO's modelling. In 2020, Watt-Logic analysis[7] indicated that during periods of high winter demand, Britain often exports electricity: Britain exported electricity to Continental Europe during 13% of the hours with the top 5% of demand during Winter 2020, while exports accounted for 16% of all hours over that period. Considering Winter 2019, which was less affected by covid, Britain exported electricity to the Continent in 18% of all hours and 12% of the hours with the highest 5% of demand.

This analysis was subsequently updated[8] for 2022 and 2023. Across the two years, Britain exported in 23% of the top 5% of hours with the highest demand. This higher figure was likely due to the specific situations in Norway and France in 2022: Norway experienced 20-year low reservoir levels, while large parts of the French nuclear fleet were offline due to systemic technical problems.

While Norwegian reservoir levels have recovered, the country has become increasingly if not hostile to then wary of exporting electricity. In 2023 it declined to award a licence to the proposed NorthConnect[9] link with Scotland, and passed legislation[10] allowing it to suspend electricity exports in times of domestic shortages. It has subsequently proposed further legislation to allow export restrictions in the case of potential rather than actual shortages[11]. There have also been suggestions of the imposition of export taxes[12] in order to keep domestic prices down. In addition, parts of the ruling coalition have proposed[13] that when existing interconnectors with Denmark reach the end of their lives in the next couple of years, they should not be replaced.

The concerns with France are different. Twice in six years large parts of the French nuclear fleet, the country's main source of electricity, have been out of action as a result of systemic problems – in 2016 due to problems with excess carbon in the steel used to build the reactors[14], and in 2021-22 due to stress corrosion[15] cracking in some of the cooling circuits. The French regulator has suggested that as the fleet ages, this situation could be repeated in future, and that there will not be a decision

[7] https://watt-logic.com/2020/12/10/fes-2020/

[8] https://watt-logic.com/2024/02/05/interconnector-imports-exports/

[9] https://www-regjeringen-no.translate.goog/no/aktuelt/avslag-pa-konsesjonssoknad-om-bygging-og-drift-av-northconnect-kabelen/id2966715/?_x_tr_sl=no&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=sc

[10] https://www-regjeringen-no.translate.goog/no/aktuelt/bedre-styring-av-forsyningssikkerheten/id2960788/?_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en-GB

[11] https://www-regjeringen-no.translate.goog/no/aktuelt/styrker-forsyningssikkerheten-for-kraft/id3017651/?utm_source=regjeringen.no&utm_medium=email&utm_campaign=nyhetsvarsel20231208&_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en-GB

[12] https://www.reuters.com/business/energy/norway-may-tax-power-exports-keep-domestic-prices-down-2023-02-15/

[13] https://us.firenews.video/tech-media/vedum-wants-to-cut-two-of-the-power-cables-to-denmark-populist-frivolous-and-easy/

[14] https://www.french-nuclear-safety.fr/asn-informs/news-releases/edf-reactor-steam-generators-in-service-could-contain-an-anomaly

[15] https://www.french-nuclear-safety.fr/asn-informs/news-releases/stress-corrosion-phenomenon-detected-on-reactors

on further life extensions until 2026, meaning that some older plants could be forced to close this decade[16].

This means that the high levels of exports experienced in 2022 could well be repeated in future.

Risks and benefits of relying on interconnectors

Interconnectors provide certain benefits to the connected markets, the principal of which is the diversification of generation sources. Electricity flows from lower priced to higher priced markets, reducing price differentials between them, and allowing resources to be used more efficiently across the wider region. The use of interconnectors also allows countries to outsource the construction of generation to other countries, meaning they avoid the upfront capital costs and risks associated with their construction (although they do incur some of the capital costs of the interconnector construction). Imports displace more expensive forms of domestic generation, reducing prices to consumer.

However, they also have disadvantages. The main drawback is the lack of certainty around their performance in times of system stress, but under normal conditions, exporting tends to increase prices in the exporting country. This has been a particular concern in Norway, leading to political interventions which may mean that exports are restricted. As Norway has the lowest weather correlation with Britain of all the markets to which Britain is connected, this could have a disproportionate impact on Britain's ability to access imports.

The benefits of interconnectors may well be overstated. During 2022-23, imports only met 4.3% of Britain's electricity demand, similar to the contribution of solar power (4.4%), which is only available during daylight hours and not at all during periods of peak winter demand. Some imports also occur at times when they are not really needed and the impact on prices is minimal – for example when wind generation is high. Watt-Logic analysis of 2022-23 data indicated that in 11% of hours there was high wind in both GB and the other nearby countries, and in 13% of hours wind was low in all countries (which is equivalent to just under one day per week). During 8% of hours it was windy in all countries and GB imported, and in 5% of hours it was not windy in all countries and GB exported. GB exported in 7% of hours when it had low wind generation and received imports in 13% hours when it had high wind generation (regardless of the wind levels in the other countries).

This analysis also highlights another limitation of interconnectors: proximity tends to result in high weather correlation. As many countries in north-west Europe (in fact most countries except for Norway and France) are following a strongly wind-led energy transition, and most of the markets with which Britain is connected may experience similar weather patterns at the same time, these shared weather conditions could result in simultaneous high wind generation producing widespread surpluses or low wind resulting in widespread shortages.

Other energy transition effects will also have an impact. Currently most domestic heating in Britian is powered by natural gas, but in France, most homes use electricity. When temperatures drop, electricity demand increases in France much faster than it does in Britain, and France moves form exporting electricity to importing, including from Britain. But the UK Government and governments elsewhere in Europe also have plans to electrify heating, meaning that winter electricity demand will be much higher and more temperature sensitive than it is today. This could well disrupt cross-

[16] https://www.lemonde.fr/en/environment/article/2023/01/24/french-nuclear-safety-authority-considers-extending-reactors-beyond-60-years-of-operation_6012884_114.html

border electricity flows, with more countries taking the same approach as Norway in protecting their domestic consumers before allowing exports.

Even where countries are willing to export, they may be unable to. Interconnectors may be unavailable due to maintenance and repair requirements, or there may have been accidental damage such as that caused by a ship's anchor to four of the eight cables of IFA-1, the oldest interconnector between Britain and France in 2016[17]. Recent events in Europe with the acts of sabotage against the Nord Stream[18] and Balticconnector[19] gas pipelines illustrate another risk to availability: deliberate damage. Bad actors have shown a willingness to attack energy infrastructure, and electricity cables may be similarly vulnerable.

Conclusion

Each year the vulnerability of the GB power system grows as reliable thermal and nuclear generation is replaced with intermittent renewable generation, primarily wind. However, wind lulls can both coincide with periods of high system demand (anti-cyclonic weather systems characterised by cold, still weather in winter and hot, still weather in summer) and can be extensive, lasting for days or even weeks, certainly beyond the capacity of any currently existing batteries to back up. They can also be shared across several countries at the same time.

So far, there has not been a system stress event, triggering delivery under Capacity Market rules, but each year the risk of this increases. However, the performance of interconnectors in such an event is described by experts as entirely "hypothetical". A combination of high weather correlation, political sensitivities and physical risks could all threaten the ability of Britain to attract imports at times of need. Relying on interconnectors could prove to be a huge gamble and one we only know we have lost when it is too late.

[17] https://assets.publishing.service.gov.uk/media/5aa2aa56ed915d4f595c5232/MAIBInvReport03_2018.pdf

[18] https://www.gov.uk/government/speeches/the-sabotage-of-the-nord-stream-pipelines-should-be-treated-with-utmost-seriousness-uk-statement-at-the-security-council

[19] https://www.politico.eu/article/balticconnector-damage-likely-to-be-intentional-finnish-minister-says-china-estonia/

References

1. National Grid ESO: *Future Energy Scenarios 2023* (https://www.nationalgrideso.com/document/283101/download)
2. Capital.com: *What is Dunkelflaute?* (https://capital.com/dunkelflaute-what-is-definition)
3. National Grid ESO: *Interconnectors' role in transitioning to net zero* (https://www.nationalgrideso.com/news/interconnectors-role-transitioning-net-zero)
4. UK Government Department for Energy Security and Net Zero: *Capacity Market auction parameters, July 2023* (https://www.gov.uk/government/publications/capacity-market-auction-parameters-letter-from-desnz-to-national-grid-eso-july-2023)
5. National Grid ESO: *Electricity Capacity Report 2023* (https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Electricity%20Capacity%20Report%202023.pdf#search=Electricity%20Capacity%20Report%202023)
6. UK Government Department for Energy Security and Net Zero: *Panel of Technical Experts Report on the National Grid ESO Electricity Capacity Report 2023* (https://assets.publishing.service.gov.uk/media/64b5d6100ea2cb001315e436/panel-of-technical-experts-2023-report.pdf)
7. Watt-Logic: *The strange, unfamiliar world of FES-2020* (https://watt-logic.com/2020/12/10/fes-2020/)
8. Watt-Logic: *Relying on interconnectors for imports carries risks* (https://watt-logic.com/2024/02/05/interconnector-imports-exports/)
9. Norwegian Government: *Refusal of a license application for the construction and operation of the NorthConnect cable* (https://www-regjeringen-no.translate.goog/no/aktuelt/avslag-pa-konsesjonssoknad-om-bygging-og-drift-av-northconnect-kabelen/id2966715/?_x_tr_sl=no&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=sc)
10. Norwegian Government: *Better management of security of supply* https://www-regjeringen-no.translate.goog/no/aktuelt/bedre-styring-av-forsyningssikkerheten/id2960788/?_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en-GB
11. Norwegian Government: *Better management of security of supply* (https://www-regjeringen-no.translate.goog/no/aktuelt/styrker-forsyningssikkerheten-for-kraft/id3017651/?utm_source=regjeringen.no&utm_medium=email&utm_campaign=nyhetsvarsel20231208&_x_tr_sl=auto&_x_tr_tl=en&_x_tr_hl=en-GB)
12. Reuters: *Norway may tax power exports to keep domestic prices down* (https://www.reuters.com/business/energy/norway-may-tax-power-exports-keep-domestic-prices-down-2023-02-15/)
13. USA Today: *Vedum wants to cut two of the power cables to Denmark: – Populist, frivolous and easy* (https://us.firenews.video/tech-media/vedum-wants-to-cut-two-of-the-power-cables-to-denmark-populist-frivolous-and-easy/)
14. Autorité de Sûreté Nucléaire: *Certain EDF reactor steam generators in service could contain an anomaly similar to that affecting the Flamanville EPR vessel*

(https://www.french-nuclear-safety.fr/asn-informs/news-releases/edf-reactor-steam-generators-in-service-could-contain-an-anomaly)

15. Autorité de Sûreté Nucléaire: *Stress corrosion phenomenon detected on Civaux 1 and 2, Chooz B2 and Penly 1 reactors* (https://www.french-nuclear-safety.fr/asn-informs/news-releases/stress-corrosion-phenomenon-detected-on-reactors)
16. Le Monde: *French Nuclear Safety Authority considers extending reactors beyond 60 years of operation* (https://www.lemonde.fr/en/environment/article/2023/01/24/french-nuclear-safety-authority-considers-extending-reactors-beyond-60-years-of-operation_6012884_114.html)
17. Marine Accident Investigation Branch: *Report on the investigation of the collision between Saga Sky and Stema Barge II English Channel, off the Kent Coast on 20 November 2016* (https://assets.publishing.service.gov.uk/media/5aa2aa56ed915d4f595c5232/MAIBInvReport03_2018.pdf)
18. UK Government: *Statement by Ambassador James Kariuki at the UN Security Council meeting on the Nord Stream gas pipeline* (https://www.gov.uk/government/speeches/the-sabotage-of-the-nord-stream-pipelines-should-be-treated-with-utmost-seriousness-uk-statement-at-the-security-council)
19. Politico: *'Everything indicates' Chinese ship damaged Baltic pipeline on purpose, Finland says* (https://www.politico.eu/article/balticconnector-damage-likely-to-be-intentional-finnish-minister-says-china-estonia/)