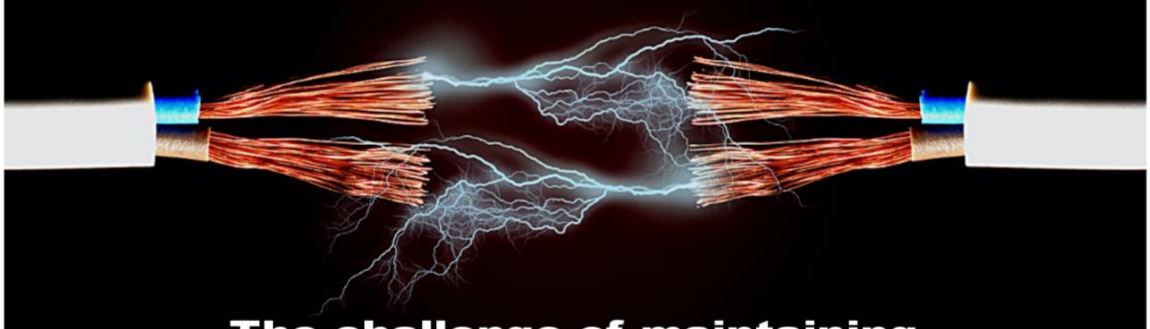
WHO PUT THE LIGHTS OUT?



The challenge of maintaining electricity supply in a Scotland outside the United Kingdom

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Executive summary

- A National Grid providing continuous reliable power for 24 hours of all 365 days of the year across the British mainland of Scotland, England and Wales was established in the 1920s.

- The grid has been able to meet the variable demands irrespective of locations between John O'Groats to Lands End by being fully integrated and operates from its Wokingham Centre in England.

- For a Scottish national grid to be truly 'independent' and self-sufficient it would have to be able to provide its customers the same highly secure and reliable electricity supply all 365 days of the year – without being significantly dependent upon another country.

- A Scottish national grid must also be able to provide a service over a wide range of conditions, from low summer to peak winter requirements, and cope with unanticipated demands and 'loss of supply' shocks.

- Scotland's current contribution to the National Grid can be up to 12500 MW of which 2400 MW is nuclear power and 1500 MW is Gas. A variety of renewable sources can provide 8600 MW of which 7000 MW relies on wind turbines.

- Average demand in Scotland is about 3500 MW with a midwinter peak of 6000 MW meaning there is capacity available for 'export' to England through interconnectors that can cope with 5750 MW.

- Technical aspects of the current National Grid and the sources of power generation will have a significant impact on any separate Scottish grid.

- The National Grid's "Electricity Ten Year Statement" of November 2019 ETYS stated: *"The rapidly increasing generation capacity, mostly from renewable sources and mainly wind, connecting within Scotland is leading to growing needs in some areas. Across all the scenarios, the fossil fuel generating capacity in Scotland reaches nearly zero."*

- ETYS also noted... "*although gross demand in Scotland is not expected to exceed 6 GW, at times of low renewable output Scotland may need to* ***import*** *power from England. The present inter-connectors should be sufficient, but a Scottish grid might have to strengthen the South [England]-to-North [Scotland] equipment." [our emphasis in bold]*

- New transmission routes are required. The expanded (and still expanding) Scottish wind industry will have no market without new transmission lines to England. The recently constructed Hunterston DC link was a £1 bn joint venture between National Grid and Scottish networks.

- There is a real danger that Scottish wind turbines could become stranded assets; If the England and Wales grid is separated from Scotland there would be little incentive for National Grid to pay for a further interconnector when supplies could instead come from generators in England that would require less expensive investment.

- The ETYS report also argued the Peterhead Gas Power Station had to remain in service if secure supplies were to be ensured in Scotland due to the unreliable nature of renewable generation.

- Such problems can be managed while Scotland benefits from the availability of English generators connected to the UK grid.

- Writing in *Engineering and Technology* magazine, David Watson, argued that by depending on so much uncontrollable renewable power starting the whole grid up following any collapse could take up to five days and only then with input from generators in England – and that a stand-alone Scottish grid, with the present mixture of power sources would be unstable.

- In August 2019 a power cut was caused by a lightning strike affecting one million consumers through loss of 150 MW, then two large power stations, Hornsea One wind farm (737 MW) and Little Barford gas-fired (690 MW) caused a plunge in mains frequency and subsequent disconnections. Two of the owners made a voluntary payment of £4.5 million each into Ofgem's redress fund.

- By 2025 National Grid envisages an expansion of installed capacity in Scotland to at least 15000 MW. Hunterston B would, however, have closed so Torness alone would be required for base load with Peterhead retained to stabilise supply. Wind turbines would have expanded from 7000 MW TO 12000 MW.

- If Scotland had its own separate National Grid then wind output would be greater than the conventional plant by a factor of four. In certain weather conditions it would be impossible to balance the varying output from the wind sector because of the few controllable resources.

- At the other extreme, with Torness and Peterhead being the only full scale secure supplies, providing 6000 MW would probably be impossible on a cold winter's day with likely low wind speed.

- The two foregoing catastrophic scenarios would be magnified if electric vehicle numbers increase quickly – and longer term if gas heating is phased out in favour of electric alternatives.

- In 2020, Scotland produced 23.2 TWh amounting to 35% of UK wind energy of 65 TWh. Estimates for UK renewable subsidies in 2019-20 are £9 Billion, with Scotland receiving about £3bn of that.

- The cost to consumers of Scottish Renewable Obligation Certificates (ROCs) is estimated at £1.37bn with wind costing Scottish consumers about £1bn. The interruption of these substantial income streams would be highly destructive.

- By 2025 England may continue to require to import 5000 MW, but also might prefer to import continuous, reliable supplies via the European inter-connectors. It may decline against the more expensive, variable wind power from Scotland making the income absent and unavailable to Scotland.

- Grid network strengthening will be required from the north coast down to the border before any new renewable power plants can export electricity to the English grid, costing many hundreds of millions of pounds. The 200km-long Beauly-Denny 400 kV link cost £1 billion for a capacity of 1200 MW.

- If Scotland seceded then the English electricity market would not be obliged to take its existing supplies but could renegotiate, making purchase decisions based on their own commercial interests.

Conclusions

- An independent Scottish Grid is non-viable on the above evidence. Separating Scotland from the stabilising effect of the much larger UK National Grid would almost certainly weaken the network beyond recovery.

- Substantial Scottish investment will be required on north-to-south interconnectors to enable the electricity from any new wind farms to be fed towards the border with England.

- Closing conventional power stations such as Peterhead and Torness at the same time as increasing the number of wind turbines will risk serious instability and lengthy power cuts. Electric cars and heating will only worsen a bad situation. At times of low wind, all generation would be required to meet Scottish demand, leaving none for export.

- If Scotland left the UK, there would be no obligation for suppliers in England to buy renewable power under the ROC or related schemes.

- In addition, National Grid's commercial strength would enable it to dominate any contractual negotiations between the two parties because of the unpredictable nature of the wind power Scotland had to sell.

- If separated from the UK National Grid, an equivalent government subsidy would have to be established from Scottish consumers to owners of renewables. Since there is a disproportionate concentration of wind farms in Scotland, the cost per capita to households could be three times that levied across the UK

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The challenge of maintaining electricity supply in a Scotland outside the United Kingdom

Background

The SNP continues to pursue its vision of an 'independent Scotland'. Although the process of leaving the UK could not be achieved for several years, some important issues need to be investigated without delay so that any decisions are taken with an understanding of the material consequences. Over the centuries, the institutions and systems of the British mainland – England, Scotland and Wales – have become deeply intertwined, so that separating them is a substantial challenge and could bring some adverse consequences. Nowhere is this question more significant than in the supply of electricity.

Since the formation of the high voltage national grid system in the 1920s, the power supply structure in the UK has operated as an integrated whole. Privatisation brought administrative changes, but the operation and control of the grid remained largely unchanged. Operations from Lands End to John O' Groats are controlled from the Wokingham centre in England. Planning, design and maintenance pays little attention to national boundaries.

- Would a Scotland separate from the rest of the UK be able to establish an equivalent Scottish Grid, independent of England and Wales?

- Would 'independence' be seriously compromised if the English grid exercised substantial control over such an important commodity as electricity?

- What costs and financial penalties might be incurred?

This article examines the feasibility and implications of a separate Scottish High Voltage (HV) power grid.

Analysis

For a national grid system to be truly independent, it has to be able to provide electricity to its customers with a high level of supply security 365 days per year, without being significantly dependent upon another country. It must be able to provide a high integrity service over a wide range of conditions, from low summer demand to peak winter, and cope with unanticipated demands and 'loss of supply' shocks.

Scotland appears to be in a healthy position in that the total capacity of generators connected to the network (12500 MW) is about twice the maximum demand. However, this is to a large an extent an illusion, since the excess is mainly wind turbines that are not controllable, with highly variable outputs that do not match the need for continuous electrical supplies. Many wind turbines have been erected to export power to England at subsidised rates and preferential conditions.

The principal generators currently connected in Scotland are:

Hunterston B Nuclear Power Station; 1200 MW
Torness Nuclear Power Station; about 1200 MW
Peterhead Combined Cycle Gas Turbine; 1500 MW
Mid-sized hydroelectric plants aggregating to a few hundred MW
Pumped storage – Cruachan 440 MW
Pumped storage – Foyers 300 MW
Biomass 285 MW
Landfill Gas 109 MW
Wind turbines with a nameplate capacity of about 7000 MW.

Since average demand in Scotland is about 3500 MW and the midwinter peak is 6000 MW, it can be seen that there is the potential for over supply that could be exported. There are inter-connectors enabling Scotland to export about 5700 MW to England, although the 2250 MW Hunterston DC link is proving unreliable, with long outages. Two questions arise. How would an 'independent' Scottish grid look in 2021, and what would be the situation if Scotland were to leave the UK in say 2025?

Technical and Engineering Aspects

An appreciation of the developing challenge can be gained from the appraisal conducted in the National Grid "Electricity Ten Year Statement" November 2019 ETYS (Ref 1). Section 3.4 summarises the situation in Scotland, with four possible scenarios for future electricity supply, depending on policies and customer behaviour. ETYS noted that….

"The rapidly increasing generation capacity, mostly from renewable sources and mainly wind, connecting within Scotland is leading to growing needs in some areas. In three scenarios, inter-connector and storage increases. Across all the scenarios, the fossil fuel generating capacity in Scotland reaches nearly zero."

Investment is required now to handle increased generation. An expanded Scottish wind industry will have no market without new HV grid transmission lines to England. The recently constructed Hunterston DC link was a joint venture between National Grid ESO (Energy System Operator) and SP Networks. It cost over one billion pounds but has proved unreliable. New transmission routes are required.

If the England and Wales grid were separated from Scotland, there would be little incentive for National Grid to pay for a further HV link, when supplies could come from generators in England, that would require less expensive network investments. Scottish wind turbines would be stranded assets.

ETYS also noted that... *"although gross demand in Scotland is not expected to exceed 6 GW, at times of low renewable output, Scotland may need to import power from England. The present inter-connectors should be sufficient, but a Scottish grid might have to strengthen the South-to-North equipment."*

Apart from the power handling issues, ETYS noted that some associated problems were emerging...

"The reduction in synchronous generation could lead to challenges detecting reduced short circuit current levels and with inertia. This potentially leads to increasingly dynamic Scottish network behaviour depending on factors such as weather condition and price of electricity. Conventional synchronous generation (such as Peterhead) must remain in service to ensure secure supplies."

These problems can be managed for the time being because Scotland benefits from the stabilising effect of the generators in England connected to the UK grid. This instability and related problems were considered in an article by David Watson in Engineering and Technology magazine, April 2019 (Ref. 2).

He described the risk of lengthy power cuts after events such as a grid substation failure, lightning or overhead line faults or cyber attack. 'Black starting' the grid following widespread collapse, with the Scottish network being overloaded with uncontrollable renewables, could take up to five days and only then with input from generators in England. It is highly improbable that a stand alone Scottish grid, with the present mixture of power sources would be stable. It follows then that it could be fairly described as 'unstable'.

The Ofgem investigation into the August 2019 power cut that affected about one million consumers illustrates the developing problem. The loss of 150 MW of distribution after a lightning strike, then two large power stations, Hornsea One wind farm (737MW) and Little Barford (gas-fired 690 MW) caused a plunge in mains frequency and subsequent disconnections. Two of the owners made a voluntary payment of £4.5 million each into Ofgem's redress fund.

The European Network of Transmission System Operators, ENTSO-E (Ref 3.) has identified similar risks of frequency abnormalities in Germany and Italy with the increase in wind and solar power. The loss of large synchronous generators has weakened the ability of protection equipment to detect and isolate faults.

The Position in 2025

National Grid envisages an expansion to at least 15000 MW of installed capacity in Scotland by 2025. Hunterston B would have closed. Torness would be required for base load; Peterhead would be retained for a stable synchronised supply. The principal generators would be:

Torness nuclear power station; about 1200 MW
Peterhead CCGT; 1500 MW
Mid-sized hydroelectric plants aggregating to a few hundred MW
Pumped storage – Cruachan 440 MW
Pumped storage – Foyers 300 MW
Biomass 285 MW
Landfill gas 109 MW

Wind turbines with a nameplate capacity of about 12000 MW are envisaged.

If Scotland had its own National Grid then the figures above show that wind output could be greater than the conventional plant by a factor of four. It would be impossible to balance the varying output from the wind sector in certain weather conditions because of the few controllable resources. At the other extreme, providing 6000 MW on a cold winter day with Torness and Peterhead being the only full scale secure supplies, would probably be impossible at times of low wind speed. This problem would be magnified if electric vehicle numbers increase quickly – and longer term by the increased electricity demand if gas heating is phased out.

Financial Considerations

The wind power sector is supported by generous subsidies. These are Contracts for Difference (Cfds); Renewable Obligation Certificates (ROCs) and Feed in Tariffs (FiTs). Precise forecasts of the liabilities for a Scottish grid are not possible, but the calculations below indicate the general situation.

In 2020, Scotland produced 35% of UK wind energy, amounting to 23.2 TWh. Total UK on and offshore generation was 65 TWh. The Global Warming Policy foundation (GWPF) has calculated that the UK renewable subsidies in 2019-20 (Cfds; ROCs and FiTs) aggregate to about £9 Billion. A pro rata income for Scotland on that basis would be about £3 billion in renewable subsidies.

The total cost of ROCs to all UK consumers is 114.7m ROC x £54.43 (the notional value of the ROC) = £6.2 Billion.

Considering the ROCs issued to each country, Scotland had 25.2m out of 114.7m issued. The cost to consumers of Scottish ROCs is given by the 25.2m ROCs x £54.43 = £1.37bn.

Some 80% of the Scottish costs are due to wind, on and offshore, which receive about 19.9m ROCs and therefore cost consumers about £1 billion. Scotland's renewable generators get about 22% of the £6.2 billion… about £1.3 Billion

The interruption of these substantial income streams would be highly destructive.

Consider the situation from 2025 described by the National Grid ETYS at which time 15000 MW of generators might be connected in Scotland. England may continue to require to import 5000 MW, but might prefer to import continuous, reliable supplies via the European inter-connectors. It may decline the more expensive, variable wind power from Scotland. Such risks need to be addressed well in advance, since the subsidies and income from electricity exports amount to considerable sums and could become absent and unavailable to Scotland.

Investments in the Transmission Network

Consider the north-to-south flows within Scotland. ETYS includes the following statement related to the boundary B4, which is just north of the Glasgow and Edinburgh

latitude. Similar statements are included about future investments for all the Scottish boundaries.

"...With increasing generation and potential inter-connectors in the Scottish Hydro Electric (SHE) transmission area for all scenarios, the required transfer across boundary B4 is expected to increase significantly over the ETYS period."

Network strengthening will be required from the north coast down to the border before any new renewable power plants can export electricity to the English grid. No firm figures an be given, but costs of many hundreds of millions of pounds must be expected. The Beauly - Denny 400 kV link cost about £1 billion for a capacity of 1200 MW and is 200 km in length.

If Scotland left the UK, then the electricity market in England would not be obliged to take supplies from Scotland. If Scotland had its own National Grid then the commercial obligations between electricity distributors and the Scottish Generators would be renegotiated. English suppliers would not be under any obligation to take "low carbon" power from Scotland. They would be able to make purchase decisions based on their own commercial interests.

Wind power has been expanded to exploit the generous subsidies available for low carbon sources (as was intended). The UK legislation compels electricity companies to take wind power in preference to other forms of generation. There is some rationale for constructing power plants hundreds of miles from the customers if they are reliable ***but not if they are intermittent***. Low wind conditions would also provide a challenge if wind farm owners were contracted to supply power to England under a commercial contract. At the time of writing, 6 Sept 2021 wind power was producing less than 1.5% of UK demand. With these conditions, output from generators in Scotland – Torness, Peterhead and the larger hydro plants – would be required for domestic customers. There would be no power available for export to England.

There are also other costs that would have to be managed by an independent Scottish Grid. Balancing Services Use of System (BSUoS) is a service with charges incurred in the first instance by National Grid, with costs that are charged to both generators and suppliers, and ultimately recovered from consumers through higher retail prices. In 2019, this was almost £1.5 billion pounds for the whole of the UK. With the instability risks, any Scottish Grid would need the support of National Grid ESO (Energy System Operator) to maintain the grid 50 Hz supply. The Scottish Grid and the main suppliers in Scotland would almost certainly have to pay for this assistance (costing many of millions of pounds) many months before the expenditure could be recovered from customers.

Conclusions

- An independent Scottish Grid looks non-viable on the above evidence. Separating Scotland from the stabilising effect of the much larger National Grid would almost certainly weaken the network beyond recovery.

- Substantial investment will be required from within Scotland on the north-to-south network in Scotland to enable the electricity from any new wind farms to be fed towards the border with England.

- Closing conventional power stations such as Peterhead and Torness at the same time as increasing the number of wind turbines will risk serious instability and lengthy power cuts. At times of low wind, all generation would be required to meet domestic needs, leaving none for export.

- If Scotland left the UK, there would be no obligation for suppliers in England to buy renewable power under the ROC or related schemes.

- In addition, National Grid's commercial strength would enable it to dominate any contractual negotiations between the two parties because of the unpredictable nature of the wind power Scotland had to sell.

- If separated from the UK National Grid, an equivalent government subsidy system would have to be established from Scottish consumers. Since there is a disproportionate concentration of wind farms in Scotland, the cost per capita to households could be three times that levied across the UK

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