Life after SF_6 Cigre A3/B3 Presentation

Matthew Kayes – Plant Policy Manager Electricity North West Ltd

Representing an ENA industry group

3rd December 2024

Overview of the ENA

Electricity transmission members

1 Scottish & Southern Electricity Networks

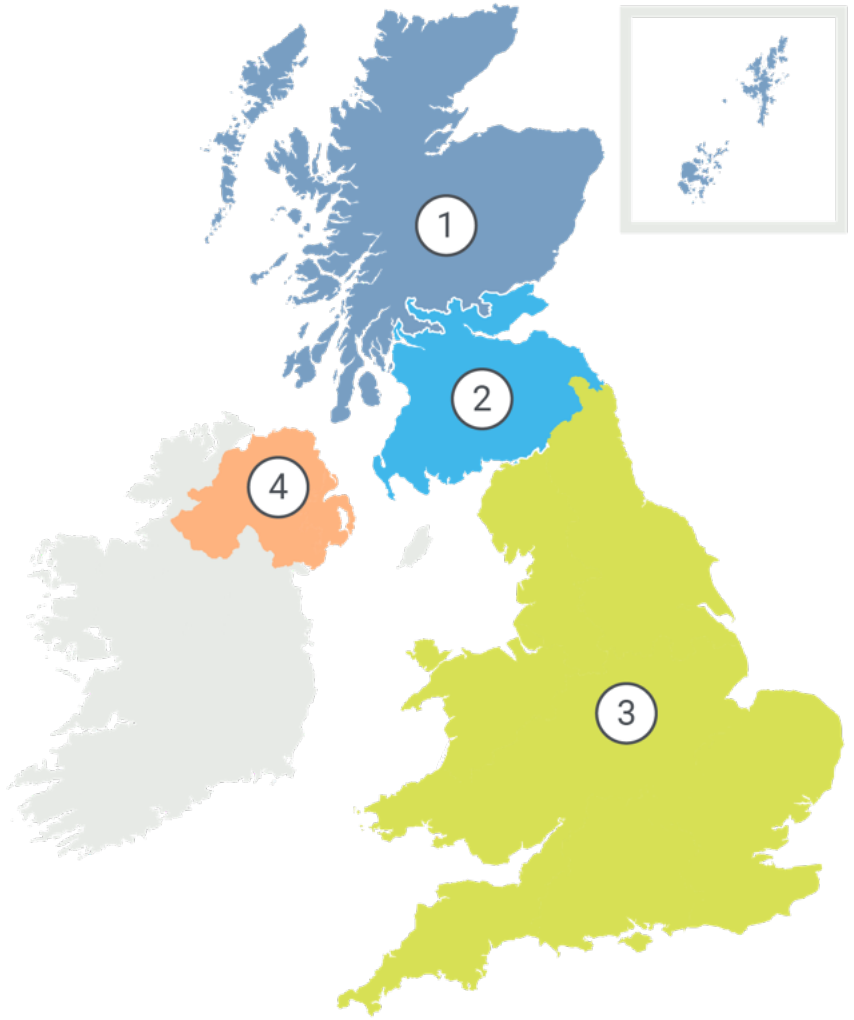
2 SP ENERGY NETWORKS

3 nationalgrid

4 Northern Ireland Electricity Networks

nationalgridESO

National Grid ESO is the transmission system operator for England, Scotland and Wales.



ena energynetworks association

Electricity distribution

1 Scottish & Southern Electricity Networks

2 SP ENERGY NETWORKS

3 NORTHERN POWERGRID

4 electricity north west
Bringing energy to your door

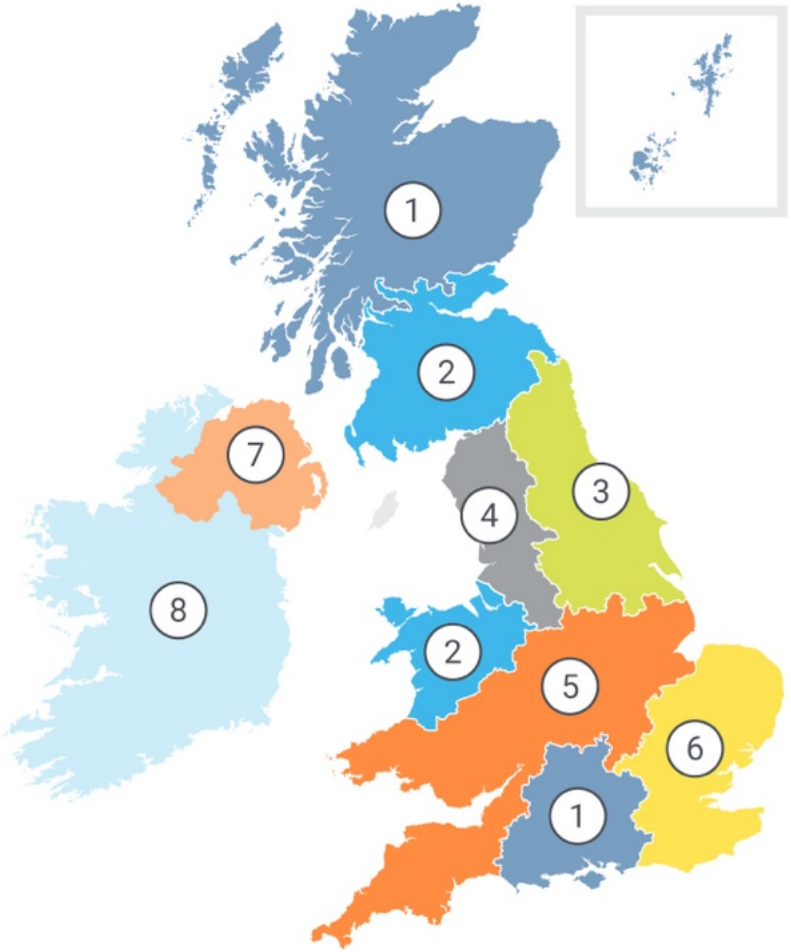
5 nationalgrid

6 UK Power Networks
Delivering your electricity

7 Northern Ireland Electricity Networks

8 ESB NETWORKS

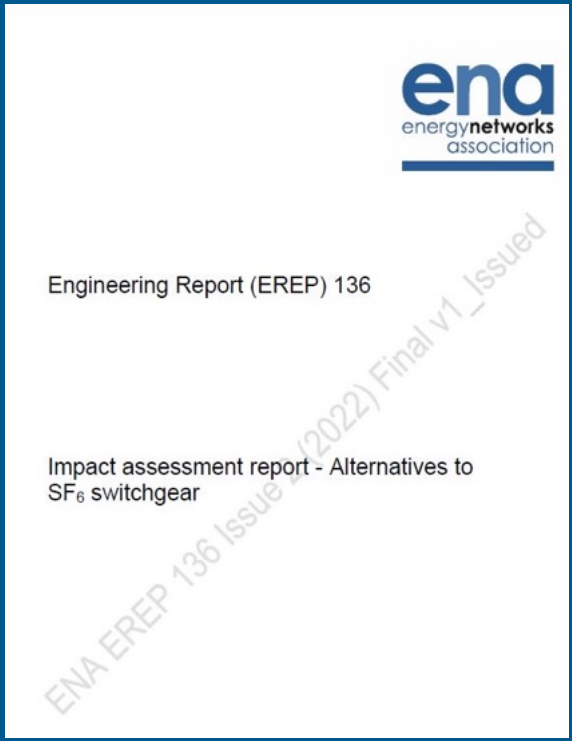
gtc Independent distribution network operator



2020 report – overview and outcomes

Engineering Report (EREP) 136

ENA Member Companies are supportive of global efforts to reduce the release of greenhouse gases to the environment.



Started in 2020.

Published in 2022.

Available to ENA Member companies.

EREP 136

- This report was commissioned to assist ENA Member Companies in the assessment of the possible effects of a move towards the use of SF_6-free distribution and transmission switchgear.

- We welcome the on-going development by switchgear manufacturers of designs of distribution and transmission switchgear which do not contain sulphur hexafluoride (SF_6) gas and are safe and practicable for use on the UK distribution and transmission networks.

- Whilst such designs have the potential to reduce SF_6 emission, they may at the same time cause other impacts on the UK electricity supply system.

EREP 136

- ‘Bottom-up’ data (individual unit data) was collected on numbers of units installed in the transmission and distribution network operating licence areas in GB and Northern Ireland, followed by a detailed study on what SF_6-free alternatives are being developed or are available (and how practical they would be to use) and an analysis of SF_6 emissions.

- A life cycle assessment of the possible alternatives was then carried out for eight to ten equipment types.

EREP 136

The asset data for SF_6 switchgear installed on the network, the SF_6-free alternatives and the life cycle analysis is representative of information collated in 2020.

Amendments to this report were completed in 2022 – these amendments focused on:

- A market review of SF_6-free alternatives (no significant changes were noted in this review at the time of issue – alternatives come to the market in line with Manufacturers road maps.)
- Inclusion of 275 kV and 400 kV switchgear replacement options in the life-cycle cost analysis.

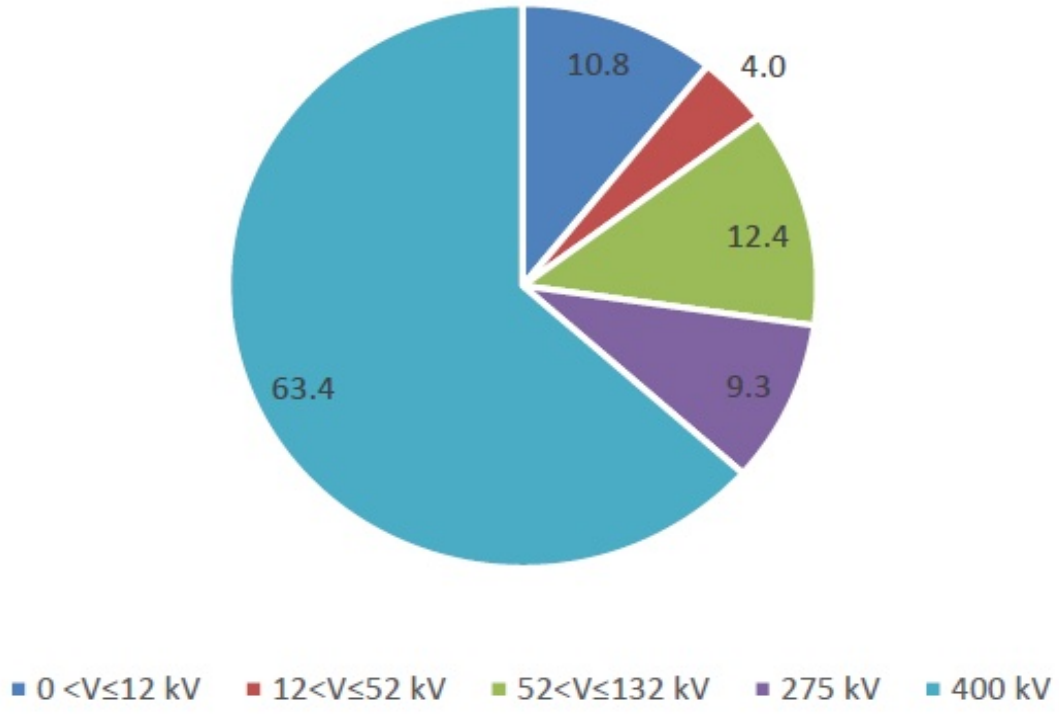
EREP 136 – Switchgear Population

The EREP looked at the volumes of Distribution switchgear which accounted for around 97% of the total population of 200,730 SF_6 switchgear units (in 2022) in service at all voltages (3% in Transmission and 97% in Distribution Networks).

Ring main units (RMUs) account for 70% of the total population of distribution SF_6 switchgear installed.

The total mass of SF_6 installed in electrical assets in the report was about 1300 tonnes. Circa 900 tonnes is on the Transmission network. Of the total remaining,15% (193 tonnes) is installed in Distribution Switchgear.

SF_6 % total mass installed by voltage range.



Emissions Data

Emission of SF_6 from switchgear in the report totalled about 15 tonnes per year. Of this, 9% (1.4 tonnes per year) is from distribution switchgear.

Despite transmission switchgear accounting for only 3% of the SF_6 switchgear population, loss of SF_6 gas from transmission switchgear represents 89% of total emissions (14.1 tonnes per year).

The remaining 2% is from abnormal top ups.

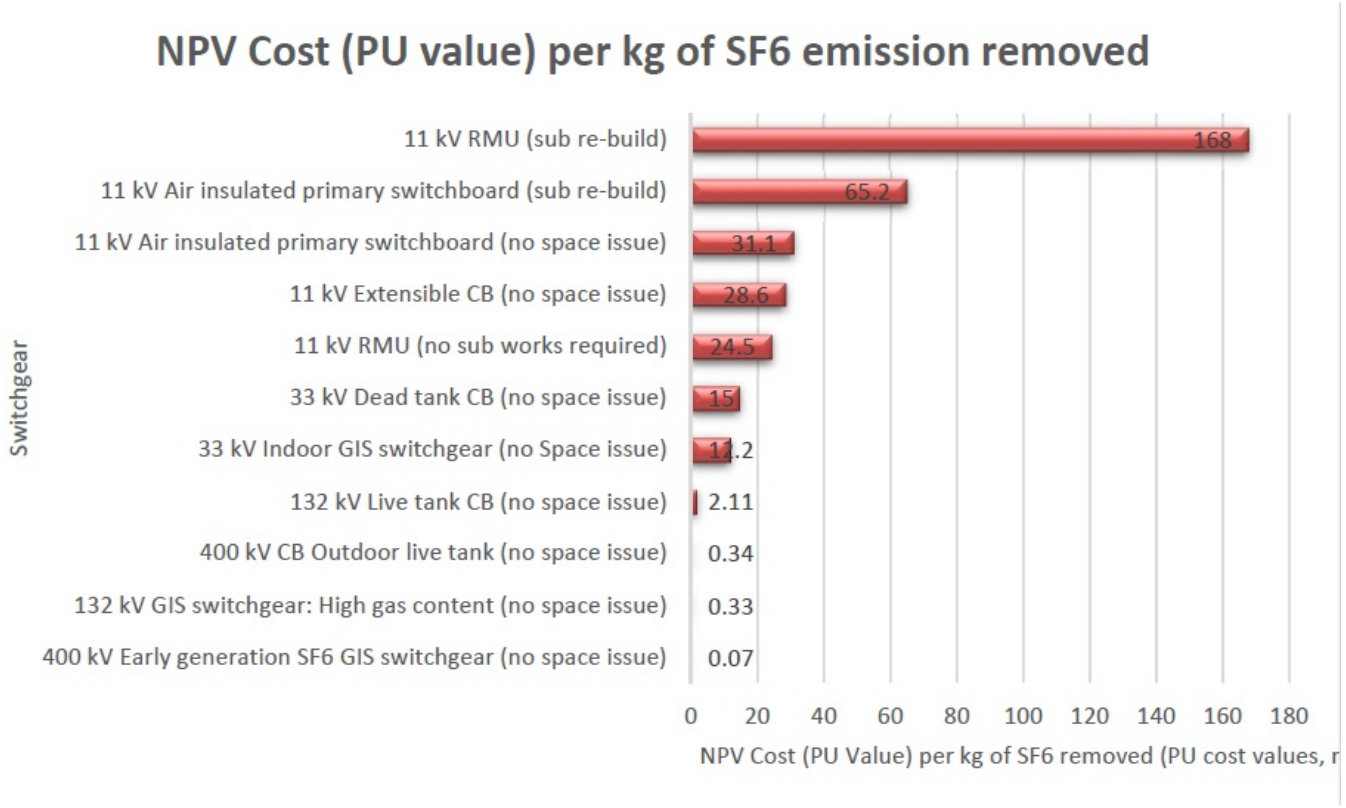
Life Cycle Analysis

A life cycle cost analysis was conducted using per unit (PU) values for purchase/installation/maintenance etc. The results of the life cost cycle analysis were used to determine a ‘cost per kg of SF_6 emission removed’ for replacement of switchgear with non-SF_6 switchgear.

The ‘cost per kg of SF_6 emission removed’ are directly comparable across the voltage levels.

Broadly speaking, the cost effectiveness decreases with decreasing voltage level, although the results are highly dependent on whether or not non-SF_6 equipment can be accommodated within existing substations. The graph on the next slide indicates the costs for a selection of switchgear types, voltages and replacement scenarios.

Life Cycle Analysis



SF_6 free alternatives

In general, there are alternatives to SF_6 switchgear on the market today for most of the switchgear applications in the range 11kV (including 6.6kV) to 132kV.

At system voltages of 66kV and above, manufacturers have been developing alternatives and working with end-users to bring these to market through pilot projects.

The rollout of non-SF_6 products at transmission voltages is in progress, with an expectation that all major switchgear applications will be addressed by 2025.

SF_6 free alternatives - continued

However, even though SF_6-free switchgear alternatives may be available, they may not be practicable for widespread adoption in the UK, particularly as like for-like replacements, due to an increased footprint or greater weight.

Other practical and operational issues specific to the UK have been identified that present barriers to the adoption of some non-SF_6-alternatives. These will require further consideration and the development of satisfactory solutions.

These issues are a greater for Distribution assets than transmission assets.

The report looked at all the issues faced for alternative products.

So where are we now?

In Limbo? Or just trying to complete the Jigsaw?

European Union

FGAS Regulations with the Implementation Dates starting on the 1st Jan 2026 through to 2030.

Network – Voltage level	SF_6 Ban Date
Distribution (6.6/11kV)	1st January 2026
145kV	1st January 2028
33kV	1St January 2030

PFAS regulations trying to ban the use of C4FN which we still need under certain conditions.

EU Reference Summary Scenario 2025 Technical Assumptions which state all FGAS emissions from all HV and MV switchgear will be net zero in 2030 (6 years' time and within the FGAS timetable).

Article 13 – implied all derogations are for Tenders post FGAS implementation dates.

UK Legislation

Current UK Legislation is the 2014 FGAS Regulations.

The ENA has written to the UK Government via Defra and DESNZ stating our support of the FGAS regulations but with a list of our concerns and questions.

The ENA is also arranging a conference on this topic in London on 11th and 12th February.

ED3 Framework Consultation recognises the EU legislation on SF_6 and the implications for the UK. (pages 101 – 103 sections 9.42 – 9.54)

9.47 The UK, Scottish and Welsh governments plan to publish a joint consultation in 2025 on potential revisions to the UK F-gas regulations. It is expected the joint consultation will propose to revise the current UK regulations to secure a more ambitious abatement of F-gases similar to the EU.

UK Legislation - continued

ED2 business plans were developed ahead of the change in legislation, and therefore were costed on the assumption of using existing equipment. Costs of alternative technologies are expected to be materially higher than these assumptions.

Ofgem recognised the uncertainty in this area and developed the Environment Re-opener to deal with changing legislation. Timing is important with re-opener applications and decisions needing to be aligned with new requirements and any effective ban date.

PFAS

ECHA (European Chemicals Agency) and the five member states published a progress report on the PFAS restriction process on the 21st November 2024.

Status – still awaiting Socio-Economic Analysis (SEAC) of PFAS ban in power sector

To date, the Risk Assessment (RAC) has reached a provisional conclusion on the hazard assessment of PFAS. In addition, provisional conclusions have been reached by the RAC and (SEAC) on five sectors: consumer mixtures and miscellaneous consumer articles, cosmetics, ski wax, metal plating and manufacture of metal products and petroleum and mining. These have a provisional status, because it is only when all sectors are discussed by both committees that final conclusions will be possible across the entire proposal. These conclusions will be documented in the final consolidated opinion from both RAC and SEAC, sent by ECHA to the European Commission.

PFAS

Considering alternative restriction options

- **The additional information brought forward in the 2023 consultation is also resulting in consideration being given to whether restriction options other than a ban may achieve the regulatory aim**
- **The proposal from 2023 suggested two ways to ban PFAS, either a full ban or a ban with time-limited derogations.**
- **They are now suggestion to, for some uses, to introduce conditions for continued manufacturing, selling and usage:**

  “ *where evidence suggests that a ban could lead to disproportionate socio-economic impacts. These alternative options are being considered for uses including, but not limited to batteries; fuel cells; and electrolysers*.”

Manufacturers and Trials

145kV Products

With 145kV products having the largest SF_6 volumes and higher leak rates all DNOs have been trialling products in this area first.

So far most of the products are available at 145kV level and member companies have trialled / trialling both dry air and alternative gas products.

- **Live Tank Outdoor CBs**
- **Dead Tank Outdoor CBs**
- **Indoor 132kV GIS**

In general, most outdoor alternatives fit existing spaces without issue. Indoor C4FN filled GIS fits into the same size buildings as SF_6 but Natural Origin Gasses need a bigger building.

The next slide demonstrates a Live Tank Outdoor C4FN filled CB on the Electricity North West Network.

Live Tank Breaker with alternative Gas

Example image of the old GEC FG1 145kV live tank.

GE's GL312 F1/4031g 145 kV live tank CB installed in 2022

33kV Indoor Switchgear

We have some time to look at the impact on these products and manufacturers are slowly demonstrating them to the DNOs and ENA. (Ban Date 2030)

The main issue here is extensions of existing products are difficult with the designs of the alternative dry air products and failure of existing assets without having to replace all of the switchgear.

The manufacturers are already ceasing SF_6 products we currently use which will mean we may have to change over earlier than the ban dates and at what cost without UK legislation.

Some of the products are bottom entry plug in style therefore needing to go back to basement substations again incurring higher civil costs and confined space mitigation.

Primary and Distribution Products – 20kV and below.

Primary switchgear has been vacuum in air for a number of years now and therefore is unaffected by this issue.

To date 20kV Distribution Product availability is very limited with Manufacturers stating they will endeavour to plug the gap in 2025.

For 11kV and 6.6kV Distribution Networks there are the following products available:-

- **Indoor extensible switchgear – needs a brick built building.**
- **IEC style extensible switchgear with an outdoor additional enclosure. (Factory Ordered).**
- **Indoor / Outdoor Ring Main Units**
- **Auto-Matic Pole Mounted Reclosers.**

Distribution Products – 20kV and below.

Missing Products at 11kV and 6.6kV

- Indoor / Outdoor rated extensible switchgear.
- Sectionalisers
- Automated enclosed switches
- Extensible Ring Main Units

There is a risk end users due to the EU date of the 1st Jan 2026 if these aren't developed in time.

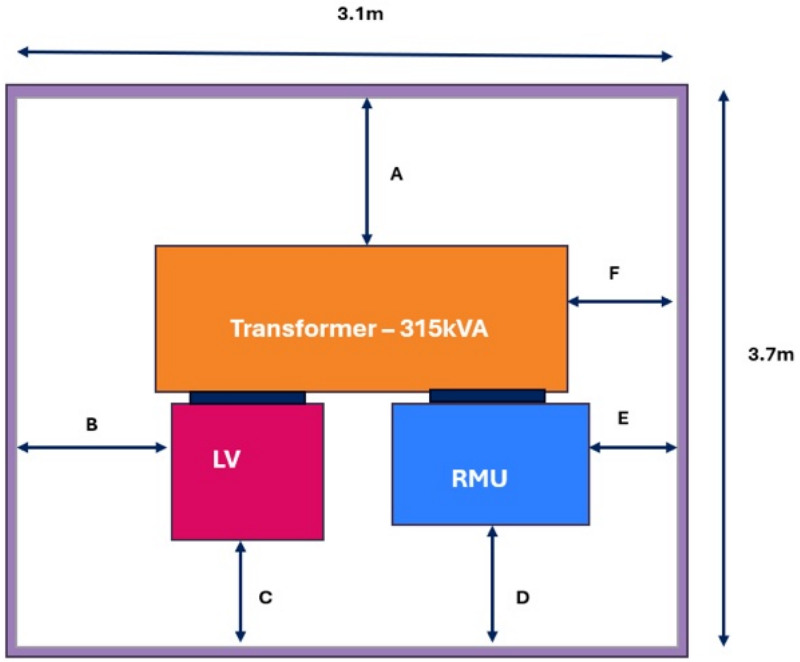
The next slide details the issues faced at distribution.

SF_6 free alternatives – permitted development

- The issues faced by Distribution assets are as follows.
  - Such factors include:-
  - Distribution substation - permitted development rules (29m3).
  - Extensions to existing assets.
  - Fault replacement of existing individual assets.
  - Internal Arc Venting Volumes when used in existing buildings.

Existing SF_6 filled Ring Main Unit in service.

Current Dimensional Assumptions



Key	SF_6	Alternative Gasses -ENWL std sub	Alternative Sub – 2.69 x 2.69m
A	1650cm		
B	75cm		
C	51cm	25.8cm	3cm
D	64cm		
E	56cm	46.5cm	3cm
F	67cm		

Distribution Switchgear Trials

UK Network Operators are committed to trialling alternative technologies to be certain of the network and cost impact.

DNOs have trialled or plan to trial in Q4 2024 / Q1 2025:-

- **Outdoor rated RMU both in Cable Connected and Unit Type Configuration.**
- **Indoor Rated extensible dry air switchgear.**
- **Pole Mounted Reclosers.**

We would like to trial more as soon as the Manufacturers have developed the missing products.

Benefits and Risks of alternative technologies.

Alternative Gasses

The switchgear manufacturers have developed two alternative solutions:

- Natural Origin Gasses (O_2, CO_2, N_2).
- C4-FN (C5-FN was discounted due to operating temperature constraints).

C4-FN (C4-fluoronitrile, C4FN) is a perfluorinated compound developed as a high-dielectric gas for high-voltage switchgear. It has the structure (CF3)2CFC≡N, which can be described as perfluoroisobutyronitrile, falling under the category of Per- and polyfluoroalkyl substances (PFAS), or per- and polyfluoroalkyl substances. C4-FN has insulation properties twice that of SF_6 and a relatively low Global Warming Potential (GWP) compared with SF_6.

C4-FN mixtures refers to the typically used gas mixtures including C4-FN mixed with natural origin gases (O_2, CO_2, N_2) which are used within high-voltage equipment. In one 145kV product as an example the gas make up is a mixture of 86.5% CO_2 / 10% O_2 / 3.5% C4-FN.

Alternative Gasses

C4-FN is seen as a credible alternative to SF_6 by the European Commission FGAS Regulations, offering the capability to replace SF_6 while keeping the same benefits of dimensional footprint and performance. But is still a fluorinated gas and comes under the PFAS regulations. C4-FN GWP is estimated at 2750 over 100 years. (compared to 23,500 for SF_6).

Natural Origin Gas technology is larger in footprint due to the need for larger clearances inside the switchgear to prevent flash over and failures. With larger sizes you need to utilise more raw materials such as steel and copper to make the larger products. Also, larger building sizes would be needed to house it. The cost of carbon for transport would also increase due to the larger size and weight.

It's a balance on carbon / environmental impacts.

Handling of Gasses Comparison

Gas	Number of Mixes	New Gas Carts Required	New Analyser Required	New PPE Required	New Handling Procedures Needed	UK Training Available	Top Up with Same Gas	Gas Quality Criteria Known
SF_6	1	No	No	No	No	Yes	Yes	Yes
Dry Air	4	Yes	Yes	Yes	Yes	No	Unknown	No*
C4FN	4	Yes	Yes	Yes	Yes	No	Unknown	No*

Under the Fgas regs from 2035 all SF_6 top ups needs to be reclaimed gas. Only one company in the UK can currently do this.

*Gas quality pass / fail seems to differ per OEM and product.

Conclusions

Conclusions

In summary the ENA and Member Companies support the FGAS regulations.

We need a UK Decision on FGAS as soon as possible to allow transition and net zero goals.

We need more companies offering training on gas handling.

We need more companies to have SF_6 reclamation plants before 2035 for asset maintenance.

We need the work on alternative good and bad gas thresholds to complete soon.

Conclusions

Trialling / using will give everyone an understanding on the impact of size, weight, transport issues and costings for the whole project including civils and the switchgear itself which is likely to be circa:-

- **10 to 20% more expensive (current indicative impact from the suppliers) at 132kV.**
- **20 to 30% more expensive at Distribution plus heavier incurring transportation carbon.**
- **Indications are that 33kV alternatives will be circa 50% more expensive.**

All DNOs are installing alternatives as well to gain an understanding on the cost and gas handling impacts of alternative technologies.

Conclusions

The manufacturers are ready for us to swap over for the bulk of the products we use.

We may need to do things slightly differently at 11kV and 6.6kV until all the current products we need supply catches up. Incurring additional civil and cabling costs.

Managing all the alternative gasses is complex due to the number of variants and mixes.

We are all using and trialling the assets with the largest volume of SF_6 already.

Conclusions

Extensions of existing assets at 33kV will be possible but may result in new switch rooms or large civil costs to allow cable connections / joggle chambers.

Extensions of 132kV existing sites is possible but as per 33kV the two bay spaces kept will reduce to one due to joggle chambers.

This long-term programme needs to be considered by the EU Reference Summary Scenario 2025 Technical Assumptions.

This is a long-term programme due to the number of assets installed and the cost to replace all existing assets is too high therefore need to be managed until end of life (40 to 60 years).

Energy Networks Association
4 More London Riverside
London SE1 2AU
t. +44 (0)20 7706 5100

@EnergyNetworks
energynetworks.org

Energy Networks Association Limited is a company registered in England & Wales No. 04832301
Registered office: 4 More London Riverside, London SE1 2AU

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