G+ Safe by design

Workshop report update: WTG service lifts – follow-up on workshop conclusions

G+ Global Offshore Wind
Health & Safety
Organisation

In partnership with

energy institute

G+ SAFE BY DESIGN REPORT

WORKSHOP REPORT UPDATE: WTG SERVICE LIFTS – FOLLOW-UP ON WORKSHOP CONCLUSIONS

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1 BACKGROUND

The G+ Global Offshore Wind Health and Safety Organisation (G+) comprises the world's largest offshore wind developers who have come together to form a group that places health and safety at the forefront of all offshore wind activity and development. The primary aim of the G+ is to create and deliver world-class health and safety performance across all activities in the offshore wind industry. The G+ has partnered with the Energy Institute (EI) to develop materials, including good practice guidelines for the offshore wind industry, in order to improve health and safety performance. Through sharing and analysis of incident data provided by G+ member companies, an evidence-based understanding of the risks encountered during the development, construction and operational phases of an offshore wind farm project has been developed. This information has been used to identify the health and safety risk profile for the offshore wind industry.

In 2014, The Crown Estate asked the G+ to take over the running and delivery of their Safe by Design workshops. The Crown Estate had run a number of these previously, covering topics such as diving operations, lifting operations, wind turbine design and installation and the safe optimisation of marine operations.

By bringing the Safe by Design workshops into the G+ work programme, the G+ aims to explore industry operations and technologies with a focus on Safe by Design principles. The G+ workshops examine the current design controls relating to a specific topic, discuss where current design has potentially failed, identify opportunities for improvement and then seek to demonstrate the potential risk reduction to be gained from these new ways of thinking.

A Safe by Design workshop on wind turbine generator (WTG) service lifts was held on 22 September 2016 in London. From this workshop a report was published, with recommendations (G+ *Safe by Design workshop report: WTG service lifts*). Due to the number of recommendations and the work required, external consultants, ORE Catapult and One Stop Wind, were contracted to close out the recommendations. Eleven reports were produced from the recommendation-close out and this document acts as a summary.

2 RECOMMENDATION 3: CONSULT WITH THE RELEVANT UK AND EU NOTIFIED BODIES WITH THE OBJECTIVE OF DEVELOPING A CONSISTENT ASSESSMENT APPROACH TO WTG SERVICE LIFTS IN USE ACROSS THE WIND INDUSTRY

2.1 LIST OF NOTIFIED BODIES

Wind turbine service lifts are excluded from the Lifts Directive 95/16/EC, because they are attached to machinery and are intended exclusively for access to the workplace. Wind turbine service lifts are included in the Machinery Directive 2006/42/EC.

Within the Machinery Directive 2006/42/EC the category of machinery which is of relevance is:

– 17. Devices for the lifting of persons or of persons and goods involving a hazard of falling from a vertical height of more than three metres.

There are at present 131 Notified Bodies listed by the European Commission (EC) Nando portal as accredited for conformity assessment according to category 17 of the Machinery Directive 2006/42/EC.

2.2 SUMMARY OF ENGAGEMENT

An initial screening was conducted by reviewing the listed webpage and any available track record for each Notified Body. This review was used to categorise the list and prioritise engagement. The result of initial website and track record screening showed:

1. 107 Notified Bodies do not outwardly advertise any relevant or specific capability relevant to category 17.
2. 14 Notified Bodies state or show some relevant track record.
3. 10 Notified Bodies explicitly state that they have a track record and/or regularly work with wind turbine service lifts.

This suggested that, whilst lifting machinery is a market well served by a number of Notified Bodies (in most cases there are several from each EU member state), the area of wind turbine service lifts remains relatively specialist and therefore is relevant to the capabilities of only a small number of Notified Bodies.

All 131 Notified Bodies were contacted using the details provided in the Nando online portal. Initial contact was made to establish whether they had experience or sufficient capability to perform conformity assessment of wind turbine service lifts in line with the Machinery Directive 2006/42/EC.

Organisations who responded to an initial enquiry were then directly asked:

1. Against which standard(s), recommendation(s), or other guidance they would conduct the conformity assessment of a service lift in a wind turbine.
2. Whether they have conducted any conformity assessment of products for this specific application in the past.

3. Whether the Client for conformity assessment(s) that they have completed was the lift system manufacturer or the wind turbine manufacturer.
4. Whether they felt that there is a consistent approach to the assessment of wind turbine service lifts across the industry at present.
5. Whether they were aware of, or had any opinion on, any initiatives already underway to address any inconsistencies.
6. To share the recommendations for use (RFU) sheet that their Notified Body would use to assess the conformity wind turbine service lifts.

On being asked these questions:

1. 77 Notified Bodies did not respond.
2. 16 Notified Bodies declined to participate either on the basis that they were not sufficiently capable or experienced in the area, they did not have enough time available, or that they would not do so without being paid.
3. 22 Notified Bodies provided a response or acknowledgement without providing any technical detail or answers.
4. 13 Notified Bodies provided at least one response, and these organisations were considered to be engaged.
5. Three Notified Bodies provided a response to each question and/or sent several responses or conversations, and these organisations were considered to be highly engaged.

2.3 FINDINGS

Through the engagement described in 2.2 it was evident that:

1. Notified Bodies who responded confirmed their accreditation and cited the Machinery Directive 2006/42/EC as the document which would govern their conformity assessment of wind turbine service lifts.
2. The essential health and safety requirements (EHSRs) contained within the Machinery Directive 2006/42/EC are clearly a key reference when performing an assessment of conformity of a wind turbine service lift.
3. There was reasonably consistent (though not universal) citation of EN 81-44 as a standard currently in development by CEN TC10 that is directly relevant to this area. Most responses citing this standard also noted the lack of certainty about a potential publication date for this standard.
4. Notified Bodies referred to several other standards as potentially of relevance in their responses. The most commonly cited are listed as follows, and a comprehensive list is provided in Annex B.
    a. BS EN 1808 *Safety requirements for suspended access equipment. Design calculations, stability criteria, construction. Examinations and tests.*
    b. BS EN 50308 *Wind turbines. Protective measures. Requirements for design, operation and maintenance.*
    c. BS EN 81-20 *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts.*
    d. BS EN 81-41 *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Vertical lifting platforms intended for use by persons with impaired mobility.*

e. BS EN 81-43 *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Lifts for cranes.*

f. BS EN 81-50 *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components.*

g. BS EN 12159 *Builders' hoists for persons and materials with vertically guided cages.*

h. ISO 22201-1 *Lifts (elevators), escalators and moving walks. Programmable electronic systems in safety-related applications. Part 1: Lifts (elevators) (PESSRAL).*

5. In general, it was stated that the client for conformity assessment would usually be the lift system manufacturer. However, there were also several references to wind turbine manufacturers instructing Notified Bodies to conduct conformity assessment on their behalf. Many Notified Bodies also provide inspection services, where their client is most commonly the turbine manufacturer or owner operator.

6. Notified Bodies generally insisted that it remains the responsibility of the lift system manufacturer to ensure that a product which is fully compliant with relevant directives is put into service. It is interesting to contrast this to the anticipated practical reality, where a lift system manufacturer may commonly not be involved in the integration and/or commissioning of their systems by the end client (usually a WTG OEM).

7. Some Notified Bodies described a track record in the type certification of wind turbines. Whilst not totally clear, it appears that, since wind turbine type certification will rely upon standards which exclude the service lift from their scope (such as the IEC 61400 series and BS EN 50308), it is expected that turbine type certification will be agnostic to the presence or particular design of lift installed in the turbine being certified.

8. Some Notified Bodies supplied or cited the public collection of current Vertical RFUs as published by the EC [2]; however, most also noted that as it remains unendorsed, the RFU specific to wind turbine service lifts has not yet been made publicly available.

9. Some Notified Bodies highlighted the status of an RFU, which serves as a recommendation but need not be considered mandatory.

10. Some Notified Bodies, generally those with some involvement in the Vertical Group (VG9) supplied a copy of the CNB/M/09.318/E/E RFU. Copies of several different revisions were received, from Rev00 to Rev06. In total, three different versions of this document were received.

11. Some Notified Bodies referenced the Lift Directive 2014/33/EU, although this was usually in reference to their experience and capabilities rather than specifically suggesting that they would use that for a conformity assessment. It was evident that there is likely to be relevant experience from Notified Bodies who are familiar with the Lift Directive even when the directive does not apply.

12. When asked about consistency, some Notified Bodies expressed a sentiment that there was adequate consistency at present, whereas others felt that there was not a consistent approach. Aspects of responses that support the view that there will at present be a consistent approach include:

    a. It is clear that any system which is assessed for conformity under the Machinery Directive 2006/42/EC should as a minimum meet the essential safety requirements described in the directive. In this aspect there must be consistency, as it seems highly likely that these minimum essential requirements are understood and applied by all Notified Bodies.

b. Referencing of standards such as EN 1808 which are relatively generic suggest that there is likely to be some conservatism built into assessments, and in some instances taking relevant parts of various standards may offer several 'bites of the cherry' to arrive at a robust assessment.

Aspects of responses which suggested inconsistency were:

a. Where there is not a public harmonised standard there is a possibility that Notified Bodies (and equipment manufacturers) will refer to parts of other potentially relevant standards with good intentions. This, in combination with the skills and experience of the Notified Body, would be used to define their assessment approach. However, because what constitutes a relevant reference may be subjective there is the possibility of an inconsistent approach.

b. There is not clarity about when either the draft RFU or draft harmonised standard will be finalised and published. As draft versions of each exists within organisations but are not publicly available it is anticipated that the application of these reference sources may be sporadic, and certainly not universal.

c. Although not suggested directly in statements, it appears possible, based on the varied content of the responses received, that a manufacturer may be exposed to a varying degree of rigour depending upon the Notified Body selected.

13. It was evident that Notified Bodies do not generally desire or seek to share information with each other, and that whilst some were aware of, and engaged with, the development of EN 81-44 (*Lifting appliances in wind turbines*) and/or vertical group (VG9) others took the position that creation of a harmonised standard should be the responsibility of system manufacturers and not the Notified Bodies themselves.

14. Some Notified Bodies who responded described periodic inspection services for the wind industry as scope within their capabilities, which may serve as a compementary means of gaining a practical understanding of lift systems 'as built' in the operational environment. Although it may be common, inspection services are not offered by all Notified Bodies, which is expected to result in varying levels of practical experience between Notified Bodies.

2.4 BARRIERS AND SOLUTIONS

Based on the engagement findings, the following may present barriers to a consistent assessment by Notified Bodies:

1. No published RFU.
2. Uncertainty about the date when the RFU will receive the remaining endorsement required to allow publication on the EC website.
3. No published harmonised standard (EN 81-44 most frequently suggested as suitable).
4. No visibility of draft copy or table of contents of EN 81-44 and uncertainty about route to, or expected date of, publication.
5. Varying levels of experience between Notified Bodies.
6. Low apparent level of knowledge and information sharing between Notified Bodies.
7. Complex landscape of potentially relevant standards for lifts and lift systems.
8. Possible ambiguity about the inclusion or exclusion of service lifts in wind turbine type certification.

Potential solutions to these barriers are:

1. Sharing of the RFU (the most recent revision, which we understand to be Rev06) with all Notified Bodies.
2. Endorsement of this RFU by the Machinery working group, and subsequent public release through the EC website [2].
3. Development and release of the EN 81-44 harmonised standard. Ideally, all Notified Bodies could also be provided with visibility of when this standard will be available as a draft for comment.
4. A mechanism to enable Notified Bodies to communicate and share knowledge with each other.
5. Consistent treatment of wind turbine type certification and a single clear definition of what is and is not in the scope of these approvals with regard to the integration of service lifts.

3 RECOMMENDATION 4: OBTAIN AND DOCUMENT THE RELEVANT DETAILS ON THE STATUS AND CONTENT OF THE IEC 61400–30 WTG SAFETY SYSTEMS AND EN 81-44 DESIGN STANDARD FOR WTG LIFTS

3.1 HARMONISED PRODUCT STANDARD

The design of the lift should minimise risks both during normal operation and foreseeable maintenance activities, such as by ensuring that the suspension ropes of the lift can be inspected from a place of safety that provides a clear view of the ropes. Operating procedures should take account of reasonably foreseeable malfunctions, such as the lift stopping at a level other than a designated landing and ensure that a safe means of escaping from the lift is available, and that personnel using the lift are trained and competent in this procedure. Inspection and maintenance programmes should ensure that the lift operation is safe and reliable throughout the lifetime of the WTG.

To date, there is no harmonised product C-standard available for WTG service lifts. The manufacturer will therefore need to have a quality assurance system in accordance with Appendix 1 of the Machinery Directive in place. Alternatively, they will need to have EC-type examination carried out by a Notified Body.

Since early 2016, a harmonised product C-standard (EN 81-44) for this type of machinery is under development. CEN/TC 10, CLC/TC 88 and ISO/TC 178 are cooperating on this work.

A harmonised standard 'is a European standard elaborated on the basis of a request from the European Commission to a recognised European Standards Organization (CEN, CENELEC or ETSI) to develop a European standard that provides solutions for compliance with a legal provision. Such a request provides guidelines which requested standards must respect to meet the essential requirements or other provisions of relevant European Union harmonisation legislation.

Compliance with harmonised standards provides a presumption of conformity with the corresponding requirements of harmonisation legislation. Manufacturers, other economic operators or conformity assessment bodies can use harmonised standards to demonstrate that products, services or processes comply with relevant EU legislation [1].'

Meanwhile, in the absence of a harmonised standard, the Machinery Directive Working Group of the European Commission has drawn up a RFU. This is a working document for Notified Bodies and this RFU should be used by manufacturers as state of the art until standard EN 81-44 has been harmonised.

3.2 IEC/TC 61400–30 WTG SAFETY SYSTEMS

- Standard reference: IEC/TS 61400-30 (Ed. 1.0).
- Standard description: *Wind turbines. Part 30: Safety of wind turbine generator systems (WTGs) – General principles for design.*
- Committee: PEL/88 Wind turbines.
- Category: Unclassified documents.

3.2.1 Current scope, status, content, and development timelines

The technical specification (TS) specifies EHSR related to the design of WTGs aimed at the safety of personnel only. EHSRs defined in this standard are related to the design of horizontal WTGs with a rotor area ≥200 m^2. For other concepts (e.g. vertical axis turbine and floating WTGs), the principles are still valid, but the specific rules and requirements must be adjusted to the actual concept. The WTG design must follow the requirements for safe operation, maintenance and repair without putting persons at risk. Identification of ESHRs, their risk assessment and risk reduction, are done by using the principles from the standard ISO 12100:2010 *Safety of machinery – General principles for design – Risk assessment and risk reduction* following its structure for a C-standard (machines safety standard dealing with safety requirements for a machine or group of machines).

The measures adopted to fulfil the EHSR shall apply with the following principles in the order given:

- Eliminate or reduce risks.
- Take the necessary protective measures in relation to risks that cannot be eliminated.
- Inform users of the residual risks due to any shortcomings of the protective measures adopted, indicate whether any particular training is required and specify any need to provide personal protective equipment.

This TS should be used together with the appropriate IEC and ISO standards mentioned in Clause 2 (of ISO 12100:2010).

The standard development timelines are shown as follows along with the status, which at the time of writing is: 3. Public Comments. There have been zero comments received.

1. Proposal (*complete*).
2. Draft (*complete – draft start date: 07/11/2015*).
3. Public comments.
4. Comment resolution (*comment resolution start date: 22/05/2017*).
5. Approval.
6. Publication (*publication expected in 2019*).

3.3 ADDITIONAL INFORMATION

The document is being developed in IEC/TC88/PT 61400-30 and a UK shadow group under PEL/88 on IEC/TS 61400-30 has been convened.

The document is still at an early stage of development and concern over speed of progress has been expressed. It is being worked on for a committee draft ballot for technical comment and is expected to be published in 2019.

It is not being voted on by European Committee for Electrotechnical Standardization (CENELEC), but could be ratified by CLC/TC 88 if a decision is taken to make it a European Standard.

The participation is by the UK, Spain, Denmark, Germany and the USA.

3.4 EN 81-44 LIFTING APPLIANCES IN WIND TURBINES

- Standard reference: EN 81-44.
- Standard description: *Lifting appliances in wind turbines*.
- Committee: CEN/TC 10.

3.4.1 Current scope, status, content, and development timelines

This European Standard specifies the safety requirements for the construction and installation of power operated lifting appliances installed permanently in wind turbines (referred to hereafter as a lift) and intended for access to workplaces on wind turbines by authorised competent persons. A lift serves defined landing levels and may move persons to working positions where they are carrying out work (which could be from the carrier) and has a carrier which is:

a) Designed for the transportation of persons and goods.
b) Guided.
c) Travelling vertically or along a path within 15 degrees maximum from the vertical.
d) Supported or sustained by rack and pinion, rope traction drive, noncircular elastomeric-coated steel suspension members (hereafter called flat belt) traction drive, rope positive drum drive, toothed belts.
e) Travelling with a speed not more than 0.74 m/s.
f) Operating ambient temperature range between – 20 °C to + 55 °C.

3.4.2 Additional information

This standard is to be harmonised under the Machinery Directive. There is cooperation between CEN/TC 10, CLC/TC 88 and ISO/TC 178, and work commenced in January 2016. The convener is Jukka Laaksonen and the secretary is Mechanical Engineering and Metals Industry Standardization (METSTA) in Finland. The participating members are manufacturers of hoists and lifts, manufacturers of wind turbines and Notified Bodies (Finland, Germany, Netherlands, Poland).

4 RECOMMENDATION 5: RESEARCH AND DOCUMENT ANY SAFETY-RELEVANT INFORMATION ALREADY IN CIRCULATION WITHIN THE NOTIFIED BODY COMMUNITY RFU SHEETS ON WTG SERVICE LIFTS AND IDENTIFY ANY INFORMATION RELEVANT TO OFFSHORE WIND FARM OPERATORS

4.1 NOTIFIED BODIES

Notified Bodies are appointed under, and operate according to, the law that transposes the provisions of the corresponding Directives. The Directives apply in the European Economic Area (EEA). Using the United Kingdom as the example, the conformity assessment bodies are appointed by the Secretary of State in accordance with the Regulations. These third-party bodies, once assessed for their competence and appointed by the Secretary of State, are then notified to the European Commission and become Notified Bodies for the purposes of carrying out conformity assessment of products under the relevant Directive.

UKAS, the UK's national accreditation body, has been appointed by the Secretary of State to carry out assessment of eligibility of applicants. All applicants are required in the first instance, to make an application for accreditation to UKAS which will undertake an assessment of the applicant against the minimum requirements of the relevant directive and (where applicable) the relevant harmonised standard(s) (see 3.3) to ensure that the applicant complies with the requirements.

These applicants for accreditation (to become a Notified Body) are required to demonstrate conformity with the requirements set out in the Regulations by being accredited to the appropriate scope of one, or more, of the relevant ISO 17000 series of standards, which contain requirements for bodies issuing certificates, performing inspections or conducting tests.

Whilst the UK was used in example above, comparable governance exists across the EEA countries.

The European Union aims to reach Mutual Recognition Agreements (MRAs) with key trading partners. Under these agreements, EU Notified Bodies may be eligible to perform conformity assessments as required by the third country's laws and, similarly, those trading partners' equivalents to Notified Bodies may be eligible for appointment to perform conformity assessments under EU Directives.

4.1.1 Role of the Notified Bodies

The role of a Notified Body is to conduct a conformity assessment under the relevant EU Directives. The conformity assessment usually involves an audit of the manufacturer's quality system and often a review of the relevant technical documentation provided by the manufacturer in support of the product safety and performance claims.

Once the Notified Body has determined a manufacturer has conformed to the relevant assessment criteria, it issues a CE certificate to show that the products assessed meet the requirements. The manufacturer signs a declaration of conformity and applies the CE mark (with or without the Notified Body number).

4.2 HARMONISED PRODUCT STANDARD

The design of the lift should minimise risks both during normal operation and foreseeable maintenance activities, such as by ensuring that the suspension ropes of the lift can be inspected from a place of safety that provides a clear view of the ropes. Operating procedures should take account of reasonably foreseeable malfunctions, such as the lift stopping at a level other than a designated landing and ensure that a safe means of escaping from the lift is available, and that personnel using the lift are trained and competent in this procedure. Inspection and maintenance programmes should ensure that the lift operation is safe and reliable throughout the lifetime of the WTG.

To date, there is no harmonised product C-standard available for WTG service lifts. The manufacturer will therefore need to have a quality assurance system in accordance with Appendix 1 of the Machinery Directive in place. Alternatively, they will need to have EC-type examination carried out by a Notified Body. Meanwhile, working group TC10/WG11 is currently working to create a harmonised product C-standard (EN 81-44) for this type of machinery and Notified Bodies are represented in this working group.

Currently, there are several manufacturers with EC type certified products but providing various safety performances. The working group for Machinery is aware of this. This working group examines issues which arise from implementing the Machinery Directive and advises the Machinery Committee. It has representatives from the member states, policy workers from the European Commission and representatives of stakeholders.

Thus, the working group has asked the Vertical group 9 (VG9) for an RFU for lifts in wind turbines to be drawn up. VG9 are Notified Bodies who have been appointed for Category 17 hoisting and lifting equipment used for lifting persons or persons and goods in the event of a free fall risk of over 3 m.

As a result, the Machinery Directive Working Group of the European Commission has drawn up a RFU. This is a working document for Notified Bodies. Thus, the RFU has become mandatory for Notified Bodies to use in the event of certification projects. This RFU should be used by manufacturers as state of the art until standard EN 81-44, has been harmonised. Endorsement of this RFU by the working group is awaited but described as merely a formality.

4.3 RFU SHEET FOR WIND TURBINE SERVICE LIFTS

The main requirements of the RFU are:

- In order to prevent impact and trap risks at the stops and if the distance from the platform to the ladder is less than 0.5 metre, both the bottom and top of the platform must be provided with a safety feature.
- The stops must be provided with doors or fencing, complemented by the above-mentioned impact and trap risk safety feature. If the distance from the platform to the stop is greater than 0.5 metre, fencing only will suffice.
- It must not be possible for the barriers to be opened at the stop before the platform has reached the required floor level.
- It must be possible to use additional facilities to open the barriers for when the ladder is used (if provided) when the platform is not there.
- It must not be possible to open the platform door between the floor levels. If this is essential for maintenance purposes, it must not be possible to lift/lower the platform

any further and additional measures must be taken for the user to prevent falling from height.

- Due to a lack of space and the risk of falling objects, usually a full enclosure of the carrier is necessary.
- Measures must be taken to be able to evacuate the users in an emergency.

4.4 AVAILABILITY OF THE WTG SERVICE LIFT RFU SHEET

All endorsed RFUs are published on the European Commission's website, which is the established process for the Notified Body community to distribute such documentation. The link to the website is: http://ec.europa.eu/growth/sectors/mechanical-engineering/machinery

There is one RFU sheet for WTG service lifts. As outlined previously, this specific RFU is not yet endorsed by the Machinery Working Group (MWG), just approved by the Vertical Group and the Horizontal Group so is not yet available on the website cited. However, the Vertical/Horizontal Group approval allows the Notified Bodies to use it whilst awaiting the formality of MWG endorsement.

4.5 NOTIFIED BODY COMMUNITY

The Notified Body community will use the RFU in certification projects until standard EN 81-44 is published. As stated in 4.4, since this specific RFU is not yet endorsed by the MWG it is not available through the European Commission's website referenced, but shared through the Notified Body community.

4.6 SURVEY DATA

Persons that work on/use WTG service lifts were surveyed to determine if they had any awareness of the RFU and if so, how useful it is with respect to safety relevant information. In addition to the online survey, face to face interviews were conducted with wind farm technicians and service lift maintenance and inspection personnel.

The results of the survey (54 responses) showed that although some respondents (~15 %) indicated they received safety relevant information from RFUs, the clear majority did not. The majority group (~85 %) indicated that they received safety relevant information from sources such as their own organisation, the turbine OEM, or wind farm owner and often from more than one of these sources.

This minority group (~15 %) of respondents who received safety relevant information from RFUs obtained this in various ways e.g. toolbox talks, email, internet search. They also stated that they received the same information contained in the RFU from other means e.g. from their own organisation/turbine OEM/wind farm owner's documentation and communications, and this was the primary method of receiving safety related information, not through RFU sheets. They confirmed that the RFUs did not contain any information that they hadn't already received via their own organisation.

Of the clear majority who did not receive safety relevant information from RFUs, most of these respondents also stated that they hadn't seen and/or were not aware of what an RFU was and its intended purpose.

4.7 FACE-TO-FACE DISCUSSIONS

When visiting wind farms and discussing Notified Bodies/RFUs with the technicians, a similar overall response was received, but with some noteworthy differences when compared to the survey results. This difference over the online survey results was attributed to the face-to-face direct discussion employed with these technicians. From these discussions, it emerged that there was little awareness of Notified Bodies/RFUs or what their purpose was, and they were not used as a source of safety related information by the technicians. This notable difference between approximately 15 % of online survey respondents recording that they use the RFU to obtain safety relevant information compared to none stating this when discussing face-to-face can be explained. It is believed that this minority of online survey respondents have interpreted the RFUs as being other documents/information such as the lift manufacturers' user manual. The online survey group was unable to ask questions or have points expanded upon and this accounts for the ~15 % who associated an RFU with an instruction manual or similar.

5 RECOMMENDATION 6: LEVERAGE THE KNOWLEDGE, SKILLS, EXPERIENCE AND CAPABILITY OF TECHNICIANS TO RATIONALISE AND PRIORITISE WHAT IS CONTAINED IN PRE-USE CHECKLISTS

Before using a service lift, the user must complete pre-use checks. The checks required are documented in the service lift user manual and they may also have been extracted and documented on a check-sheet. The asset owner should ensure the check-sheets/user manual to instruct the pre-use checks required for the make/model of service lift and means to record results (e.g. on check-sheet or logbook etc.) are provided. Whether separate check-sheets are provided or not, the user manual should always be provided. In a sample of different lift manufacturers, the user manuals each clearly stated that only trained people may use the lift and that the manual must always be available to staff during installation, maintenance and operation. Lift manufacturers' websites can be very useful for pre-use check information. For example, one includes detailed documentation with excellent diagrams for the required checks and the logbook to record these checks. Additionally, a 'Daily Check' (pre-use) video tutorial is provided and this can also be accessed from mobile devices by scanning a QR barcode. This QR is available on the website and on stickers applied to the actual on-site lift.

In practice, lift users may have different pre-use check experiences between types of lift, on different wind farms and even from turbine to turbine within the same wind farm. This can be because of several factors, including the quality and clarity of pre-use checks varying between lift user manuals (hard copy and online material), or how clear and comprehensive any prepared stand-alone checklists are that have been extracted from the user manual. The technician may also find that occasionally, no hard copy pre-use check information is available at point of use. Additionally, not all lift manufacturers have set up online access to this material through scanning QR barcodes for example, and even where available the users may not have the mobile devices to access it.

Whatever method is employed, the pre-use checks are intended to ensure that the safety related features of the service lift are in good working order before the lift can be used.

5.1 TYPICAL PRE-USE CHECKS

Examples of typical pre-use checks performed by the lift users are shown in Table 1. Note however that not all these checks are specified by every lift manufacturer in their pre-use check instructions for every model.

Table 1: Typical pre-use checks

Check	Comments
Verification of labels, lift serial no. and hour counter	To check that inspections/services are not overdue, all labels are legible, and logbook serial number matches that on the lift
Inspection of logbook	To check that any previous issues/malfunctions that prevented the lift from being used have been resolved

Table 1: Typical pre-use checks (continued)

Check	Comments
Check all limit switches/safety plate arrangements e.g. top stop, ultimate top stop and bottom stop	Lift operation should be prevented when engaged
Visual inspection of the suspension, the safety and the guiding (for wire guided lifts) steel wire rope (SWR)	Would include checks such as weight block for the suspension SWR should be free and able to rotate, the safety SWR is at the correct pre-tension and guides at the correct tension
Functionality of interlocking systems	Lift must not operate when interlocking activated
Emergency stop	All operations impossible when activated
Access door and door switch	Door functional and lift does not move if door open
Fall arrest system (FAS)	Triggering of the fall arrester and a load test
Service brake	Functional test of the brake to ensure that it holds the lift
Visual inspection of the cabin/ operating panel for damage	To check that the operating panel is fully functional and pilot lights working
Inspection of the seals	Usually overload and control cabinet

5.2 ADEQUACY OF PRE-USE CHECKS

To determine the adequacy of pre-use checks, technicians and other users of service lifts were canvassed for their thoughts and opinions. Both an online survey using G+ Focal Group channels, other contacts, and on-site face-to-face discussions were used to gather the feedback.

Table 2: Use of pre-use checklists

	Do you use a WTG service lift pre-use checklist?			
	Always	Mostly	Sometimes	Never
No. of responses	35	6	7	12
Percentage	58	10	12	20

Table 3: Adequacy of pre-use checklists

	Do believe the pre-use checklist is adequate?		
	Yes	No	Don't know
No. of responses	48	5	7
Percentage	80	8	12

5.3 PROPOSED NEW CHECKS

The 'new' checks identified may not actually be new to some technicians. As highlighted in 3.1 there is variability in the checks prescribed for the different makes and models of service lift. However, the opinion was that the following two checks should be included across all makes and models as shown in Table 4.

Table 4: Proposed new checks

Proposed new service lift pre-use checks	
1	A check of the lift service/maintenance records to ensure that all works are up-to-date and successfully completed
2	A check of the lift hour counter to ensure the limit has not been exceeded

5.4 IMPROVEMENT IDEAS

Most of the improvement ideas were around making the pre-use check experience quicker, better and easier for the technician. This is not a surprise, as one of the most commonly suggested reasons for users not always or fully completing pre-use checks was that they were time- consuming and onerous. The main improvement ideas suggested are summarised here.

– Make the checks more concise, with a focus on the safety critical features.
– Use more images/diagrams to replace a lot of the long wordage.
– Where checklists have been created from the lift manufacturers' manual, ensure that nothing has been lost in the transfer.
– Design smart lifts where the results of pre-use checks must be entered (and within specifications) for the lift to operate.

5.5 PERCEIVED INADEQUACIES

Several of the comments shown in Table 3 have highlighted current checks that are believed to be inadequate by the respondents. An example is the creation of an overspeed by a heavy stamp in the lift. These types of checks have been explored by the G+ and have been covered in the new EI/G+ *Good practice guideline: Working at height in the offshore wind industry*.

5.6 OTHER FINDINGS

Whilst the scope of this is to identify whether any new tasks should be included in WTG service lift pre-use checks, another finding was that some users of service lifts do not use pre-use checklists at all. The online survey was not scoped to examine this, so it would be speculation to say why they are not conducting the designated pre-use checks, but this is obviously a concern for the industry. A little more insight was gained when conducting face -to-face discussions with the technicians. Although these users were unwilling to say outright that they did not routinely conduct the documented pre-use checks, they gave suggestions as to why they may not be conducted, as shown as follows:

- Information on pre-use checks is not always available at point of use.
- The checks take time and can be perceived as onerous.
- Perception that a few of what the technicians consider the main checks, e.g. FAS, will suffice rather than conducting all the checks.
- Familiarity with the equipment breeding complacency in use.
- Not required to log checks.
- Supervision/enforcement of checks not consistently in place and applied.
- Lift will still operate whether checks are done or not i.e. they are not 'smart' lifts.
- Unclear on whose responsibility it is to do checks e.g. where more than one company is working on the turbine and using the lift.
- Reluctance to find an issue e.g. hour counter over limit, that would put the service lift out of use and result in the need to climb.
- Poor behavioural safety culture.

6 RECOMMENDATION 8: CONSIDER OPPORTUNITIES TO ADDRESS SAFETY FEATURE OVERRIDE OR DEFEAT BY USERS

6.1 SERVICE LIFT – TYPICAL SAFETY FEATURES

Safety feature	Comments
Overload detection	Detects if the maximum safe working load has been exceeded to prevent use in this condition
Emergency stop	Disables all electrical controls and stops the lift immediately
Travel route limits	Limit switches to stop the lift at the top or bottom of its travel route
FAS	Detects overspeed on lift descent and trips to arrest fall (often, in case of emergency, these can also be manually activated)
Motor primary brake	Electromechanical brake that is activated when there is no power for the motor (e.g. emergency stop, limit switch activation, power failure, etc)
Interlocking systems	For example, key transfer system for safe access to platforms/ gates, to prevent unintentional opening of doors and to only allow lift to move when doors are closed
Dead man's switch	Must be actively engaged at all times by the user to enable the lift to move up or down
Warning beacon	To indicate movement or imminent movement of the lift
Anchor points	On inside of cabin and on outside in case of emergency evacuation
Emergency descend device	Allows the cabin to be manually moved downwards in the event of a power failure
Visible hours of use counter	Shows hours since last inspection

6.2 SAFETY FEATURES ADEQUACY

To determine the adequacy of service lift safety features a user survey was conducted. This involved online completion by lift users and face-to-face feedback from technicians at site. The survey question specifically asked if the users believed that the existing service lift safety features were adequate. There were 60 responses and the results are shown in Table 5.

Table 5: Adequacy of service lift safety features

	Do you believe that existing WTG service lift safety features are adequate?		
	Yes	**No**	**Don't know**
No. of responses	51	7	2
Percentage	85	12	3

When discussing face-to-face with the technicians, what was considered adequate was subjective. There was also the view that almost all safety features on any piece of equipment/machinery could be defeated or bypassed. The results of these responses are shown in Tables 6 and 7.

Table 6: Defeat of service lift safety features

	Do you believe that existing WTG service lift safety features can be defeated?		
	Yes	**No**	**Don't know**
No. of responses	44	6	10
Percentage	73	10	17

Table 7: Safety features – identified methods of defeat

Safety feature	How defeated/overridden/bypassed	Additional comments
Dead man's switch	Depending on the lift design, these may be defeated by applying an adjustable wrench, or a magnet and screw, or even a bottle top to activate switch/button	In some cases, if these are left in position then the hour counter may continue to turn, showing added hours despite the lift not being used. This results in additional intrusive maintenance as it cannot be confirmed when the hour clock was last accurate
Gate interlocking systems	Where gates are opened by standard panel keys, then multiple keys may be left in gates and/or carried by technicians	Gate interlock systems were not always standard and became a retrofit 5-7 years ago. Some older sites may not have this engineering control in place

Table 7: Safety features – identified methods of defeat (continued)

Safety feature	How defeated/overridden/ bypassed	Additional comments
Cabin door interlocking systems	The door opening limit switch may be adjusted e.g. by simply loosening a nut, for the lift to travel with its doors fully open	Typically, these switches are a simple contact arm and this can be adjusted to prevent contact being made and therefore allowing travel with door open
Top/bottom/ultimate safety limit	These again are contact switches like the door and may be removed or repositioned with a screwdriver to prevent the contact being made	Safety brake may occasionally lock on at the top of turbine. To release it, the lift is taken up further, sometimes even past the ultimate limit
Time delay before starting	With the correct knowledge the delay in turning switch to start and the lift starting may be defeated by adjusting the timer in control box	The normal delay of several seconds to warn of imminent movement may be reduced to virtually no delay
Overload capacity	The overload control in the more rudimentary lifts may be easily defeated with simple hand tools	This may allow heavier loads to be taken to the nacelle, especially when the crane is not in operation and particularly during construction phase of turbine life

6.2.1 Reasons

The reasons put forward to explain why users may attempt to defeat safety systems were:

- To get a job done quickly/easier e.g. lift doors remaining open whilst travelling up and down to inspect the tower.
- Holding the dead man's switch can be painful on hands/fingers whilst travelling up/down the tower.
- Convenience e.g. gate interlocks disabled.
- Poor behavioural safety culture.

7 RECOMMENDATION 9: COLLECT INFORMATION FROM G+ MEMBERS ON CURRENT LIFT SERVICE SCHEDULES TO SHARE KNOWLEDGE OF CURRENT PRACTICE

7.1 INFORMATION SOURCES

In total, 23 documents covering five different lift system manufacturers were reviewed as part of this study. These documents contained information on the manufacturer's recommended service schedule and maintenance activity. Whilst the sample of documentation represents only a percentage of service lift make and models available to, and in use by, the offshore wind industry, this information is considered to be a reasonable representation of typical lift system manufacturer's recommendations.

Table 8: Summary of lift system manufacturer service schedules

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
A	Daily inspection by user (person trained as a user by manufacturer and with valid (in date) certification) Scope: Overall/travel zone (integrity, free of obstructions)	–	–	Annual maintenance by certified technician (person trained in the scheduled task by manufacturer and with valid (in date) certification) Scope: Overall/travel zone Control and safety devices Cabin Traction hoist	Every 2 years maintenance by Certified Technician (person trained in the scheduled task by manufacturer and with valid (in date) certification)	Every 5 years or 50 hours (whichever comes first), or every 10 years or 125 hours (whichever comes first) if strict compliance with maintenance programme and the daily inspections is documented	Every 20 years or 250 hours of use (whichever occurs first) Scope: Return traction hoist and fall arrest device to manufacturer workshop

Table 8: Summary of lift system manufacturer service schedules (continued)

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
A (continued)	Control and safety devices (check all interlock, limit functions and emergency stop functions) Fall arrest device (activate deactivate fall arrest device) Record hours in inspection log sheet			Fall arrest device Overload limiter Traction and safety wire ropes Guiding System electrical System information signs and documents Doors and hatches Cabin control box Safety switches Interlock system Platforms For taller towers (e.g. V164) replace wire guides annually or every 125 hours of operation	Scope: Maintenance of fall arrest device by Certified Technician (person trained in the scheduled task by Avanti and with valid (in date) certification)	Scope: Maintenance of traction hoist by Certified Technician (person trained in the scheduled task by manufacturer and with valid (in date) certification) Maintenance of fall arrest device may be extended to 10 years or 125 hours (whichever comes first) if strict compliance with maintenance programme and the daily inspections is documented	

Table 8: Summary of lift system manufacturer service schedules (continued)

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
B	Daily check must be carried out every working day by a qualified service lift operator in the presence of one other person Scope: Before use (visual inspection of components, and physical check of tension of wire rope) Seals (check cabinet and overload seals are in place) Fall arrest device (activate/ deactivate fall arrest device, visual observation of centrifugal force mechanism)	–	Manual descent documentation Scope: All uses of the manual descent function (in the event of a power failure) must be documented	–	–	–	–

Table 8: Summary of lift system manufacturer service schedules (continued)

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
B (continued)	Hoist (visual observation and functional test of rope hoist system) Record results of daily inspections in the logbook						
C	Check the logbook for any remarks or observations before using the service lift Daily inspection Scope: Visual inspection (labels, stickers, anchor points, fall arrest device, hoist, marking plate number, hours counter) record in logbook	The service lift shall be inspected on commissioning/first use and thereafter one (1) time each year, by a certified competent person	–	The service lift shall be inspected on commissioning/first use and thereafter one (1) time each year, by a certified competent person Scope: Check thickness of wire rope using calibrated callipers Overload and dynamic tests of hoist and overload Pull test and static test of fall arrest Anchor point inspection	–	Scope: Static, overload, and dynamic tests of hoist and overload Pull test and static test of fall arrest	Every 5 years or 50 hours whatever comes first Scope: Hoist and overload Fall arrest (if activated due to an overspeed situation then fall arrest and mounting bolts should be replaced) If exposed to a fall the anchor point shall be replaced and the supporting structure shall be inspected

Table 8: Summary of lift system manufacturer service schedules (continued)

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
C (continued)	Visual inspection of wire ropes Functional test of key system, door and switch Bottom and top obstruction plate and limit switches Emergency stop Fall arrest device (activate/ deactivate fall arrest device) Functional test up/down including operating panels and lights						

Table 8: Summary of lift system manufacturer service schedules (continued)

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
D	Daily check list. Tests must be carried out every time before using the lift Scope: Visual inspection of lift for loose or missing parts Functional test of gate, door and interlock and emergency stop Function test of no power manual descent function Visual observation of overspeed governor function Check that bottom limit switch functions	Scope: Complete commissioning report Carry out the daily checklist Check function of top limit switch Perform test run and verify smooth operation to top of tower Verify bottom limit switch Test bottom obstruction system Overload and adjust the overload limiter Store completed report, installation and operation manual in document holder	–	Maintenance may only be carried out by suitably trained personnel Basic service annually	–	Maintenance may only be carried out by suitably trained personnel Overhaul and testing every 5 years or 200 hours of operation, whichever comes first	–

Table 8: Summary of lift system manufacturer service schedules (continued)

Lift manufacturer	Pre-use check	Post-commission	Ad hoc requirements	Annual service	Every 2 years	Overhaul (in field)	Overhaul (remanufacture or replacement)
E	Obligatory daily checks before use, everyone who uses the cabin must be familiar with it and must have read the manual Scope: Visual inspection of pins and rollers for good condition Check that parts and switches are correctly located Check that cabling is in good condition without apparent breakages or imperfections Check operation of safety devices: door interlock, obstacle detector, emergency stop, key	The lift must be commissioned by qualified, suitably trained persons only, authorised by the lift system manufacturer All commissioning operations must be recorded, for which there is a checklist attached to the commissioning manual. This checklist must be filled in correctly	–	The lift must be maintained by qualified, suitably trained persons only, authorised by the lift system manufacturer All maintenance operations must be recorded, for which there is a checklist attached to the commissioning manual. This checklist must be filled in correctly	–	–	–

7.2 REGULATIONS

The inspection intervals defined in the UK by the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) are every six months for lifting equipment used to lift people. This interval is out of step with most other 'statutory inspection' activity, which tends to take place in offshore wind every year. For example, cargo lifting equipment, fall protection and anchor points, fire protection and emergency systems all normally require an inspection frequency of a year. The relatively low use of lifts, coupled with the potential inefficiency of frequent visits to reinspect a lift, has driven the industry to rely on 'written scheme of examinations' to use a risk assessment approach, to justify an increased period between inspections.

Without a significant change in either engineering, technology, regulations or perhaps a combination of all three, it seems unlikely that inspection intervals of greater than a year will become routine in the foreseeable future.

7.3 CURRENT STATE OF THE ART

7.3.1 Daily pre-use check

All lift system manufacturers describe a pre-use check or daily check that they recommend for users of their system. Lift user training is generally provided to all wind turbine technicians. Since basic lift user training is provided almost universally to full-time wind turbine technicians, it is considered that working parties will include someone who is competent to conduct a pre-use check.

The broad objectives of all pre-use checks are similar, but the level of complexity required to complete a pre-use check does vary between manufacturers. Aspects of pre-use checks that vary between manufacturers include:

- Not all documentation describes a visual check of overspeed or fall arrest devices, and this is probably because variance in design between different types makes this difficult. For example, some devices will include a small window or observation port through which the function can be observed.
- Some checks require the use of tools.
- Some checks require partial dismantling of systems, e.g. removal of covers.
- Some checks will only be possible with two people.
- Some checks will require climbing or access above and/or below the lift.
- Not all checks state what documentation is required, for example review of previous check/service record and/or recoding of the check performed. Others are very prescriptive of what should be recorded and when.
- Some manufacturers recommend that records of emergency or unpowered descent are maintained and reviewed prior to use.

The G+ *Good practice guideline: Working at height in the offshore wind industry* states that pre-use checks, which involve intentionally causing the system to slip on its drive mechanism, are not satisfactory. Manufacturer documentation does not always align with this guidance.

7.3.2 Commissioning

Equipment will be required to undergo a thorough examination before it is used for the first time. This inspection was not described in all documentation reviewed. It is thought highly likely that this activity is conducted on all projects.

It is not clear whether documentation generated during commissioning and thorough examinations will remain with the lift system (physically offshore), whether there will be multiple copies, or whether it will be held centrally. It may be that provision of this information to all parties involved: lift system manufacturer, wind farm owner operators, and technicians at point of use could represent a relatively easy way to have a meaningful positive impact.

7.3.3 Periodic inspection and service

All lift system manufacturers have a requirement for annual maintenance of their systems by a competent person and that a logbook is used to record what maintenance was performed when. Maintenance activities that are common across most manufacturers are:

1. Inspection for damage and thickness checking of SWRs.
2. Cleaning and in some cases lubrication of steel wire ropes.
3. Checking for general integrity (fixings, fasteners, damage, breakage or other defects in lift cabin).
4. Functional testing and adjustment of limit switches, interlocks, obstruction cut-outs and emergency stop features.
5. Integrity and functional test of control and warning systems, switches, lamps and sounders.
6. Checking and recording of value on the hours in use counter.
7. Visual inspection of anchor points.
8. Correct functioning of lift door, and in some cases platform access gates.
9. Electrical power cable, cable storage and electrical connections visual inspection.
10. Detailed inspection, cleaning and functional testing of traction hoist.
11. Visual inspection and functional testing of fall arrest device.
12. Overload test and functional test of overload limiter.
13. Structural integrity of mounting points, for example tower top, tower bottom and any intermediate fixings, wire rope mounting or guides. Checking for tightened fixings and fasteners, cracking of welds or corrosion.
14. Documentation and information/warning signs. Usually there is a stated requirement to document the maintenance work and in some cases the maintenance specifically describes checking that appropriate documentation is available with the lift at point of use: user manuals, inspection and maintenance records and serial numbers.

Some lift manufacturers supply only a lift system, whereas others will also be contracted to provide ladders, landing platforms and access gates or some combination of these. The extension of maintenance scopes, to include these peripheral systems therefore varies between manufacturers.

Additional maintenance is usually recommended if the fall arrest device and/or emergency descent function are used. In the event of either occurrence, records should be kept and be available for subsequent users and maintenance teams, as in some instances, the lift should not be used until additional maintenance has been completed.

7.3.4 Overhaul

Lift manufacturers stipulate requirements for more intensive maintenance work. A threshold of 40-50 hours is often recommended or between two-to-five years, whichever comes first, as a trigger for overhaul (to include maintenance of fall arrest devices and traction hoists). This may involve dismantling the subsystems in the field or returning to a workshop and rebuild with new internal components.

Ultimate life of systems, again most commonly the traction hoist and fall arrest, are usually described at between 100 and 250 hours or 10 to 20 years. After this time, most manufacturers recommend replacement of systems or return for disassembly and remanufacturing.

As with other maintenance activities, good record keeping is important here, particularly in the event that, for example, a traction hoist is replaced but wire ropes are retained (or vice versa), hours of use and age of both components should be clearly recorded in order that subsequent maintenance complies with recommendations.

8 RECOMMENDATION 10: REVIEW THE CAUSES OF SERVICE LIFT UNAVAILABILITY AND CONSIDER THE MERIT/ FEASIBILITY OF INSTALLING A BACK-UP SOLUTION

To determine the perceived availability of service lifts a user survey was conducted. The results are shown in Table 9.

Table 9: Service lift availability

	In your opinion how frequently are service lifts unavailable for use?				
	Never	**Rarely**	**Occasionally**	**Quite regularly**	**Often**
No. of responses	1	24	27	4	4
Percentage	2	40	45	6.5	6.5

8.1 CAUSES

From the results of the stakeholder survey and discussions with those using and maintaining service lifts, the most commonly cited causes of service lift unavailability were obtained along with any further supporting comments. These are shown in Table 10.

Table 10: Causes of service lift unavailability

Cause	Further supporting comments
Damaged/broken power cables	For example, the power cable for the lift snags on the wire guide system or gets twisted/damaged in other ways. This was most common on lifts that coil the cable in a 'bucket' under the bottom station of the lift. The cable could pile up on the floor, and the lift would rest on the pile when it reached the bottom station. This is particularly common if the tower is swaying due to wind Note: Where the 'bucket' has been replaced with a 'bag' the problem seems to have been resolved
Damaged drive wires	Birdcaging commonly cited as the type of damage along with kinks, crushes, wire breaks, loops and bends. An example of birdcaging is shown in Figure 1 Additionally, causes such as heat damage, corrosion and diameter below specification have resulted in lifts being out of use

Table 10: Causes of service lift unavailability (continued)

Cause	Further supporting comments
Damaged guide wire	As above
Damaged hoists	No further comments
Safety brake problems	For example, unable to be activated at pre-use test
Motors slipping on wire	No further comments
Locked out as inspection overdue	No further comments
Sensor malfunction	For example, sensors used to detect slack traction on the SWR or those used to detect lift levelling
Locked out awaiting repair	No further comments
Misuse damage	No further comments
Phase relay related problems	Various electrical issues
Miscellaneous faults requiring inspection	No further comments
Damaged interlock key	They can also sometimes be removed and misplaced
Limit switch faults	No further comments
Safety alerts	Can be industry-wide safety issues concerning make/ model(s) of lift that result in lift use being prohibited until concern addressed and lift certified as safe for use

8.2 POTENTIAL BACK-UP SOLUTIONS

8.2.1 User feedback

The view from the technicians was that ladder climb-assist systems should be used across the industry, as the back-up solution when the service lift is not in use. Several technicians were of the view that climb-assist was the preferred way of ascending the tower, even when the lift was available, although not possible where the lift is ladder mounted.

It is worth highlighting that the use of a climb-assist system is identified as the second key principle within the new G+ *Good practice guideline: Working at height in the offshore wind industry*, as shown in the extract below.

In addition to climb-assist systems, the users believed that planning was important, and this is an area that could be improved upon, including:

- Improved planning to ensure lift inspection schedules are adhered to.
- More effective planning, to ensure technicians are only routed to turbines where the service lift is operational where possible.
- Better planning of required tooling/equipment and sequencing of works to limit the need to return to deck/ground level.
- Improved checking/monitoring of the lift use counter to ensure technicians don't arrive on the turbine only to find they can't use the lift as it is over its hours of use limit.

Some other suggestions were also made by the users, including:

- Use of helicopters for access to top of turbine.
- Spiral staircase in future large towers.

8.2.2 SME market

In addition to user feedback, the SME market was explored for any potential innovative back-up solutions, when service lifts are unavailable. The feedback from the SMEs and the results of research were that this is an area that has not been regarded as a viable priority, except for the climb-assist systems. The current established view is that technicians use the service lift and, on the occasions that they are unavailable, then the technicians climb. Other disruptive innovative solutions were not identified.

Several factors were revealed as blocks to progress in this area, which included that the industry need was perceived to be low, in addition to space constraints within the turbine and expected high costs of developing/implementing a disruptive innovative back-up solution that was not a variant of climb-assist.

8.3 FEASIBILITY AND MERITS OF SERVICE LIFT BACK-UP SOLUTIONS

8.3.1 Climb-assist systems

Technicians had similar views on climb-assist, as mentioned previously. Climb-assist systems were very popular with the users and most believed climb-assist systems should be available as standard in every turbine, where possible to do so, in addition to the lift. During face to face discussions, around half of the technicians that had used a climb-assist system preferred using it rather than using a service lift.

A few of the service lift manufacturers, in addition to others, have developed climb-assist products and there are several choices on the market. They work on similar principles with the aim of:

- reducing the load (physical burden) on the climber and the exertion from climbing;
- reducing the occupational health risks associated with climbing;
- reducing the time taken to perform climbs, and subsequently, and
- increasing productivity.

More recently, next generation climb-assist technologies have come onto the market. Some of these are being promoted by their manufacturer as a better alternative to service lifts. Some of the advantages being claimed include:

- Increases safety by avoiding an obstruction hazard (ladder guided service lift) in an emergency.
- Better value through multifunctionality (climb assist, fall prevention, rescue, evacuation and work positioning (against solely access by a lift).
- Lower capital cost and lower operating cost.
- Adds value through use during construction phase (can be installed in several positions where required before its final position).

- Adds value through diagnostic and data recording functions with supervisory control and data acquisition (SCADA) compatibility (e.g. can self-detect problems before a technician is routed to that turbine).
- Uninterruptable power source (UPS) battery back-up in event of a power failure.
- Faster time to ascend/descend turbine.
- Keeps work force healthy whilst reducing occupational health risks.

Climb-assist systems are viewed positively by technicians and there are accepted benefits over unassisted climbing. However, to have these in addition to service lifts (where it is possible to fit them) as a back-up solution for times that service lifts are unavailable is not an obvious decision. Cost is the obvious factor and each wind farm owner operator would have to conduct a detailed cost-benefit analysis specific to the wind farm, considering factors such as the service lift history/performance (in operational windfarms) and obtaining comprehensive views of the technicians.

It is a topic that is currently under review within the G+ Focal Group.

8.3.2 Helicopter access

Helicopter access has been a consideration for wind farm operators for several years and many advantages/disadvantages have been identified.

The G+ is currently producing a good practice guidance on helicopter operations.

9 RECOMMENDATION 13: RECONSIDER THE USE OF E-LEARNING VERSUS MANUAL TRAINING FOR SAFE LIFT USE

9.1 AVAILABLE WIND TURBINE SERVICE LIFT TRAINING AND TYPE COMPLETED

A gap analysis was conducted of available training for each service lift type in the wind energy industry. All service lift manufacturers offer on-site training for their products consisting of theoretical learning and practical application. Some also offer e-learning courses.

Table 11: Summary of questionnaire responses regarding training methods for service lift use

	E-Learning	**Practical training**
Training type completed	66 %	83 %
Preferred training type	3 %	85 %
Reasons for preference	Siemens e-learning package where you control a technician and undertake pre-use checks was exceptional. Could repeat time and time again without having to travel to Glasgow for Skyman training that is then easily forgotten (I think it is important to have hands on training if it is the first time using a particular lift type). For refresher training then e-learning is sufficient and more cost-effective	Practical training will always be better than e-learning for any subject Allows practical input to troubleshoot issues with the lift Combination of e-learning and practical training gives best outcome Learning skills improve massively with hands-on training Anecdotal detail from the trainer is valuable Performing pre-use checks on the lift instead of on an e-learning platform is more effective More realistic Best to learn with hands on Practical training is always better as 'doing' is always more beneficial than just seeing I think it is important to have hands-on training if it is the first time using a particular lift type. (For refresher training then e-learning is sufficient and more cost-effective)

9.2 ALTERNATIVE TRAINING METHODS

Virtual reality is an example of a technology that is being used to bridge the gap between e-learning and practical training. By immersing the learner in the virtual environment, it gives them the sense of being in that location, which is the main reason for practical training being so successful: full immersion in the task. The effectiveness would again depend on the required outcome and the complexity of the virtual reality training set up. For example, if the requirement is to train someone in a highly complex task such as assembling a component, then virtual reality may not be detailed enough to simulate the real-world situation. The trainee will be unlikely to get a real feel for the intricate parts and how they fit together. In the case of service lifts, virtual reality may be able to play a role in improving the current course offerings; however, it is unlikely to replace practical training courses entirely due to the complexity of the situation. It could however be a better option than current e-learning courses.

Other options such as games creation and interactive videos also exist as methods of increasing a learner's engagement with online content; however, these are seen to be enhancements to classic e-learning courses rather than alternatives.

E-learning and practical training methods both have advantages and disadvantages; the question of which one is most suitable to a situation depends on the outcome required.

From the literature review, it seems that for a foundation level of knowledge, e-learning is adequate, providing a cheap and convenient solution. However, for practical skills, hands-on training will be required to develop a deeper understanding and the ability to replicate the practical tasks in the real-world environment.

This suggests that the most suitable option in the case of wind turbine service lift use would be practical training. This was supported up by the questionnaire responses, with a majority stating that this was preferred as they felt it was more effective.

It is unlikely that any alternative training methods would be effective enough to replace practical training. However, it is recommended that a blended learning approach is followed, covering both theory (either e-learning or in-class) and practical training to achieve deeper knowledge and skills development for the safe use of service lifts.

10 RECOMMENDATION 14: REVIEW OF INDUSTRY STANDARDS FOR FASs, REFLECTING ON RECENT DEVELOPMENTS OR POTENTIAL TO IMPROVE

10.1 INDUSTRY STANDARDS FOR FASs

There are numerous national, European and international standards for FASs. It is likely that in some instances differing guidance or standards exist. Particularly when considering other geographies, readers should be aware that there may be differences when working in international markets.

The following standards are relevant for FASs:

– BS EN 341:2011 *Personal fall protection equipment. Descender devices*.
– BS EN 353-1:2014 *PPE against falls from height. Guided type fall arresters on a rigid anchorage line* (note that the 2002 version of this standard was amended in the UK in 2005 (BS EN 353-1:2002 to include a national foreword and national annex warning about potential shortcomings of the standard, particularly the use of a fixed vertical fall arrest system for work positioning. The current status is 'work in hand' with an amendment released for public comment on 13/01/2017, hence a revised standard should be expected by late 2018).
– BS EN 353-2:2002 *PPE against falls from height. Guided type fall arresters including a flexible anchor line.*
– BS EN 354:2010 *PPE against falls from height. Lanyards* (note that this standard includes a national foreword in the UK (BS EN 354:2010), warning about the lack of reference in this standard to testing of textile materials to ultraviolet degradation and abrasion).
– BS EN 355:2002 *PPE against falls from height. Energy absorbers.*
– BS EN 358:2018 *PPE for work positioning and prevention of falls from height. Belts for work positioning and restraint and work positioning lanyards.*
– BS EN 360:2002 *PPE against falls from height. Retractable type fall arresters* (note that a draft was released for comment in February 2016 (16/30332882 DC) and hence a revised standard should be expected).
– BS EN 361:2002 *PPE against falls from height. Full body harnesses.*
– BS EN 362:2004 *PPE against falls from height. Connectors.*
– BS EN 363:2008 *Personal fall protection. Personal fall protection systems* (note that the 2008 version of this standard includes a national foreword in the UK which warns of potential shortcomings of the standard, particularly in relation to work positioning where BS8437:2005 and the UK Work at Height Regulations (2005) require additional consideration).
– BS EN 364:1993 *PPE against falls from height. Test methods*.
– BS EN 365:2004 *PPE against falls from height. General requirements for instructions, inspection, marking and packaging*.
– BS EN 795:2012 *Personal fall protection equipment. Anchor devices* (note current status is 'under review' and that almost immediately upon publication was the subject of a formal objection).

- BS EN 813:2008 *PPE against falls from height. Sit harnesses* (note that this standard includes the statement: 'Sit harnesses are not suitable to be used for fall arrest purposes').
- BS EN 1868:1997 *PPE against falls from height. List of equivalent terms.*
- BS EN 1891:1998 *PPE against falls from height. Low stretch kernmantel ropes.*
- BS 7883:2005 *Code of practice for the design, selection, installation, use and maintenance of anchor devices*.
- BS 8437:2005+A1:2012 *Code of practice for selection use and maintenance of personal fall protection systems*.
- BS EN 12277:2015+A1:2018 *Mountaineering equipment. Harnesses. Safety requirements and test methods.*
- BS EN 12841:2006 *PPE. Rope access systems. Rope adjustment devices* (note current status is 'Under review').
- BS EN 50308:2004 *Wind turbines. Protective measures. Requirements for design, operation and maintenance.*
- ISO 10333-1:2000 *Personal fall arrest systems – Part 1: Full body harnesses.*
- ISO 10333-2:2000 *Personal fall arrest systems – Part 2: Lanyards and energy absorbers.*
- ISO 10333-3:2000 *Personal fall arrest systems – Part 3: Self retracting lifelines.*
- ISO 10333-4:2000 *Personal fall arrest systems – Part 4: Vertical rails and vertical lifelines incorporating a sliding-type fall arrester* (note that current status is 'under review').
- ISO 10333-5:2001 *Personal fall arrest systems – Part 5: Connectors with self-closing and self-locking gates.*
- ISO 10333-6:2004 *Personal fall arrest systems – Part 6: System performance tests* (note that current status is 'under review').
- ISO 15709:2002 *Personal fall arrest systems – Connectors with self closing and self locking gates.*
- ISO 22159:2007 *Personal equipment for protection against falls – Descending devices.*
- ISO 22846-1:2003 *Personal equipment for protection against falls – Rope access systems – Part 1: Fundamental principles for a system of work.*
- ISO 22846-2:2012 *Personal equipment for protection against falls – Rope access systems – Part 2: Code of practice.*

Standards which are relevant for 'rescue equipment' are relevant here as they will commonly be used in conjunction with equipment governed by standards in the above list. These include:

- BS EN 1496:2017 *Personal fall protection equipment. Rescue lifting devices.*
- BS EN 1497:2007 *Personal fall protection equipment. Rescue harnesses* (note current status is 'under review').
- BS EN 1498:2006 *Personal fall protection equipment. Rescue loops* (note current status is 'under review').
- BS 8405:2003+A1:2009 *PPE against falls from height. Descender devices. Single-hand operated descender devices for self or assisted rescue.*

Standards which are somewhat on the periphery of the subject of FASs, but which nevertheless may contain relevant information include:

– BS 7985:2013 *Code of practice for the use of rope access methods for industrial purposes*. *Recommendations and guidance supplementary to BS ISO 22846.*

10.2 RECENT DEVELOPMENTS

Based on the standards identified in 10.1, the following list contains further developments to those already mentioned:

– BS EN 795:2012 *Personal fall protection equipment. Anchor devices.* The BSI website currently describes this standard as 'current, under review'. Further work will probably be required before the landscape of relevant standards in this area is stable. PD CEN/TS 16415:2013 covers very similar anchor devices, but specifically only those intended to be used by more than one person simultaneously. It is not clear when or whether a revised version of the BS EN 795:2012 which has now been withdrawn will be developed. It is understood that technical revisions are ongoing (as of 2016), but it remains possible that the standard will be subordinated to personal protective equipment (PPE) and/or construction products directives at some point since 2016 or in the future. The 2012 revision of this standard increased the strength which single anchor points are required to provide and fundamentally altered the testing requirements, specifying that anchor points should be tested for strength in the combination of materials within which they will finally be used.

– BS EN 12841:2006 *PPE. Rope access systems. Rope adjustment devices.* The BSI website currently describes this standard as 'current, under review'. Noteworthy criticism of the fitness-for-purpose, quality and relevance of this standard exists in the public domain. It is not the function of this report to provide further critique. However, those considering equipment which falls within scope of this standard are advised that compliance with this standard on its own should be considered a relatively weak endorsement and are encouraged to investigate other potentially relevant standards (such as EN 353-2) and in practice may be advised to consider this standard to be inadequate if used in isolation. It is not clear when or whether a revised version of this standard which has been withdrawn will be developed.

– BS EN 1497:2007 *Personal fall protection equipment. Rescue harnesses.* The BSI website currently describes this standard as 'current, under review'. It is not clear when or whether a revised version of this standard which has been withdrawn will be developed.

– BS EN 1498:2006 *Personal fall protection equipment. Rescue loops*. The BSI website currently describes this standard as 'current, under review'. It is not clear when or whether a revised version of this standard which has been withdrawn will be developed.

10.3 FURTHER SOURCES OF INFORMATION – GUIDANCE DOCUMENTS

– G+ *Good practice guideline: Working at height in the offshore wind industry (*second edition). This document provides practical guidance on navigating the landscape of standards relevant to fall arrest (and work at height in general) for the wind industry. It will significantly aid in the appropriate design, selection, use and maintenance of fall arrest equipment.

– Renewable UK *Offshore wind and marine energy health and safety guidelines*, Issue 2. This document provides some specific commentary on FASs and perhaps most importantly underlines the potentially unsafe shortcomings of the current EN 353-1 standard.
– Renewable UK *Working at height & rescue training standard*, Issue 1. This document makes clear the level of training, which those who have attended a compliant Renewable UK/GWO accredited training course will have in the selection and use of FASs.
– Renewable UK *Onshore wind health & safety guidelines*, Issue 1. This document provides similar guidance to the offshore guidelines provided, but is still considered valuable.
– IRATA *Application of IRATA International rope access methods for work on wind turbines,* second edition. This document is a useful reference when considering rope access work and highlights the potential incompatibility of training and/or equipment between wind and rope access industry norms.
– Occupational Safety and Health Administration (OSHA) standards include some mandatory and some non-mandatory guidance relating to fall arrest equipment.
– HSE RR 657 *Investigation Investigation into the fall-arresting effectiveness of ladder safety hoops, when used in conjunction with various fall-arrest systems* (first edition). Whilst the use of safety hoops or caged ladders is thought to be unlikely in the offshore wind industry, it is nevertheless pertinent to highlight the finding of this research report. The research described established that pieces of fall protection/arrest equipment, which complied with applicable standards when used in isolation, were not safe and potentially dangerous when used together in combination or in a situation or configuration not anticipated by the relevant standards.
– Fall arrest equipment manufacturers also provide guidance documents specific to the selection and application of their technology, both in the form of information and user manuals, and as more general advice, white papers and market summary documents and training material.

10.4 INNOVATION

10.4.1 PPE

Suppliers of the various pieces of PPE that form part of a FAS continue to develop new and improved products. Innovations in this area are typically relatively small and remain governed by the various relevant standards. By way of example, some years ago full body harnesses used in the wind industry would typically be those which would comply with the relevant EN standard (BS EN 361), which is not particular to any individual industry. However, today it is possible to procure full body harnesses from several suppliers that, whilst remaining fully compliant with BS EN 361, also include specific design features which make them better suited to work in the wind industry. These evolutions may include:

– simplification to reduce entanglement or snagging hazards;
– revisions to ease donning/removal, particularly in a tight space;
– revision of design to better resist likely sources of wear (for example back against turbine tower whilst climbing), and
– alternations to improve compatibility with other items of PPE used in the wind industry, such as life jackets.

These types of small incremental improvements in the functional design of PPE associated with fall arrest are anticipated to continue steadily in the coming years.

10.4.2 Emergency response

When considering the related area of emergency response, and especially emergency evacuation and rescue, it seems that the landscape of technology is less mature and the number of, and design approach of, available solutions are still relatively diverse. It looks likely that much development will continue in this area.

Presently, it is common practice for a small number of emergency evacuation kits, including constant rate descenders, to be stored, permanently sealed in the nacelle for use in an emergency. Certain rescue scenarios will be specific to individual sites or turbine types, and as such may employ differing solutions. For example, in older smaller wind turbines, having a single point of egress and evacuation may be suitable or indeed all that it is practicable to provide, where a small team of technicians may use one or two constant rate descenders to evacuate the turbine in an emergency. However, if a larger team is present, potentially including visitors or subcontractors not familiar with the make and model of the emergency descender available, some confusion may arise in an emergency.

As turbine size increases and logistics concepts also evolve, the most appropriate emergency response may also need to change. Consider, for example, a large turbine with several egress points throughout the nacelle; in this case will an evacuation kit be provided near each of the hatches available for escape, and if not, what planned response will be used if a single emergency evacuation kit is inaccessible (for example due to fire or smoke)? An emerging trend for compact self-carried back-up emergency evacuation kits may be a direct response to this type of challenge.

Procedures in the wind industry have predominantly been developed on a principle of almost always downwards evacuations. However, with increasing deployment of helicopter hoisting platforms, the capability and compatibility of fall arrest and emergency evacuation systems may need to change. For example, considering the potential need to safely evacuate a casualty upwards from within a nacelle to a helicopter platform for hoisting will require careful selection and use of both fall arrest and emergency response PPE.

10.4.3 Climb assist

Technology development has also enabled blurring of boundaries between powered access, descenders, FASs and PPE in recent years. Innovations in climb assist have progressed faster than the development of standards and would appear likely to be increasingly more popular in coming years as greater turbine hub heights increase.

ANNEX A
ABBREVIATIONS AND ACRONYMS

BSI	British Standards Institution
CENELEC	European Committee for Electrotechnical Standardization
EC	European Commission
EEA	European Economic Area
ESHR	essential health and safety requirement
EI	Energy Institute
FAS	fall arrest system
G+	G+ Global Offshore Wind Health and Safety Organisation
HSE	Health and Safety Executive
IRATA	International Industrial Rope Access Trade Association
ISO	International Organization for Standardization
LOLER	Lifting Operations and Lifting Equipment Regulations 1998
MWG	Machinery Working Group
METSTA	Mechanical Engineering and Metals Industry Standardization
MRA	Mutual Recognition Agreement
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
RFU	recommendations for use
SCADA	supervisory control and data acquisition
SWR	steel wire rope
TS	technical specification
UPS	uninterruptable power source
WTG	wind turbine generator

ANNEX B
REFERENCES

British Standards Institution (BSI)
https://www.bsigroup.com

BS 7883:2005 *Code of practice for the design, selection, installation, use and maintenance of anchor devices*.

BS 8405:2003+A1:2009 *PPE against falls from height. Descender devices. Single-hand operated descender devices for self or assisted rescue.*

BS 8437:2005+A1:2012 *Code of practice for selection use and maintenance of personal fall protection systems*.

BS EN 81-20:2014 *Safety rules for the construction and installation of lifts. Lifts for the transport of persons and goods. Passenger and goods passenger lifts.*

BS EN 81-41:2010 *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Vertical lifting platforms intended for use by persons with impaired mobility.*

BS EN 81-43:2009 *Safety rules for the construction and installation of lifts. Special lifts for the transport of persons and goods. Lifts for cranes.*

BS EN 81-50:2014 *Safety rules for the construction and installation of lifts. Examinations and tests. Design rules, calculations, examinations and tests of lift components.*

BS EN 341:2011 *Personal fall protection equipment. Descender devices*.

BS EN 353-1:2014 *PPE against falls from height. Guided type fall arresters on a rigid anchorage line*

BS EN 353-2:2002 *PPE against falls from height. Guided type fall arresters including a flexible anchor line.*

BS EN 354:2010 *PPE against falls from height. Lanyards*

BS EN 355:2002 *PPE against falls from height. Energy absorbers.*

BS EN 358:2018 *PPE for work positioning and prevention of falls from height. Belts for work positioning and restraint and work positioning lanyards.*

BS EN 360:2002 *PPE against falls from height. Retractable type fall arresters*

BS EN 361:2002 *PPE against falls from height. Full body harnesses.*

BS EN 362:2004 *PPE against falls from height. Connectors.*

BS EN 363:2008 *Personal fall protection. Personal fall protection systems*

BS EN 364:1993 *PPE against falls from height. Test methods*.

BS EN 365:2004 *PPE against falls from height. General requirements for instructions, inspection, marking and packaging*.

BS EN 795:2012 *Personal fall protection equipment. Anchor devices.*

BS EN 813:2008 *PPE against falls from height. Sit harnesses*

BS EN 1496:2017 *Personal fall protection equipment. Rescue lifting devices.*

BS EN 1497:2007 *Personal fall protection equipment. Rescue harnesses.*

BS EN 1498:2006 *Personal fall protection equipment. Rescue loops*.

BS EN 1808:2015 *Safety requirements for suspended access equipment. Design calculations, stability criteria, construction. Examinations and tests.*

BS EN 1868:1997 *PPE against falls from height. List of equivalent terms.*

BS EN 1891:1998 *PPE against falls from height. Low stretch kernmantel ropes.*

BS EN 12159:2012 *Builders' hoists for persons and materials with vertically guided cages.*

BS EN 12277:2015+A1:2018 *Mountaineering equipment. Harnesses. Safety requirements and test methods.*

BS EN 12841:2006 *PPE. Rope access systems. Rope adjustment devices.*

BS EN 50308:2004 *Wind turbines. Protective measures. Requirements for design, operation and maintenance.*

PD CEN/TS 16415:2013 *Personal fall protection equipment. Anchor devices. Recommendations for anchor devices for use by more than one person simultaneously.*

PD IEC/TS 61400-30 (Ed. 1.0). *Wind turbines. Part 30: Safety of wind turbine generator systems (WTGs) – General principles for design.*

G+ Global Offshore Wind Health and Safety Organisation (G+)
https://www.gplusoffshorewind.com

Good practice guideline: Working at height in the offshore wind industry (second edition).

Safe by Design workshop report: WTG service lifts (first edition).

Health and Safety Executive (HSE)
https://www.hse.gov.uk

RR 657 *Investigation Investigation into the fall-arresting effectiveness of ladder safety hoops, when used in conjunction with various fall-arrest systems* (first edition).

International Industrial Rope Access Trade Association (IRATA)
https://irata.org

Application of IRATA International rope access methods for work on wind turbines, second edition.

International Organization for Standardization (ISO)
https://iso.org

ISO 10333-1:2000 *Personal fall arrest systems – Part 1: Full body harnesses.*

ISO 10333-2:2000 *Personal fall arrest systems – Part 2: Lanyards and energy absorbers.*

ISO 10333-3:2000 *Personal fall arrest systems – Part 3: Self retracting lifelines.*

ISO 10333-4:2000 *Personal fall arrest systems – Part 4: Vertical rails and vertical lifelines incorporating a sliding-type fall arrester*.

ISO 10333-5:2001 *Personal fall arrest systems – Part 5: Connectors with self-closing and self-locking gates.*

ISO 10333-6:2004 *Personal fall arrest systems – Part 6: System performance tests.*

ISO 12100:2010 *Safety of machinery – General principles for design – Risk assessment and risk reduction.*

ISO 15709:2002 *Personal fall arrest systems – Connectors with self closing and self locking gates.*

ISO 22159:2007 *Personal equipment for protection against falls – Descending devices.*

ISO 22201-1:2017 *Lifts (elevators), escalators and moving walks. Programmable electronic systems in safety-related applications. Part 1: Lifts (elevators) (PESSRAL).*

ISO 22846-1:2003 *Personal equipment for protection against falls – Rope access systems – Part 1: Fundamental principles for a system of work.*

ISO 22846-2:2012 *Personal equipment for protection against falls – Rope access systems – Part 2: Code of practice.*

Occupational Safety and Health Administration (OSHA)
https://www.osha.gov

Various standards relating to fall arrest equipment.

Renewable UK
https://www.renewableuk.com

Offshore wind and marine energy health and safety guidelines, Issue 2.

Working at height & rescue training standard, Issue 1.

Onshore wind health & safety guidelines, Issue 1.

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