

Good practice guidelines

Arc flash and shock labeling and associated signage in the offshore wind industry



G+ Global Offshore Wind
Health & Safety
Organisation

In partnership with



GOOD PRACTICE GUIDELINES
ARC FLASH AND SHOCK LABELING
AND ASSOCIATED SIGNAGE IN THE
OFFSHORE WIND INDUSTRY

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FOREWORD

Arc flash poses a significant risk to personnel working on electrical systems, with high consequences including severe burns and death, as well as damage to equipment (EI, 2018).

The Global Offshore Wind Health and Safety Organisation (G+) convened a virtual US Offshore Wind Electrical Safety workshop in September 2021. Participants included representatives from offshore renewable energy developers, original equipment manufacturers (OEMs) and suppliers.

The workshop's objectives were to:

- Facilitate coordination and consultation between offshore wind industry leaders to discuss offshore wind electrical safety.
- Build upon previous offshore wind electrical safety standardization (industry best practices) efforts to explore the activities needed to operationalize standards.
- Identify materials and next steps to operationalize processes related to labeling and safe system of work.

As a result of this workshop, it was agreed that issues surrounding regional differences in approach to arc flash labeling were prevalent. One major issue that came to the fore was the agreement on:

- when equipment labels are applied;
- who is responsible for applying them; and
- differences in the analysis and study processes carried out before equipment labeling.

At this workshop it was further agreed that more clarity across the industry would lead to both better safety outcomes and less inefficiency around this matter. This led to the development of a framework presented in this document.

G+ welcomes any feedback. This should be sent to gplus@energyinst.org.

1 INTRODUCTION AND SCOPE

1.1 INTRODUCTION

The framework proposed in this document has been developed in conjunction with major OEMs and developers operating in the offshore wind industry. Its intention is to generate agreeable guidance around which developers, OEMs and national safety authorities can coalesce to allow each to successfully meet their obligations under the applicable regulatory or legislative frameworks. While the document focuses heavily on the wind turbine generator (WTG), there is no reason why the same philosophies cannot be applied, with agreement, to the installation, commissioning and operation of other electrical equipment.

The framework's purpose is to act as recommended good practice for the performance of arc flash hazard control by defining timelines and responsibilities to produce arc flash analysis data and, following the production of such data, details on the format, style and application positioning of the required warning labeling.

There is no intention for this framework to supersede or override any existing regulatory, legislative or contractual obligations, already or in the future, placed upon any of the interested parties.

Serving as facilitator for disseminating this document and its intended purposes to windfarm owners, equipment manufacturers and suppliers, and other industry stakeholders, G+ will help to accelerate a more consistent and collegiate approach to equipment labeling in the offshore wind energy sector. Equipment owner requirements can then reference this document to help drive forward this consistent approach into their supply chains and direct their suppliers to more effectively manage electrical safety and the associated arc flash, arc blast and shock risks.

It should be noted that the hierarchy of controls dictates that engineering controls are far more effective for controlling the arc flash hazard. As such, organizations should, where possible, engineer out hazardous situations.

1.2 SCOPE

The scope of this paper is to define an industry recommended practice framework, in the context of key reference documentation, for arc flash and shock labeling and associated signage.

This document brings together the widely agreed and clear process for the determination of:

- equipment label content;
- equipment label placement;
- timing of equipment label placement, and
- responsibility for equipment label placement.

2 RELEVANT STANDARDS AND GUIDANCE

2.1 NFPA 70E – STANDARD FOR ELECTRICAL SAFETY IN THE WORKPLACE

The global offshore wind industry, largely speaking, is adopting the USA's National Fire Protection Association (NFPA) 70 E as the standard to work pertaining to the safety-related work practices, control and mitigation of arc flash, arc blast or shock related electrical hazards.

2.2 IEEE 1584 – GUIDE FOR PERFORMING ARC FLASH HAZARD CALCULATIONS

The Institute of Electrical and Electronics Engineers (IEEE) Std 1584 provides mathematical models for designers and facility operators to apply in determining the arc flash hazard distance and the incident energy to which workers could be exposed during their work on or near 3-phase, alternating current (AC) electrical equipment and conductors operating from 208V to 15kV. The document does not deal with direct current (DC) or single-phase AC systems.

2.3 NEC ARTICLE 110.16 – ARC FLASH HAZARD WARNING

Article 110.16 of the National Electrical Code (NEC) states the requirements for arc flash labeling of new equipment. It requires that:

electrical equipment, such as switchboards, switchgear, panel boards, industrial control panels, meter socket enclosures, and motor control centres, in other than dwelling units, that are likely to require examination, adjustment, servicing, or maintenance while energized, to be field or factory marked to warn qualified persons of potential electric arc flash hazards. The marking must meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

2.4 NEC ARTICLE 110.21B – FIELD APPLIED HAZARD MARKINGS

NEC Article 110.21B requires that:

Where caution, warning, or danger signs or labels are required by this Code, the labels shall meet the following requirements:

1. *The marking shall adequately warn of the hazard using effective words and/or colors and/or symbols.*

Informational Note: ANSI Z535.4-2011, Product Safety Signs and Labels, provides guidelines for suitable font sizes, words, colors, symbols, and location requirements for labels.

2. *The label shall be permanently affixed to the equipment or wiring method and shall not be handwritten.*

Exception to 2: Portions of labels or markings that are variable, or that could be subject to changes, shall be permitted to be handwritten and shall be legible.

3. *The label shall be of sufficient durability to withstand the environment involved.*

2.5 ANSI Z535.4 – PRODUCT SAFETY SIGNS AND LABELS

The American National Standards Institute's (ANSI) Z535.4 is where we find the standard adopted across the USA and Canada for safety labels. This is not considered a mandatory standard but coalescence around this standard makes for a more straightforward compliance test. It is thought that, in the eyes of the law, deviation from this standard would need to prove increased effectiveness over the standards should the need to test compliance arise.

The options for labeling include a warning triangle with exclamation mark followed by either:

- Signal word: Danger – white text on red background.
- Signal word: Warning – Black text on orange background.
- Signal word: Caution – Black text on yellow background.

The signal word is intended to communicate the significance of the hazard. The signal word is followed by a message panel area detailing the hazard and required control measures and mitigations.



Figure 1: Examples for ANSI Z535.4 compliant signal word formats

2.5.1 Signal Word Definitions

- DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- CAUTION indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

2.6 NFPA 70E ARTICLE 130.5(H)

NFPA 70E Article 130.5(H) Equipment Labeling details the requirements for arc flash labeling of

electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units and that are likely to require examination, adjustment, servicing, or maintenance while energized shall be marked with a label containing all the following information:

1. *Nominal system voltage*
2. *Arc flash boundary*

3. *At least one of the following:*
 - a. *Available incident energy and the corresponding working distance, or the arc flash PPE category in the NFPA Tables [130.7(C)(15)(a) or 130.7(C)(15)(b)] for the equipment, but not both.*
 - b. *Minimum arc rating of clothing*
 - c. *Site-specific level of PPE*

2.7 OSHA 191.335(B)(1) – SAFETY SIGNS AND TAGS

The US Occupational Safety & Health Administration's (OSHA) Standard 191.335(b)(1) requires that:

Safety signs, safety symbols, or accident prevention tags shall be used where necessary to warn employees about electrical hazards which may endanger them, as required by § 1910.145. for safety from general hazards

§ 1910.145 again, points us to ANSI Z535.4 for guidance on formatting.

3 ARC FLASH CALCULATIONS

3.1 IEEE STD 1584

IEEE 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, gives the methodology for calculating the possible incident energy due to an arc flash event. The relevant IEEE committee of the has developed a set of equations to enable these calculations.

The IEEE calculations method is valid for the tabularized parameters in Table 1:

Table 1: IEEE parameters for arc flash calculation

Parameter	Value/Limit/Range
System Voltage	208 V – 15 kV
Frequency	50 Hz – 60 Hz
Fault type	3 Phase
Bolted Fault Current	0.7 kA – 106 kA
Electrode Gap	13 mm – 152 mm
Grounding Type	Ungrounded, Grounded and High Resistance Grounding
Enclosure Type	Open Space, Enclosed Box, Panel, Switchgear and Cables

It is noteworthy that the arc flash incident energy from equipment designed to operate at 15 kV and above cannot be calculated using this standard. See 5.2 for details on calculation methodology for voltages of 15 kV and greater.

3.2 NFPA 70E ANNEX D

The full title of Annex D is: NFPA 70E *Informative Annex D Incident Energy and Arc Flash Boundary Calculation Methods*. From here on referred to as Annex D.

There is no specification within NFPA 70E as to how calculations of incident energy or arc flash boundary should be carried out; although Annex D, appended for informative purposes only, details some recognized methodologies.

The Other Electrical Hazard: Electrical Arc Flash Burns by Ralph Lee uses calculation methods, developed from first principles, and can be used to calculate the incident energy and arc flash boundary, for an arc in open air, for equipment rated >600 V.

The so-called Doughty Neal paper, *Predicting Incident Energy to Better Manage the Electrical Arc Hazard on 600 V Power Distribution Systems* by Doughty, et al. provides a methodology for calculating incident energy and arc flash boundary for equipment operating at 600 V and below in a three-phase system. It applies to short-circuit currents between 16 kA and 50 kA.

Together, these methodologies, widely known as NFPA 70E, D2, D3 are heavily caveated, placing onus upon the responsible party to correctly interpret and deploy the equations provided.

Dan Doan's paper, *Arc Flash Calculations for Exposure to DC Systems* is applicable for DC systems up to 1000 V and is discussed in Annex D.5.

This document recommends the above as a common approach. This is also in line with the findings in the National Renewable Energy Laboratory (NREL) document *Offshore Wind Electrical Safety Standards Harmonization: Workshop Proceedings*.

4 RECOMMENDED LABEL DESIGN, CONTENT AND INTERPRETATION

4.1 RECOMMENDATIONS FOR EQUIPMENT LABEL CONTENT

The recommendation, derived from the definitions in 4.5.1, for label design is to adopt the orange 'warning' style. This is on the basis that a yellow 'caution' design is not sufficient as it implies no more than minor or moderate injury and 'danger' is too severe as it implies certain death or serious injury which is not the case under a well-managed electrical safe system of work. While it remains a possibility, it is considered an overall low probability. However, it is widely accepted that red 'danger' style labels are commonly used in situations where the calculated incident energy exceeds 40 cal/cm² and, in some circumstances, where the voltage exceeds 600 V.

It should be noted that these recommendations are not intended to be binding and agreements between the asset owner (with legal responsibility for the hazard) and the parties supplying the labels should be made and label specification agreed.

Arc flash labeling is not an assessment of the hazard. There is a requirement for effective setting to work process; most likely through a permit to work system or similar. The information that is provided on a label should only be considered a verification of the information and instruction provided on the work permit. This has the added benefit of enabling a strategy of variable personal protective equipment (PPE) throughout a work area to match the hazard rather than a blanket level which could possibly be excessive for most locations in a WTG as it works to the worst-case scenario.

With the information noted in 4.6, the recommendation for information to be placed on arc-flash labels is as follows:

1. Nominal system voltage.
2. Arc flash boundary.
3. Available incident energy and the corresponding working distance.
4. Minimum arc rating of clothing.

For incident energy to be a useful reference for workers, it is advised that the working distance at which incident energy is determined is standardized throughout the WTG. This avoids confusion of the need for operative to mentally recalibrate the information at different locations. Consideration should be given to standardizing this distance, as part of this framework, across the offshore wind sector.

4.2 RECOMMENDATION FOR LABEL DESIGN

An example for label design based on ANSI Z535.4 is given in Figure 2.




 WARNING			
 Arc-Flash Hazard		Shock Hazard 	
Arc-Flash Boundary:	2.8m 2' 10"	Nominal Voltage:	0.69kVAC
Incident Energy:	3.52 Cal/cm²	Limited Approach Boundary:	1000mm 3' 6"
Working Distance:	458mm 18"	Restricted Approach Boundary:	300mm 1' 0"
Bus Name:	Cabinet X	Label No:	0001
Upstream Protective Device:	CB Y on Board Z	Report No:	321654
		Study Date:	1st Oct '23

Figure 2: Standard label design for arc flash and shock hazard

Although contrary to the ANSI Z535.4, there may be cases where the asset owner, responsible for the application of labels decides that a red 'danger' label is more appropriate. The design in Figure 3 is suggested as an alternative to the preferred orange warning label shown in Figure 2.




 DANGER													
 Arc-Flash Hazard	Shock Hazard 												
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;">Arc-Flash Boundary:</td> <td style="padding: 2px;">6m 19' 8"</td> </tr> <tr> <td style="padding: 2px;">Incident Energy:</td> <td style="padding: 2px;">51.39 Cal/cm²</td> </tr> <tr> <td style="padding: 2px;">Working Distance:</td> <td style="padding: 2px;">1m 36"</td> </tr> </table>	Arc-Flash Boundary:	6m 19' 8"	Incident Energy:	51.39 Cal/cm²	Working Distance:	1m 36"	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;">Nominal Voltage:</td> <td style="padding: 2px;">34.5kVAC</td> </tr> <tr> <td style="padding: 2px;">Limited Approach Boundary:</td> <td style="padding: 2px;">1.8m 6'</td> </tr> <tr> <td style="padding: 2px;">Restricted Approach Boundary:</td> <td style="padding: 2px;">762mm 2' 6"</td> </tr> </table>	Nominal Voltage:	34.5kVAC	Limited Approach Boundary:	1.8m 6'	Restricted Approach Boundary:	762mm 2' 6"
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Bus Name:	Cabinet X												
Upstream Protective Device:	CB Y on Board Z												
Label No:	0001												
Report No:	321654												
Study Date:	1st Oct '23												

Figure 3: Alternative label design for arc flash and shock hazard

4.3 EQUIPMENT LABEL INTERPRETATION

It is important for employers to correctly communicate to their employees and contractors the information required to accurately interpret the applied equipment labels. Operatives are required to have adequate levels of training to understand the information being conveyed by equipment labels.

This is important. Firstly, so that operatives can easily understand the information being provided to them on the label and relate it to the control measures that have been put in place. Secondly, so operatives understand when they may be exposed to the incident energy detailed on the equipment label.

As an example, it may be the case that operatives are only exposed to the detailed incident energy when a cabinet is being accessed, but safe from the hazard when the cabinet is securely closed. As such, an operative, in this hypothetical situation, may only require a lower level of PPE displayed on the equipment label when working adjacent to the closed cabinet, requiring enhanced PPE only when accessing the cabinet.

5 RECOMMENDED LABEL POSITIONING

The quantity of labels applied should be limited to what is necessary to warn of the hazard. Counter to what may be, for some, intuitive, multiple labels could lead to confusion of 'blindness' to the warning caused by clutter.

Adopting a strategy of minimizing the number of labels applied while maximizing their effectiveness has the added, albeit minor, benefit of reducing initial costs and the costs, time, and effort required for any future re-labeling campaigns.

Labels should be positioned, where possible, at eye level. Where this is not possible, placement should be conspicuous to anyone accessing the equipment, for example, adjacent to the handle or locking mechanism.

Where cabinets have access front and rear, consideration should be given to labeling both access points.

6 RECOMMENDATIONS

6.1 MANAGING THE RISK

A basic requirement in the effective control of any hazard, including arc flash, is a suitable and sufficient risk assessment.

Once a risk assessment has identified the need to mitigate risk of arc flash, the following four stages should be followed in order.

1. Calculation of incident energy. It can only be possible to know what mitigation is required once the level of exposure is fully known.
2. Application of a hierarchy of control leads to engineering the hazard out to prevent exposure to the hazard in the first place.
3. Administrative controls, including processes, policies and procedures to limit, for example, actions of individuals as a positive contributor to a safe workplace.
4. The final step is personal protection which looks at providing PPE. This should be noted as a last resort which, if the previous three steps have been correctly applied, will deal with residual risk only.

6.2 CALCULATIONS AND DATA COLLECTION

This document recommends that the calculation methodology to be deployed as a component of the wider arc flash risk assessment (AFRA) is based upon details laid out in Section 5. This recommendation is based purely on obtaining a level of consistency across the industry, but it remains the prerogative of the OEM or the asset owner to make the final decision on the calculation methodology to be deployed.

The OEM will be responsible for producing relevant non-grid connected data and information for the WTG. This could be in the form of an arc flash information pack (AFIP), a template which is not specified in this document. These data and any associated calculations may be carried out by a competent third party or carried out internally by the OEM and appropriately validated. OEMs will be responsible for providing suitable details to allow calculations to be made by owners or appointed third parties, including what assumptions were made in the OEMs WTG fleet/type calculations, such as use of the IEEE 1584 rule, converter short circuit fault currents, and generator impedance values.

Calculations produced should account for all operating modes of the WTG where personnel would be reasonably expected to access the asset or specific points within the asset. This should include off-grid and where the WTG is supplied by an external generator or uninterruptable power supply or other self-powering function. The studies should consider turbines set in maintenance mode and operational mode. Where policy exists that determines persons will not access the turbine unless protection setting have been adjusted to maintenance mode, consideration can be given to dispensing with the need to study operational mode.

The owner, furnished with suitable and sufficient WTG data/information from the OEM (including assumptions, limitations, and appropriate data sheets), will produce calculations for a grid-connected scenario. This may be in conjunction with the owner and/or operator of the network to which the windfarm will connect. As an alternative, the asset owner may agree with the OEM to provide the necessary data for the OEM to carry out on-grid studies in addition to off-grid studies. In this scenario, the owner must provide the required system

data (cable, offshore substation, onshore substation, and grid full short circuit fault current) to the OEM.

All data exchanges should be as early as possible in the development phase of the windfarm, well in advance of the construction phase. This will allow the accurate incident energy values in an arc flash event to be calculated in time for labels to be printed and attached by the OEM at manufacture or in the pre-assembly site.

The asset owner, in accordance with NFPA 70E, retains overall responsibility for ensuring that the appropriate calculations and studies are completed, and that adequate equipment labeling is applied. Any of this activity may be contracted out to either the OEM or some other competent third-party provider.

It should be further noted that there is an ongoing requirement for the asset owner to regularly (at least every five years or where there is a material change in circumstances) revisit the calculation and update equipment labelling if a change in value is detected. The suggested equipment label format provides for the inclusion of the most recent, valid calculation date.

6.3 LABEL PLACEMENT/INSTALLATION

Under this framework, a collegiate approach to quantifying the arc flash hazard and mitigating through equipment labeling is enabled. It is expected of all parties that information will flow in a timely manner and to a level of detail that the receiving party can reliably and effectively use the information for their purposes.

Where the asset owner elects to procure and install equipment labeling, all other interested parties will provide accurate information within the agreed timescales.

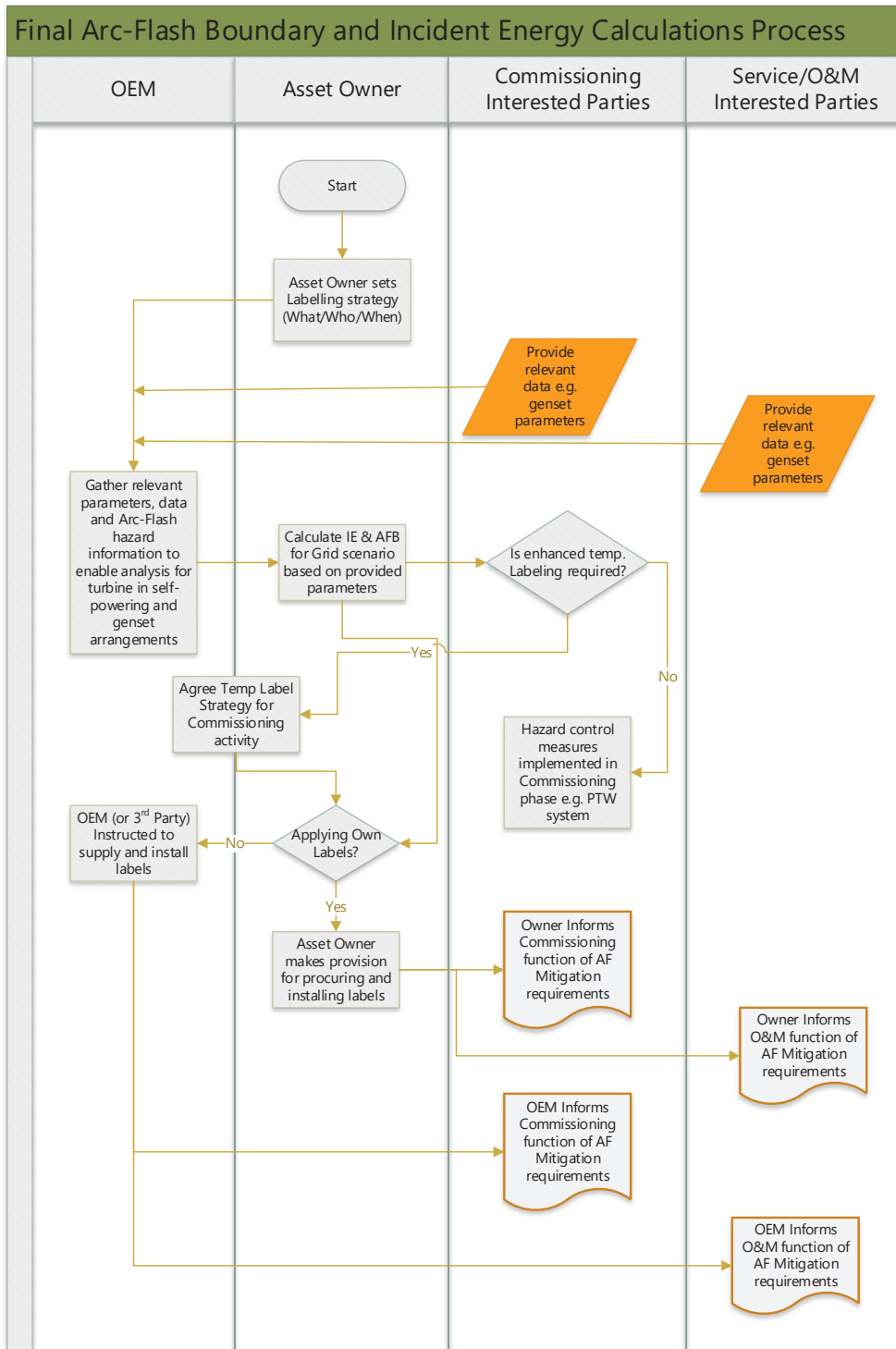
Where the asset owner appoints the OEM or some other third party to carry out all or part of the calculation and equipment labeling activity, the asset owner will endeavor to provide all necessary information, following the required studies for grid-connected scenarios such that the appointed, responsible party can meet their obligations in a timely way.

The asset owner and the commissioning interested parties, when setting the labeling strategy, will decide upon the need to apply temporary labels during the commissioning phase when, due to turbine configuration and temporary power supply arrangements, the incident energies are usually expected to be higher. This document suggests that temporary 'commissioning phase' labels could lead to confusion and add unnecessarily to cost. It is the recommendation, therefore, that exposure to higher incident energies during the commissioning phase is managed through robust information flows and, preferably managed via a strict permit to work process so that a worker's exposure to arc flash is adequately communicated to them and, more importantly, adequately controlled. It is important that the permit to work system deployed accounts for the company's PPE requirements. It is advised that specific PPE requirements are communicated clearly within the permit to work system.

The arc flash boundary and incident energy calculation process flowchart in Figure 4 shows the high-level interactions as the process develops through to completion (application of adequate labeling).

Where it is not possible to carry out the full system arc flash studies in the pre-construction phase, temporary labels may be required. This should be agreed when producing the arc flash labeling strategy.

Figure 4: Arc flash boundary and incident energy calculation process flowchart



7 RESPONSIBILITIES SUMMARY

The division of responsibilities has been detailed in the flowchart in Figure 4 of this document.

It is the recommendation of this document that the interested parties detailed in the flowchart agree timescales for the interactions and production/transmittal of information at contract placement stage.

This should include all relevant milestones measured in a baseline program. While this will inevitably contain some commercial implications, this document recommends a strong collaborative approach that produces the very best in safety outcomes for frontline operatives and others exposed to the electrical hazard. It is important to consider all interested parties during the contract placement phase. This should allow for appropriate communications beyond the developer and OEM. Any relevant subcontracting parties, for example, should also remain informed.

8 PPE REQUIREMENTS

As determined by an adequate risk assessment, PPE will be made available to all relevant operatives involved in constructing, commissioning, operating and maintaining electrical assets. Considering the critical electrical safety risk areas within a WTG:

- turbine nacelle;
- high voltage equipment;
- medium voltage equipment;
- electrical panels and cabinets;
- electrical cables and wiring, and
- any other area where personnel are exposed to energized electrical conductors or circuit parts.

To mitigate the possible effects of the electrical hazard, organizations are obliged to produce and maintain an effective electrical safe system of work. In relation to PPE, it must be observed that, as detailed in 9.1, the use of PPE is the last line of defense and that safe systems of work that consider a robust hierarchy of control are required to control the hazard. These safe systems of work should manage engineering and administrative control of the electrical hazard but should also detail the requirements for:

- provision of arc flash and shock PPE;
- regular inspection of arc flash and shock PPE;
- replacement/repair of appropriate arc flash and shock PPE, and
- audit on the use of arc flash and shock PPE.

While this document does not seek to require any of the sponsoring organisations to approach its PPE obligations in any particular way, it was considered prudent to include some basic information and guidance on possible approaches to the matter.

Table 2 provides the reader with details of the standards that are required to be met when considering the procurement of arc-rated PPE.

Table 2: Examples of arc rated PPE standards

Type of PPE	PPE Product Description	EU Specification	US Specification
Arc-Rated Clothing Protection	<ul style="list-style-type: none"> - Arc Flash Workwear Trousers - Long sleeve Arc Flash Workwear Top (t-shirt, polo etc.) - Arc Flash Winterwear - Arc Flash Rainwear - Arc Flash Balaclava 	<p>EN 61482-1-2, Class 1, ≥ 8 cal/cm² (Arc Flash)</p> <p>EN ISO 11612:2015 (Heat & Limited Flame Spread)</p> <p>EN 1149-5:2018 (Electrostatic Discharge)</p> <p>EN ISO 11611 (Welding & Allied Processes)</p> <p>EN ISO 20471 2016 Class 2 (Hi-Viz if applicable)</p> <p>EN 342 (Rainwear)</p> <p>EN 343 Class 3:3 (Winterwear)</p>	<p>ANSI/ISEA 107 (Hi-Viz)</p> <p>ASTM F1506 (Arc Flash)</p> <p>ASTM F2178</p>
Foot Protection	<ul style="list-style-type: none"> - Safety Boots or Shoes 	<p>EN ISO 20345: S3</p>	<p>ASTM F2412-11</p> <p>ASTM F2413-11</p>
Head Protection	<ul style="list-style-type: none"> - Safety Helmet suitable for electrical work (non-vented) 	<p>EN 397</p> <p>EN 12492 (1)</p> <p>EN 50365</p>	<p>ANSI Z89.1 Type I Class E</p>
Eye/Face Protection General Purpose	<ul style="list-style-type: none"> - Safety Glasses 	<p>EN 166 (F):2002</p>	<p>ANSI Z87.1</p>
Face Protection Electrical Work	<ul style="list-style-type: none"> - Safety Visor <p>Attached to helmet or integrated in to the helmet</p>	<p>EN 166:2001</p> <p>EN 170:2002</p> <p>E DIN 58118:2011</p> <p>DGUV GS-ET-29:2011</p> <p>ASTM F2178 \geq ATPV 8 cal/cm²</p>	<p>ANSI Z87.1</p> <p>ASTM F2178 \geq ATPV 8 cal/cm²</p>

Table 2: Examples of arc rated PPE standards (continued)

Type of PPE	PPE Product Description	EU Specification	US Specification
Hand Protection General Handling	– Protective Gloves	EN 388:2018 4X44F	ANSI/ISEA 105: 2016 CUT A7
Hand Protection Electrical work	– Electrical Insulated Protective Gloves w/ leather protectors (if applicable)	EN 60903 Class 00 – 4	ASTM D120, Standard Specification for Rubber Insulating Gloves
Hearing Protection	– Hearing Protectors e.g. in ear canal plugs (ear plugs) or ear muffs	EN 352	ANSI S3.19
<p>Notes:</p> <p>While there may be no legal or corporate requirement to wear hi-visibility garments when working on or near a fully commissioned asset this document recommends their use as a matter of course. Where an organisation deploys a policy that only requires operatives to wear hi-visibility garments in certain areas or circumstances, that hi-visibility garment will be required to be compatible with the system of arc flash garments being worn i.e. a hi-visibility over-vest is required to be arc flash rated.</p> <p>Layering of arc flash clothing to achieve higher overall arc flash protection levels can be a technically beneficial, easier for operatives to wear and also cost effective. This document recommends an 'everyday use base layer' of arc flash clothing that achieves a minimum of 8 cal/cm² (CAT 2) and a combination of garments there after can be used to increase the arc flash protection using the below matrix as a guide.</p> <p>Non-flame resistant garments, for example, man-made fibres such as polyester, should not be worn with (under or over) arc flash rated clothing. This document recommends that arc and flame protective garments made from inherent fabric such as modacrylics or aramids that are permanently safe regardless of the number of washes or the way the garments are washed. Arc and flame protective garments made from fabrics that rely on a chemical treatment such as 100% cotton or cotton/nylon or cotton/polyester blend are best avoided as the protection is not permanently guaranteed in any garment care situation. As such, it cannot be known what level of protection these garments offer the wearer without a program of costly continual replacement.</p> <p>It is a recommendation of this document that, when an organisation is procuring arc flash rated PPE, it shall only consider garments that have been tested to the relevant standards detailed in this table and that each garment has an identified arc thermal performance value (ATPV).</p>			

Table 3 provides a reference to illustrate possible configurations of PPE for different arc flash scenarios. It is important to note that the actual PPE required should be determined based on a thorough AFH analysis of the specific arc flash risk present in each situation, in accordance with the guidelines outlined in the NFPA 70E standard. Stakeholders are advised to customize their PPE layering system to ensure optimal protection based on measured risks and applicable safety standards.

Table 3: Example PPE layering combinations for arc flash risk mitigation

Incident Energy Level (Cal/cm ²) – Range	Hazard risk category	PPE type	PPE details
1–4	1	1	This document recommends that this category is not routinely used in the electrical environment of the wind industry as the protection values are too low for many situations and garment weights and costs are equivalent for clothing rated to Category 2, which will form the minimum requirement for arc flash protection.
4.1–8	2	2	<ul style="list-style-type: none"> – One layer arc flash rated workwear solution that has wrist closures. – An arc flash rated single layer balaclava should also be worn to protect the head and face. – Suitable head protection with a full-face polycarbonate arc flash rated visor. – Required electrically insulated gloves to the correct voltage will also be worn when proving for absence of voltage, making isolations, working live.
8.1–25	3	3	<ul style="list-style-type: none"> – One or two layer arc flash rated workwear solution that has wrist closures. – An arc flash rated single layer balaclava shall also be worn to protect the head and face. – Suitable head protection with a full-face polycarbonate arc flash rated visor. – Required electrically insulated gloves to the correct voltage will also be worn when proving for absence of voltage, making isolations, working live.

Table 3: Example PPE layering combinations for arc flash risk mitigation (continued)

Incident Energy Level (Cal/cm ²) – Range	Hazard risk category	PPE type	PPE details
25.1–40	4	4	<ul style="list-style-type: none"> – Typically, a one-layer arc flash rated two-piece jacket and bib trouser combination are worn. – An arc flash rated hood and visor and gloves to the correct voltage.

8.1 PPE SUPPLEMENTARY NOTES

- In instances where the incident energy to which an operative will be exposed exceeds 40 cal/cm², PPE is not an option for mitigation. In this case, it is recommended that de-energization of the equipment is mandated in the appropriate safe system of work.
- Considerations should be made to wearer comfort and wearability – the objective should be to issue clothing that has the highest arc protection in the lightest weight fabric to reduce the heat burden on operatives but also to reduce the need for additional layering, or at least require a lesser weight additional layer.
- Once the incident energy level is known then the PPE selected must match or exceed this incident energy value. For example, if the incident energy calculated is 18 cal/cm², then the PPE worn must be tested and certified to meet or exceed this value in either a single layer or dual layer clothing combination.
- When arc rated clothing is being layered to achieve a higher arc rating, then there must be the provision of arc flash test certification from the vendor to prove that the clothing layered combination/s has been tested and certified to the said arc flash level.

9 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AC	alternating current
AF	arc flash
AFB	arc flash boundary
AFH	arc flash hazard
AFIP	arc flash information pack
AFRA	arc flash risk assessment
ANSI	American National Standards Institute
DC	direct current
IE	incident energy
NEC	National Electrical Code
NFPA	National Fire Protection Association
NREL	National Renewable Energy Laboratory
IEEE	Institute of Electrical and Electronics Engineers
O&M	operation and maintenance
OEM	original equipment manufacturer
OSHA	Occupational Safety & Health Administration
PPE	personal protective equipment
WTG	wind turbine generator

10 REFERENCE DOCUMENTATION

- ANSI Z535.4: *Product safety signs and labels*. <https://webstore.ansi.org/>
- IEEE 1584: *IEEE Guide for performing Arc Flash hazard calculations*. <https://standards.ieee.org/>
- NFPA 70E: *Standard for Electrical Safety in the Workplace*. <https://www.nfpa.org/>
- OSHA 1910.335 *Safeguards for personnel protection*. <https://www.osha.gov/>
- Energy Institute (2018): *Assessing and managing the risk of Arc Flash*. <https://publishing.energyinst.org/topics/power-generation/assessing-andmanaging-the-risk-of-arc-flash>
- NREL (2020): *Offshore Wind Electrical Safety Standards Harmonization: Workshop Proceedings*
- Ralph Lee (1982): *The Other Electrical Hazard: Electrical Arc Flash Burns*
- Doughty, et al. (2000): *Predicting incident energy to better manage the electric arc hazard on 600 V power distribution systems*
- Dan Doan (2010): *Arc Flash Calculations for Exposure to DC Systems*



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