Powerful-CB Safety Support

Powerful-CB Safety Case Report

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Executive Summary

This Safety Case Report (SCR) presents the Safety Case for the ABB 2000A Fault Limiting Circuit Breaker (FLCB), including a pictorial safety argument in a "Claims Argument Evidence" (CAE) format. The Safety Case is required to support the development of the FLCB device and to demonstrate that its use on a public 11kV distribution network is safe.

The Safety Case demonstrates the safety of the FLCB device. In particular, it shows that:

- All risks associated with the FLCB device are Tolerable and reduced to a level that can be considered As Low as Reasonably Practicable (ALARP);
- All prescriptive safety requirements are met.

The single recommendation of this Safety Case Report is:

> Before any further use of the FLCB device, e.g., further trials, Business As Usual (BAU), the safety argument and its supporting evidence should be reviewed to determine whether any evidence items require development or update.

Contents

1 Introduction

A Safety Case is required to support the development of the Fault current Limiting Circuit Breaker (FLCB) device and to demonstrate that its use on an 11kV electrical network is safe. Accordingly, the purpose of this document is to present the Safety Case, in particular a pictorial safety argument (Annex A), for the ABB 2000A FLCB device.

1.1 Background

The local network was designed to manage the prospective fault levels within its system with equipment rated to withstand and clear the prospective fault current. When new generation is added, or the system is expanded in other ways, the prospective current level might increase. When this occurs, the system has to be upgraded to accommodate the higher prospective fault current. This is typically done by re-design and / or replacement of substation equipment to a higher design fault level rating. Another possibility is to limit the existing fault level so that existing equipment is still within design rating, thus avoiding upgrades. Fault current limiting equipment technologies can be used to alleviate fault level constraints associated with interconnection, short cable distances and other factors, which are limiting the growth of low-carbon generation on distribution networks in Great Britain. FLCBs provide a means to allow the continued growth and connection of Distributed Generation (DG) onto the distribution network in a cost-effective manner by rapidly disconnecting some of the fault current and allowing existing equipment to handle the reduced fault current. In this way, expensive and possibly difficult upgrades of the system and its protection can be avoided.

In developing the safety argument[1] for the ABB 2000A FLCB it is important to recognise that public distribution networks are not inherently risk free and are subject to flashovers or electric shock and degradation from operation, switching, wear etc. from existing switchgear. These risks are well known and well-managed, and safety analysis of the FLCB device demonstrates it does not have an adverse effect on these pre-existing network risks. However, the FLCB device does introduce a new safety risk in that, with increasing DG, there is potential for existing switchgear to experience a fault current above its design rating if the FLCB fails to operate on demand. The Safety Case presented in this SCR considers this 'additional' risk and ultimately argues the risk can be reduced to be Tolerable and ALARP.

FLCBs have only been developed to a proof of concept stage and are currently not used for the purpose of fault level limiting protection anywhere in the world. UK Power Networks (UKPN) secured funding for a dual trial of two different, innovative, 11kV fault limiting devices through the Ofgem introduced Electricity Network Innovation Competition (NIC):

- The first device, produced by ABB, is designed for deployment in 33/11kV primary substations. It is the subject of this Safety Case Report.
- The second, produced by Applied Materials (AMAT), was designed for direct connection to customer generators. This device is no longer part of the project and is not addressed further.

A trial has been undertaken to provide data on the performance of the ABB FLCB. The successful outcome of the trial will accelerate development by ABB and adoption of the device by Distribution Network Operators (DNOs).

[1] The "safety argument" (Annex A) can be considered a part of, or a representation of, the Safety Case.

1.2 Report Structure

This Safety Case Report structure is as follows:

- Section 2 discusses the scope of the Safety Case.
- Section 3 provides brief technical details on the FLCB device and its trial.
- Section 4 discusses the process by which the Safety Case was developed.
- Section 5 details the safety argument for the FLCB device.
- Section 6 provides conclusions and recommendations.
- Section 7 lists references.
- Section 8 details abbreviations and provides a glossary of terms.
- Annex A presents the safety argument in pictorial form.
- Annex B tabulates the evidence that supports the safety argument and Safety Case.

2 Scope of the Safety Case

The operation of the existing 11kV distribution network is not free from risk as there is an inherent potential for arcing / flashovers or electric shock etc. from existing switchgear. These risks are well known and well-managed and considered to be Broadly Acceptable. Safety analysis of the ABB FLCB device shows it will not adversely affect this. However, the use of the FLCB device introduces a new risk that potential fault currents may exceed the ratings of network equipment.

The scope of the Safety Case is bound by the FLCB device itself, its functionality and its operating environment. Initially, this was constrained to a trial at one specific site but the Safety Case also considers BAU operation on the wider 11kV distribution network (i.e., a generic application case) to ensure that the Safety Case is comprehensive. This has been developed as part of the Safety Management process (see Section 4).

It is recognised that compliance with the Electricity at Work Regulations (ref. 2) is essential to demonstrate safe operation. In particular, it is important to consider Regulation 5, which states:

> *No electrical equipment shall be put into use where its strength and capability may be exceeded in such a way as may give rise to danger.*

The key aspect of this requirement is that equipment must not fail, or fail to operate in such a way that may give rise to danger. The Powerful-CB project has interpreted this requirement as not prescriptively preventing the use of a FLCB to increase the level of potential fault current but, instead, requiring that (ref. 3, Section 6.3):

> *Each FLCB device and the corresponding protection measures shall be sufficiently reliable, or have suitable mitigation installed, such that the likelihood of the network equipment seeing a fault current above its rating is 'Broadly Acceptably' or that the risk has been reduced to be 'Tolerable and ALARP'.*

Ultimately, the Safety Case demonstrates that the FLCB and its use in both trial and general application is considered to be 'Safe' i.e., the risks have been demonstrated to have been reduced to Broadly Acceptable, or Tolerable and ALARP, and relevant prescriptive Safety Requirements have been met.

3 System Description and Operating Environment

This section describes the technical challenge that the FLCB device has been designed to address, the FLCB itself and the FLCB trial.

3.1 Technical Challenge

A conventional circuit breaker interrupts the flow of fault current by physically separating its contacts, allowing a resulting arc between the contacts. This arc is then dissipated and eventually extinguished via various methods incorporated into the switchgear design. A typical vacuum circuit breaker takes up to 60ms to open its contacts, then another 10-15ms to extinguish the arc, for a total interrupting time of 75ms. Interruption times can be longer for aged equipment due to 'stuck' contacts and in the worst case could be up to 100ms.

An FLCB can operate rapidly compared to a conventional circuit breaker, and support systems with increased prospective fault current, e.g., with increased DG. An alternative to upgrading the system is to use an FLCB to quickly remove part of the fault current in the system, allowing existing protection equipment to handle the reduced fault current. For this to be possible, the limitation and interruption of the fault current has to be fast enough. For the Powerful Circuit Breakers project, the design criteria are for a prospective fault current of 25 kA RMS and for peak current to be limited below 13 kA within a few milliseconds.

Further, due to space constraints and requirements on efficiency, the FLCB should be designed to handle the nominal current without an active cooling system.

The trial at Glaucus Street primary substation has been carried out within the LPN region. However, as previously mentioned and following a successful outcome, BAU installation may include installation onto the Eastern Power Networks (EPN) and the South Eastern Power Networks (SPN).

3.2 ABB 2000A FLCB

ABB is a global leader in power and automation technologies with a long tradition in developing state of the art technologies and products. They have a solid track record of working on Low Carbon Networks Fund/NIC projects involving power electronics and fault level solutions.

To meet the requirement on fault speed interruption and network losses, a hybrid FLCB consisting of a combination of high power semiconductors and fast mechanical switches has been developed. ABB's 2000A FLCB solution eliminates conduction losses by using an innovative "fast commutating switch" (FCS) that bypasses the power electronics during normal operation, and opens within 0.35ms in the event of a fault. This eliminates the need for a bulky cooling system, making this technology feasible to install in an existing indoor substation.

ABB propose that this prototype can be housed in three 1000mm-wide modular switchgear cubicles. This is much smaller than other FLCB designs seen to date, and further size reductions may be possible for a commercial product. The FCS also reduces network losses, which translates to lower operating costs. The FCS is a novel design and has not been proven for network protection purposes in service anywhere at present.

The UK Power Networks Engineering Technical Standard for Indoor 12kV power electronic FLCBs (ref. 5) describes requirements that are specific to the FLCB. The UK Power Networks Engineering Technical Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations (ref. 6) defines the overall general requirement for the switchgear and the process for achieving technical approval for use within their networks.

The Powerful-CB project has trialled the 2000A FLCB installed at the Glaucus Street primary substation, in parallel with the existing bus coupler, in series with a transformer incomer feeder and as a bus coupler between two busbar systems that experience the infeed from three transformers to prove the technology. The trial did not have the potential to exceed any existing fault level limits on the substation equipment.

3.3 Trial

The FLCB's final intended BAU usage is to alleviate the fault level headroom (i.e., design fault level minus operating fault level) of substations without needing to upgrade existing switchgear. However, for the purposes of the trial, the design fault rating of the existing switchgear was not exceeded. Therefore, the impact of the FLCB failing to operate on demand was similar to that of a conventional circuit breaker (CB) failure.

Additionally, during the trial, the site`s fault clearance capabilities could not be compromised as the FLCB was not fully relied on to isolate a fault. If a fault occurred during the trial, the FLCB operation (or lack of operation) would not have been critical for the network, as the conventional protection could clear the fault if needed. The purpose of the trial was to monitor and record the FLCB performance to provide proof for the manufacturer's claims.

For the purposes of the trial, the FLCB was installed with two conventional CBs in series, one on either side. This design provided the necessary back up fault current breaking requirements as well as isolating capabilities if required. The existence of the adjacent CBs presented the opportunity to use a modified "CB Fail" protection philosophy as an additional safety measure during the trial.

To understand the main risks with the FLCB concept, and to mitigate them as far as possible during the design and verification phase, several activities were initiated. This included, for instance, Failure Modes and Effects Analysis (FMEA), network simulations, Probability of Failure on Demand (PFD) reliability analysis and various verification activities. Some of the more critical functions are mentioned below and are addressed in the design and verification activities planned within the project.

- Mechanical and electrical endurance of the FCS
- Interruptions capability of the Insulated Gate Bipolar Transistor (IGBT)
- Commutation capability of the FCS
- Insulation withstand of the FCS
- Short circuit capability of the FCS
- Failures with possible arcing in the panel
- Effect of single components on the overall reliability
- Reliability of the FCS drive circuit
- Reliability of FLCB controller

Section 5.3.3 provides reference to the evidence of the verification activities and standardised testing that support the argument that the FLCB device was tested and commissioned for use at the trial site.

4 Safety Case Process and Principles

This section discusses the Powerful-CB safety management process, Safety Case Principles that guided the generation of the FLCB Safety Case and what “safe” means for the FLCB.

4.1 Safety Management Process

A Safety Case Process and Principles document (ref. 3) was developed to define the process for production, review and approval of the Safety Case, define the Safety Case principles, and communicate the approach to safety to all relevant stakeholders. An overview of the safety management process is shown in Figure 1. Details of how each step in the process has been used to develop the safety argument can be found in Section 5 of this SCR.

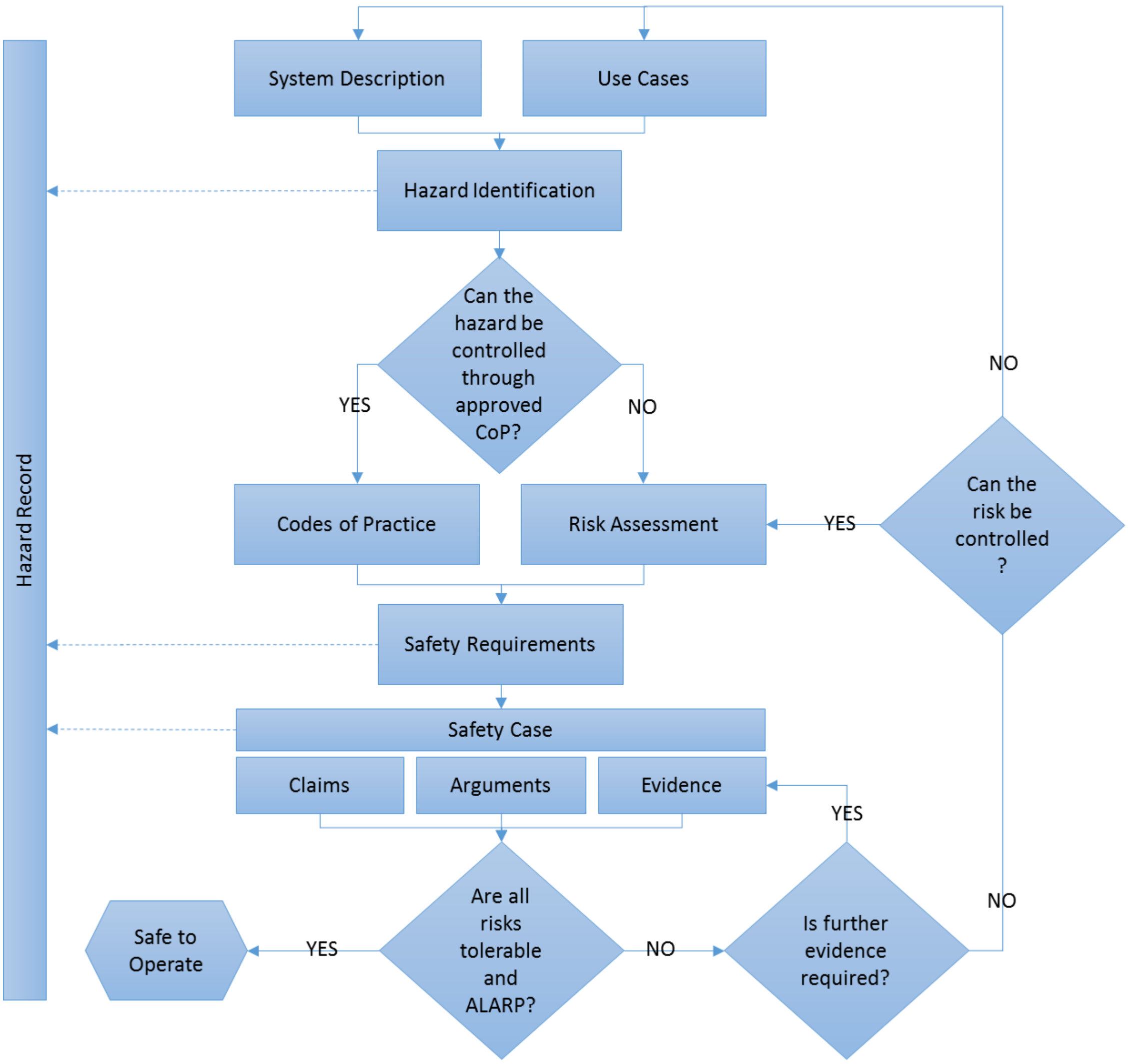


Figure 1: Safety Management Process

4.2 Safety Case Principles

The following high level Safety Case Principles (SCPs) have been derived which have informed the development of the Safety Case.

SCP 1 The Safety Case should demonstrate that the management system (policy, organisation, documentation, training, performance monitoring, change control etc.) is adequate to ensure compliance with the relevant statutory provisions and show an appropriate level of control during each phase of the 'system' life cycle (i.e., from initial testing and implementation through to end of life replacement & decommissioning).

SCP 2 The Safety Case should describe how the principles of risk evaluation and risk management are being applied to the design to ensure that risks will be controlled so as to ensure compliance with the relevant statutory provisions.

SCP 3 A systematic process should be used to identify all reasonably foreseeable hazards that apply to the 'system', together with potential initiating events or sequences of events.

SCP 4 The methodology and evaluation criteria adopted for risk assessment should be clear.

SCP 5 The identification of risk reduction measures should be systematic and take into account new knowledge as it arises. Risk reduction measures identified, as part of the risk assessment, should be implemented if they are reasonably practicable.

SCP 6 In deciding what is reasonably practicable, the case should show how relevant good practice and judgement based on sound engineering, management and human factors principles have been taken into account.

SCP 7 Where remedial measures are proposed to reduce risk, the timescale for implementing them should take account of the extent of such risks and any practical issues involved.

SCP 8 Appropriate control and mitigation measures should be provided to minimise the likelihood of an accident and protect personnel from the consequences. Measures and arrangements for controlling an emergency should identified and take account of likely conditions during emergency scenarios.

4.3 Acceptance Criteria

The FLCB is considered 'Safe' if its associated risks are Broadly Acceptable or Tolerable, and ALARP, and relevant prescriptive safety requirements have been met. Accordingly, the Safety Case presents the safety argument to support the following Claim (the 'Top Goal' in Annex A):

The FLCB device is safe to use in its specified operating environment.

5 Safety Claims, Arguments and Evidence

This section lays out the safety argument for the FLCB device. Annex A contains the full safety argument. Section 5.1 provides an overview of the safety argument notation, while Sections 5.2-5.6 detail the safety argument (one section for each of the five main Claims, C1-C5, in the safety argument). Section 5.7 summarizes the status of the evidence that supports the safety argument.

5.1 Overview

The overall safety argument for the FLCB device is expressed using a Claims Arguments Evidence (CAE) structure. The highest level of this structure are the safety claims; these can be thought of as the high-level safety 'goals' that, if all successfully achieved, will result in the FLCB device having an acceptable level of safety. Each of the claims is supported and explained by a series of arguments. Each argument is then substantiated with a set of robust evidence. The status of each piece of evidence for the Glaucus Street trial is defined as:

- Green – A complete issued version of the evidence is held;
- Orange – A draft version is held, or there is some minor issue with the evidence; or
- Red – No evidence currently exists.

Where evidence items are coloured orange in Annex A, the corresponding text in Sections 5.2-5.6 is given an orange fill.

The CAE approach allows the safety argument to be presented pictorially which shows the links between each piece of evidence, the argument and the claim that it supports. Figure 2 below encapsulates definitions and illustrates how the diagram is presented.

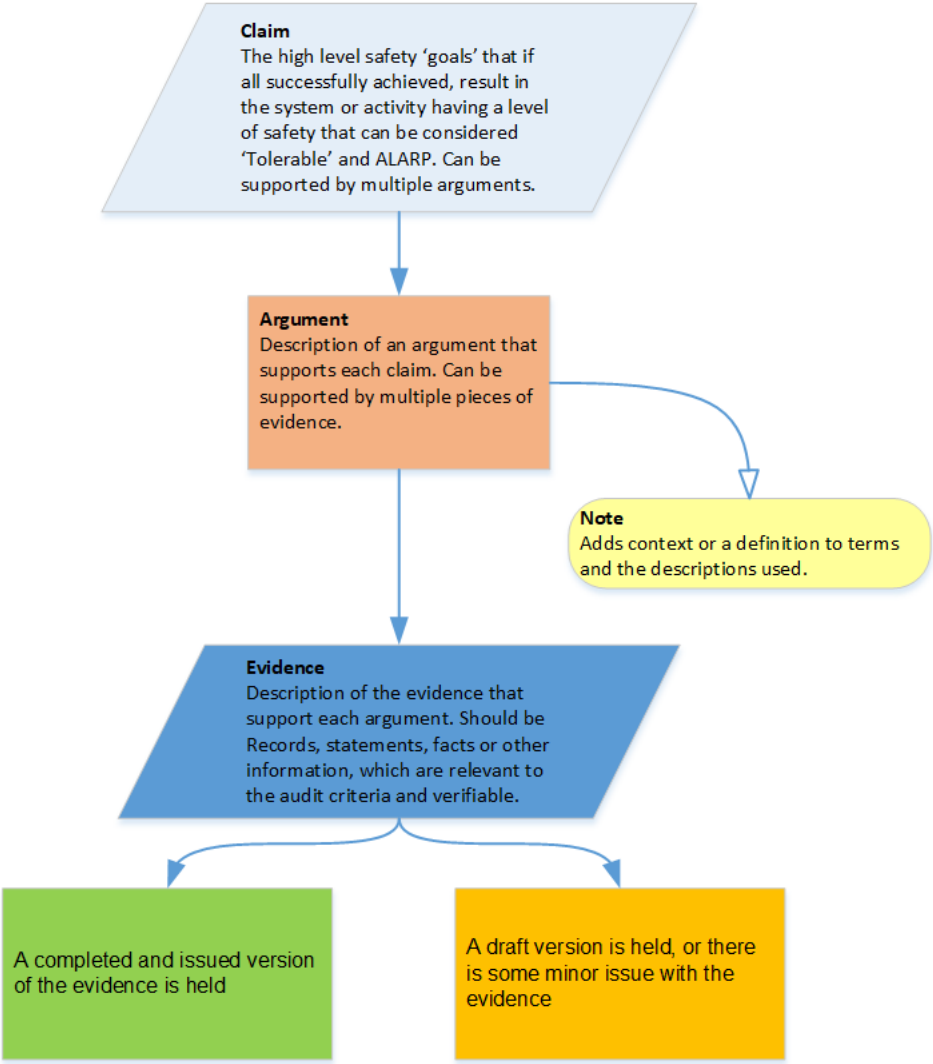


Figure 2: CAE Definition Diagram

The CAE diagram for the FLCB device can be found in Annex A, which identifies five key safety claims (C1-C5) all supporting the overall "Top Goal".

The following sections present each safety claim, associated arguments and the evidence that supports it. Each piece of evidence can be found in the Safety Case Evidence Table in Annex B along with the associated reference and evidence status.

5.2 Claim C1 – Safety Requirements

"***A suitable and sufficient safety assessment process has been undertaken and appropriate Safety Requirements have been identified or derived.***"

The Safety Management process is defined in the Safety Case Process and Principles document (ref. 3) and is summarised in Section 4 of this Report. This section details how each individual step is used to produce the safety case for the FLCB device.

5.2.1 Argument A1.1

"***The FLCB device and its use case has explicitly been defined and described.***"

To bound the scope of the Safety Case, it is important to explicitly define and describe the ABB FLCB device and its use case. This ensures that the activities undertaken to develop the Safety Case are well focussed and provide credible evidence to the process.

5.2.1.1 Argument A1.1.1

"*Technical specifications have been produced which set out the requirements for the device and systems related to the Powerful-CB project.*"

The Standard for Indoor 12kV Power-Electronic FLCBs [E21] sets out the requirements for indoor FLCBs being trialled as part of the Powerful-CB project.

The Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations [E22] sets out the requirements for indoor switchgear at these substations for UK Power Networks.

5.2.1.2 Argument A1.1.2

"*A description document of the FLCB device has been produced by ABB*"

The Implementation as input to safety case study [E8] for the ABB FLCB Device contains a concept description, panel integration, network configuration and control system implementation and interaction overview for the FLCB device.

5.2.2 Argument A1.2

"***A systematic, robust approach has been used to identify all reasonably foreseeable hazards of the system together with potential initiating events or sequences of events.***"

The purpose of the Hazard Identification (HAZID) undertaken was to identify all reasonably foreseeable hazards which are then assessed. The HAZID was systematic and structured. Correct HAZID underpins the whole risk management process and gives assurance that the risks are being managed in the project.

During the feasibility study Preliminary Hazard Identification (PHI) was undertaken to help gain an understanding of the bounding challenge to safety that the FLCB is designed to provide protection against. The PHI also helped to identify whether the device might introduce any other undesirable consequences that have a detrimental impact on safety.

Following on from the feasibility study, a HAZID Workshop was held on 21st June 2017 at the Frazer-Nash offices in Dorking. The workshop was conducted using a 'guide word examination' technique which is a deliberate search for deviations from the design intent. Attendees were asked to apply a series of 'Guidewords' in conjunction with 'Parameters' to each 'Node' to generate deviations from the design intent which can lead to undesirable consequences.

This HAZID workshop was chaired and staffed by Suitably Qualified and Experienced (SQEP) persons, and a record of their relevant qualifications and experience kept. Prior to commencement of the workshop, the team present was assessed by the HAZID Chairman to confirm they are SQEP.

5.2.2.1 Argument A1.2.1

"*A Preliminary hazard identification has been carried out to identify an initial set of hazards and supports the safety case feasibility assessment.*"

The Feasibility of Safety Case Report [E4] includes a summary of the approach taken and the results and conclusions drawn from the information. It consisted of three stages:

- Identifying the bounding safety challenge;

- Failure mode identification; and
- Hazard identification.

5.2.2.2 Argument A1.2.2

“*A HAZID workshop was undertaken to identify hazards and to identify initiating events and accident sequences for the FLCB device in both the trials and general application.*”

The full output of the workshop is contained within the HAZID Workshop Report [E2].

The HAZID workshop was preceded by a Briefing Note [E1] which described the system and scope to be considered and the methodology being proposed for use in that workshop.

The hazards and all accompanying information identified during the workshop have been used to create the project Hazard Record [E3].

5.2.2.3 Argument A1.2.3

“*The HAZID was carried out by SQEP individuals.*”

An attendance sheet is shown in the HAZID Workshop Report [E2] and signed SQEP forms for each attendee are held separately on record by Frazer-Nash.

5.2.3 Argument A1.3

“***Criteria for assessing and accepting risks have been developed specifically for the use of ABB FLCB devices on the electricity distribution network, and agreed by stakeholders***”

For assessment of risk, a risk classification matrix is used which defines the boundaries between the ‘Unacceptable’, ‘Tolerable’ and ‘Broadly Acceptable’ regions for both the exposed worker (staff or contractors) and the general public.

The risk matrix has been developed specifically for use of the FLCB device on the electricity distribution network. It is based on the Health and Safety Executive (HSE) upper limit of tolerability for individual risk per annum for workers and for members of the public, and calibrated specifically to the risk associated with the FLCB, accounting for the specific hazards and exposures in question.

5.2.3.1 Argument A1.3.1

“*The risk classification matrix and acceptance criteria are documented and communicated to relevant stakeholders*”

The risk classification matrix, including details of its derivation, are detailed in the Safety Case Process and Principles Document [E5].

5.2.3.2 Argument A.1.3.2

“*The risk classification matrix and acceptance criteria have been agreed by stakeholders*”

Stakeholders agreed to the risk matrix and acceptance criteria at the April 2022 Safety review Meeting, as evidenced by the minutes of that meeting [E17].

5.2.4 Argument A1.4

“***A suitably sufficient and robust process has been undertaken to assess risks and identify potential risk reductions***”

The Risk Assessment followed on from the HAZID activities as an essential part of the hazard management process to assess whether the risks arising from use of the FLCB device on the 11kV network can be controlled to levels which are Tolerable and ALARP.

The Risk Assessment (RA) workshop, held on 27 September 2017, was chaired and staffed by SQEP persons, and a record of their relevant qualifications and experience kept. Prior to commencement of the workshop, the team present was assessed by the Workshop Chairman to confirm they were SQEP.

The workshop focused on assessing the consequences, and any secondary consequences which may follow, of the various risks. Each consequence was assessed to determine the exposure group, severity in terms of harm, and the likelihood of occurrence. Additionally, the workshop identified clearly practicable Safety Measures that could be implemented to reduce the risks to a level that is Tolerable and ALARP. These are recorded in the "Additional Safety Measures" column in Annex B of the Risk Assessment Report (ref. 7), and they have been addressed and/or implemented.

Most FLCB risks are assessed as well-understood and ALARP by the application of authoritative good practice for controlling them (ref. 7). Three exceptions were identified:

- Network exposed to excessive fault current;
- Flashover / local explosion; and
- Electric shock.

It was determined that the likelihood of flashover following installation of the FLCB devices or an electric shock from the FLCB device is no different from any other type of switchgear. The same controls apply based on switchgear construction standards, relevant good practice of current switchgear and following current procedures. As such these safety risks can be considered to be Broadly Acceptable.

However, it was recognised that a disruptive failure of a circuit breaker due to the network being exposed to excessive fault current would pose a risk that is different to that which is currently present. This risk was therefore agreed to be investigated further using a CBA (Section 5.2.5 refers).

5.2.4.1 Argument A1.4.1

"*A Risk Assessment workshop was undertaken to assess risks of implementing the FLCB device on the network and to identify potential Safety Measures*"

The full output of the workshop is contained within the RA Workshop Report Issue 1 [E6].

The RA workshop was preceded by a Briefing Note [E7] which described the system and scope to be considered and the methodology being proposed for use in that workshop.

The Safety Measures and all accompanying information identified during the workshop have been used to create the project Hazard Record [E3].

5.2.4.2 Argument A1.4.2

"*RA Workshop was carried out by SQEP individuals.*"

An attendance sheet is shown in the RA Workshop Report Issue 1 [E6] and signed SQEP forms for each attendee are held separately on record by Frazer-Nash.

5.2.5 Argument A1.5

"***Cost Benefit Analysis has been carried out, using recognised methodologies and robust data, to determine whether potential risk reductions are reasonably practicable.***"

CBA can be used as part of ALARP decisions and aids the decision making process by giving monetary values to the costs and benefits, including safety benefits, of various options. This enables a comparison of the advantages and disadvantages of multiple options to be compared using the 'like quantity' of financial value.

The CBA is based on findings from the RA workshop held on 27 September 2017, that were validated at the Safety Review Meeting on 13 April 2022 (ref. 9). It evaluates the safety mitigations identified at the Workshop and uses data sourced from multiple actions raised at the Workshop.

The CBA determines whether the cost to implement the additional Safety Measures identified in the RA workshop is grossly disproportionate to the safety benefit obtained. This informs the ALARP decision for the "excessive fault current" risk.

Three Safety Measures were agreed to be included in the analysis:

- Option 1 – Adaptive Protection;
- Option 2 – CB Fail Approach; and
- Option 3 – Ultra-Fast Earth Switch.

Determination of the risk benefit offered by each of the above Safety Measures has been considered in isolation by comparison to the baseline risk (i.e., the unmitigated risk associated with 'disruptive failure to a circuit breaker'), in order to determine ALARP status.

5.2.5.1 Argument A1.5.1

"*The input data used in the CBA is accurate and relevant*"

The data used for the CBA is listed in Appendix C of the Risk Assessment Report (RAR) [E19], each supplemented with a reference.

5.2.5.2 Argument A1.5.2

"*The CBA was conducted in accordance with recommended good practice*"

The RAR [E19] summarises the outputs of the RA Workshop and details the findings of the CBA. It contains an analysis of the three identified Safety Measures and comparison against the existing network and baseline option. Sensitivity analysis was used to ensure suitably cautious assumptions have been made and the robustness of the CBA.

The Safety Measures and all accompanying information identified during the workshop are detailed in the project Hazard Record [E3].

5.2.6 Argument A1.6

"***Safety requirements were derived from relevant applicable policies, procedures or regulations and the Risk Assessment.***"

To demonstrate that risk associated with the adoption of the FLCBs is reduced to a Tolerable and ALARP level, control measures (i.e., design changes, additional control measures) that are applicable to the design, installation, testing and commissioning of the devices were identified and assessed. Where relevant, control measures identified by the hazard management process are designated as Safety Requirements.

Risks may be sufficiently controlled to a level that is ALARP though the application of UK Power Networks policies and procedures or by adherence to Regulations. Where this is identified as being the case, no further risk assessment was undertaken.

Compliance against these requirements is a key part of the evidence needed to build the safety case (Sections 5.3.4, 5.3.5 & 5.3.8 refer).

5.2.6.1 Argument A1.6.1

"*Safety requirements were derived from the risk assessment at the HAZID and Risk Assessment workshops.*"

The full output of the workshops is contained in the HAZID Workshop Report [E2] and the Risk Assessment Report [E19].

5.2.6.2 Argument A1.6.2

"*A Hazard Record has been developed which records the safety requirements.*"

Prescriptive safety requirements (legislation, standards and regulation), as well as derived safety requirements are recorded in the Hazard Record [E3].

5.2.7 Argument A1.7

"***The outputs from all safety related activities are recorded and maintained throughout the project***"

The Hazard Record will remain live and continue to be managed throughout the project. It records the outputs from the HAZID activities, risk assessment, Safety Measures and Safety Requirements.

5.2.7.1 Argument A1.7.1

"*A Hazard Record has been developed and is continually updated throughout the project.*"

A Hazard Record [E3] has been developed for the ABB device to capture the output from HAZID and RA activities. The Hazard Record is a live document and is continually updated throughout the project.

5.3 Claim C2 – FLCB Design

"***The FLCB device has been designed to operate safely and satisfies identified and derived Safety Requirements.***"

Supporting information around the design of the FLCB device can be found in Annex A of this report. This section details the activities associated with the development process of the design of the FLCB device so to meet the Safety Requirements.

5.3.1 Argument A2.1

"***The FLCB device has been designed by competent designers to operate safely.***"

The FLCB device has been designed to operate satisfactorily within system parameters and meets the various design requirements set out in the applicable standards.

Due to the nature of the device and the environment that it will be used in, safety has been considered through all stages of the project. Principles such as 'Diversity' and 'Redundancy' have been adopted when designing the device and the system to enhance safety.

5.3.1.1 Argument A2.1.1

"*Internal UKPN Standards have been followed to ensure the device and associated equipment to be installed at the Grid and Primary substations operate effectively and correctly.*"

The standard for Indoor 12kV Power-Electronic FLCBs [E21] lists requirements for the design and construction of the FLCB device. The standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations [E22] lists additional design requirements and requirements for the maintenance and operation of the device. This equipment is designed to meet the normal service conditions for indoor switchgear and control gear as specified in clause 2.2 of ENA TS 41-36.

5.3.1.2 Argument A2.1.2

"*ABB FLCB Device Design Report presents the details of the device*"

The Implementation as input to safety case study [E8] provides details of Powerful-CB project members and responsibilities. The report details the various safety activities and verification activities for it to work effectively and correctly.

5.3.2 Argument A2.2

"***The designers have been integral to the safety assessment process and that process has therefore been able to influence the design during the development.***"

The project has undertaken a series of safety assessment activities using a wide range of design expertise throughout. This has ensured the design of the device controls the risks associated and complies with relevant statutory provisions.

It is important to note that an integrated, safety-led approach has been adopted to the development of the design, and that the design development can be iterative. Reasons that multiple iterations may be required include, but are not limited to:

- Changes to the functional requirements or Safety Requirements;
- The discovery challenges to the design in the HAZID;
- The results of testing and validation; and
- The results of trials and substantiation.

5.3.2.1 Argument A2.2.1

"*Designers had involvement in producing the Feasibility of Safety Case Report for the ABB device*"

The Feasibility Report [E4] documents the achievability of producing a safety case supporting the Powerful-CB approach: deployment of the FLCB on 11kV networks to facilitate the additional connection of Distributed Generation.

5.3.2.2 Argument A2.2.2

"*Designers have attended the HAZID and RA Workshops and had an opportunity to review the outputs*"

The full output of the HAZID workshop is contained within the HAZID Workshop Report [E2].

The RA workshop Report Issue 2 [E19] summarises the outputs of the RA Workshop and details the findings of the CBA. It contains an analysis of the three identified potential Safety Measures and comparison against the existing network and baseline option. It also documents the key outputs of the April 2022 Safety Review Meeting.

Each workshop has had the SQEP personnel available to produce the required outputs. ABB attended the HAZID Workshop held on 21 June 2017, the RA Workshop held on 27 September 2017 and the Safety Review Meeting held on 13 April 2022. ABB have had consistent communication with the project and have been responsible for addressing numerous actions raised at the various workshops and meetings.

5.3.3 Argument A2.3

"***The FLCB device has been tested and commissioned for use***"

Before proceeding with use, the following activities ensure that it is safe to do so. Activities at this stage include:

- Confirm that the FLCB has been successfully built in accordance with the detailed design;
- Specify the testing required to confirm the functionality and safe operation of the FLCB;
- Establish any limitations of use;

- Identify situations that involve personnel working on sites or in conditions that they are not familiar with;
- Review the HAZOP, FMEA and PFD reliability analysis as applicable to check this is all still relevant and correct.

5.3.3.1 Argument A2.3.1

"*Reliability data and FMEA support the testing and commissioning of the device for safe implementation*"

Evidence for the successful testing and commissioning of the FLCB device can be found in the Commissioning Report [E9].

5.3.4 Argument A2.4

"***The FLCB device meets the legislative Safety Requirements***"

The principal legislative requirement is to reduce risks So Far As Is Reasonably Practicable (SFAIRP, ref. 1). Other legislative requirements are embodied in regulation (Section 5.3.5 refers).

5.3.4.1 Argument A2.4.1

"*The principal legal requirement is to reduce risks SFAIRP. Other legislative requirements are embodied in regulation (see A2.5)*"

The ALARP principle is a Health and Safety Executive interpretation of SFAIRP that is well tested by case law. Accordingly, to show risks are reduced SFAIRP, it suffices to show they are reduced ALARP. The Risk Assessment Report [E19] argues that all FLCB risks are Tolerable and ALARP.

5.3.5 Argument A2.5

"***The FLCB device meets regulatory Safety Requirements***"

The relevant safety regulations for the FLCB are:

1. The Regulations made under the Health and Safety at Work Act 1974 and the Electricity Act 1989;
2. The Electricity at Work Regulations 1989;
3. The Provision and Use of Work Equipment Regulations 1998;
4. The Manual Handling Operations Regulations 1992;
5. The Confined Spaces Regulations 1997;
6. The Construction (Design and Management) Regulations 1994;
7. The Electricity Safety, Quality and Continuity Regulations 2002.

5.3.5.1 Argument A2.5.1

The regulations are embedded in UK Power Networks working procedures and UK Power Networks is regularly audited against those procedures and regulation to ensure compliance. Evidence of compliance with the regulations is contained in the Risk Assessment Report [E19], CPP Construction File [E24], UK Power Networks Distribution Safety Rules [E25] and the various site visit/works Risk Assessment Method Statements [E26].

5.3.6 Argument A2.6

"***The design of the FLCB device satisfies the derived Safety Requirements***"

Only one derived safety requirement has emerged from FLCB safety activities.

SR 01: The FLCB device shall operate effectively for all postulated network fault conditions with a probability of failure on demand of less than 10^{-3}

It is noted that this reliability requirement, which applied both to the trial and to BAU, is not particularly onerous.

5.3.6.1 Argument A2.6.1

"*The FLCB device meets the derived Safety Requirements*"

A demonstration that the SR 01 PFD requirement is comfortably met by the FLCB device is contained in the ABB "Simplified PFD Calculation for Powerful-CB" Report [E20].

5.3.7 Argument A2.7

"***Data gathered during the trials substantiates the Safety Case***"

Design and type testing is limited to the technical design and does not include any long term effects. Hence before the device is installed to be used as BAU a trial has been carried out. This trial has provided sets of performance data which will be used to determine whether the device will operate as reliably and safely as required for BAU.

5.3.7.1 Argument A2.7.1

"*Trial Reports for the ABB FLCB Device*"

SDRC 9.2.3 [E10] reports on the FLCB trial and provides evidence for the safety of the FLCB. It is noted that there have been no events or incidents that would suggest that the FLCB risk assessments are too optimistic. In particular:

- None of the risks (potential hazardous events) identified *before* the trial occurred during the trial.
- *Successful* "confidence switching" testing of the FLCB device has been carried out on a monthly basis during the trial, to verify its response and status.
- The FLCB has detected and cleared several real network faults during the trial, further strengthening the capabilities shown in the testing.

5.3.8 Argument A2.8

"***The FLCB device meets safety-related standards***"

The relevant safety-related standards for the FLCB are:

1. EDS 05-0001 Grid and Primary Protection and Control Schemes
2. EDS 07-0105 Grid and Primary Substation Civil Design Standards
3. ETS 03-6510 Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations
4. EDS 05-2001 Production, Application and Management of Protection Settings
5. ENA TS 41-36 Switchgear for service up to 36kV (cable and overhead conductor connected)
6. ETS 03-6511 Specification for Indoor 12kV Power-electronic Fault-Limiting Circuit Breakers

5.3.8.1 Argument A2.8.1

Evidence that the cited standards are met is contained in the Site Index [E27], Commissioning Report [E28] and the ENA TS 41-36 Type Test Conformance Declaration to ENA TS 41-36 [E12].

5.4 Claim C3 – Implementation

"***The ABB FLCB devices can be implemented safely onto the electricity networks***"

Sufficient evidence is needed from the safety assessment process to ensure that the FLCB device can be safely implemented onto the network in line with the Commission Implementing Regulations (ref. 4). This section presents the various arguments and evidence that ensure the device is considered safe to put on the network.

5.4.1 Argument A3.1

"***An engineering construction standard has been developed***"

The purpose of the engineering construction standard is to offer a safe, efficient and structured approach to installing the FLCB devices onto the electricity network.

It is important to note that an integrated, safety-led approach has been adopted to the development of the system design, and that the design development can be iterative. Reasons that iterations may be required include, but are not limited to:

- Changes to the functional requirements or Safety Requirements;
- The results of testing and validation; and
- The results of trials and substantiation.

5.4.1.1 Argument A3.1.1

"*Engineering construction standard has been produced*"

For the trial, an instruction manual [E11] has been provided by ABB to meet the need for an Engineering Construction Standard. Whilst an Engineering Construction Standard may not have been necessary for the trial, it is anticipated one would be required for BAU.

5.4.2 Argument A3.2

"***Systems have been commissioned with the FLCB devices installed on the network.***"

Following installation of the devices onto the network, the commissioning activities will verify that the as installed device is in accordance with the strategy, and therefore meets the requirements for safe operation.

5.4.2.1 Argument A3.2.1

"*Installation and Commissioning Report has been produced.*"

SDRC 9.2.3 [E10] addresses installation and commissioning, and contains or references relevant reports.

5.4.3 Argument A3.3

"*Specific precautions are in place for the use of the FLCB device on the electricity network.*"

Due to the nature of the device, specific precautions were in place to allow for safe operation during the trial. As such the potential fault current limit of the network at present will not be exceeded.

5.4.3.1 Argument A3.3.1

"*An engineering construction standard has been produced.*"

For the trial, an instruction manual [E11] has been provided by ABB to meet the need for an Engineering Construction Standard. Whilst an Engineering Construction Standard may not have been necessary for the trial, it is anticipated one would be required for BAU.

5.4.4 Argument A3.4

"***There are sufficient resources to support the implementation of the FLCB Device for BAU.***"

Use of the FLCB devices for the trial required extra workforce and an analysis team. This is not expected to be the case for BAU.

5.4.4.1 Argument A3.4.1

"*Resource plan for the implementation of the FLCB device for BAU has been produced.*"

It is not expected that a resource plan [E13] will be required for the BAU use of the FLCB device.

5.5 Claim C4 - Operation

"***The safe operation of the FLCB devices can be sustained through life, and the workforce is capable of installing, maintaining, operating and decommissioning the devices safely, supported by accurate asset information.***"

It is necessary that the FLCB device in normal operation does not introduce any unexpected or additional safety risks. This section presents the arguments and evidence to support the safe operation of the FLCB device on the network.

5.5.1 Argument A4.1

"***The workforce is trained and competent to discharge their duties.***"

Implementation of the devices onto the network for BAU will require trained and competent personnel. This is to ensure a safe installation and that the devices operate as intended, which will reduce risks in future operations.

5.5.1.1 Argument A4.1.1

"Training documents have been produced and utilized."

Training materials have been produced [E14].

5.5.2 Argument A4.2

"Sufficient and appropriate resources are available to enable the workforce to discharge their duties."

For safe and efficient operation, trained and competent personnel must be available for the required tasks for BAU.

5.5.2.1 Argument A4.2.1

"A Resource plan has been produced to ensure resource needs requirements and appropriate tools are in place and available when required."

It is not expected that a resource plan [E13] will be required for the BAU use of the FLCB device

5.5.3 Argument A4.3

"A fit for purpose assurance management system exists."

For safe installation, maintenance and operation an assurance management system must be in place.

5.5.3.1 Argument A4.3.1

"Contractors operate robust assurance regimes that monitor and assess the performance of the implementation of the FLCB devices."

The UK Power Networks Safety Management System (Section 5.6 refers) [E23] contains the details of the robust assurance regimes that contractors adhere to.

5.5.4 Argument A4.4

"The state of the infrastructure at any point in time is defined and available."

For safe installation, maintenance and operation the state of the infrastructure must be known.

5.5.4.1 Argument A4.4.1

"Infrastructure Reports are produced and include any planned changes"

Details of infrastructure status and any planned changes are contained within the PowerOn Network [E16].

5.6 Claim C5 – Safety Management System

A robust Safety Management System is necessary to ensure that the safety of the FLCB device is well-managed and that the devices are safe in service. A robust Safety Management System is also required by Safety Case Principle 1 (Section 4.2 refers) and provides confidence in the Claims in the safety argument (i.e., the claims in Section 5 of this report).

5.6.1 Argument A5.1

"The UKPN SMS is distributed through multiple UKPN policies, procedures, etc. supporting the UKPN Health, Safety and Sustainability Policy. UKPN are audited against the distributed SMS to ensure compliance."

The UK Power Networks Health, Safety & Sustainability Policy, BS00, Version 8.0 [E23] contains the policy that overarches the Safety Management System.

5.7 Evidence Summary

Annex B of this report lists each piece of evidence which is used to support the arguments and claims made above.

Claim 1 contains arguments supporting the safety assessment of the device. Various safety activities undertaken as part of the project and supporting documents support this claim. The documents provide clear and concise supporting evidence.

Claim 2 is supported by arguments which prove the device meets the Safety Requirements. The reliability of the device is based on predicted analysis and trials data.

Claim 3 is supported by arguments detailing how the devices will be installed onto the network. Potential evidence gaps exist that were not significant for the trial but may require addressing for BAU.

Claim 4 relates to the safe operation and maintenance of the devices. Potential evidence gaps exist that were not significant for the trial but may require addressing for BAU.

Claim 5 addresses the Safety Management System that ensures all FLCB safety management is carried out appropriately. It is well-supported by evidence.

6 Conclusions

This Safety Case Report summarizes the Safety Case for the ABB 2000A FLCB device. In particular, it incorporates a pictorial safety argument (Annex A) and provides a detailed commentary on that safety argument (Section 5).

The Safety Case demonstrates the safety of the FLCB device. In particular, it shows that:

- All risks associated with the FLCB device are Tolerable and reduced to a level that can be considered ALARP (Sections 5.2 & 5.3);
- All prescriptive safety requirements are met:
  - Legislative (Section 5.3.4)
  - Regulatory (Section 5.3.5)
  - Standards (Section 5.3.8)
  - Derived (Section 5.3.6).

The single recommendation of this Safety Case Report is:

> Before any further use of the FLCB device, e.g., further trials, Business As Usual, the safety argument and its supporting evidence should be reviewed to determine whether any evidence items require development or update.

7 References

1. The Health and Safety at Work etc. Act 1974
2. Electricity at Work Regulations 1989
3. FNC 52680-45804R, Powerful-CB Safety Case Process and Principles, Issue 2.1, 21 February 2020.
4. Commission Implementing Regulations (EU) 2015/1136 amending Implementing Regulation (EU) No. 402/2013 on the Common Safety Method for Risk Evaluation and Assessment.
5. ETS 03–6511, Specification for Indoor 12kV Power-Electronic Fault-Limiting Circuit Breakers, Version 1.1, June 2017.
6. ETS 03-6510, Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations, Version 5.0, August 2017.
7. FNC 007740/53393R Powerful-CB Risk Assessment Report, Issue 2, May 2022.
8. HSE guidance on the ALARP Principle, www.hse.gov.uk/managing/theory/alarpglance.htm.
9. Minutes of the Powerful-Circuit Breakers Safety Review Meeting (held 13 April 2022), FNC 007740/129743V.

8 Abbreviations and Glossary

8.1 Abbreviations

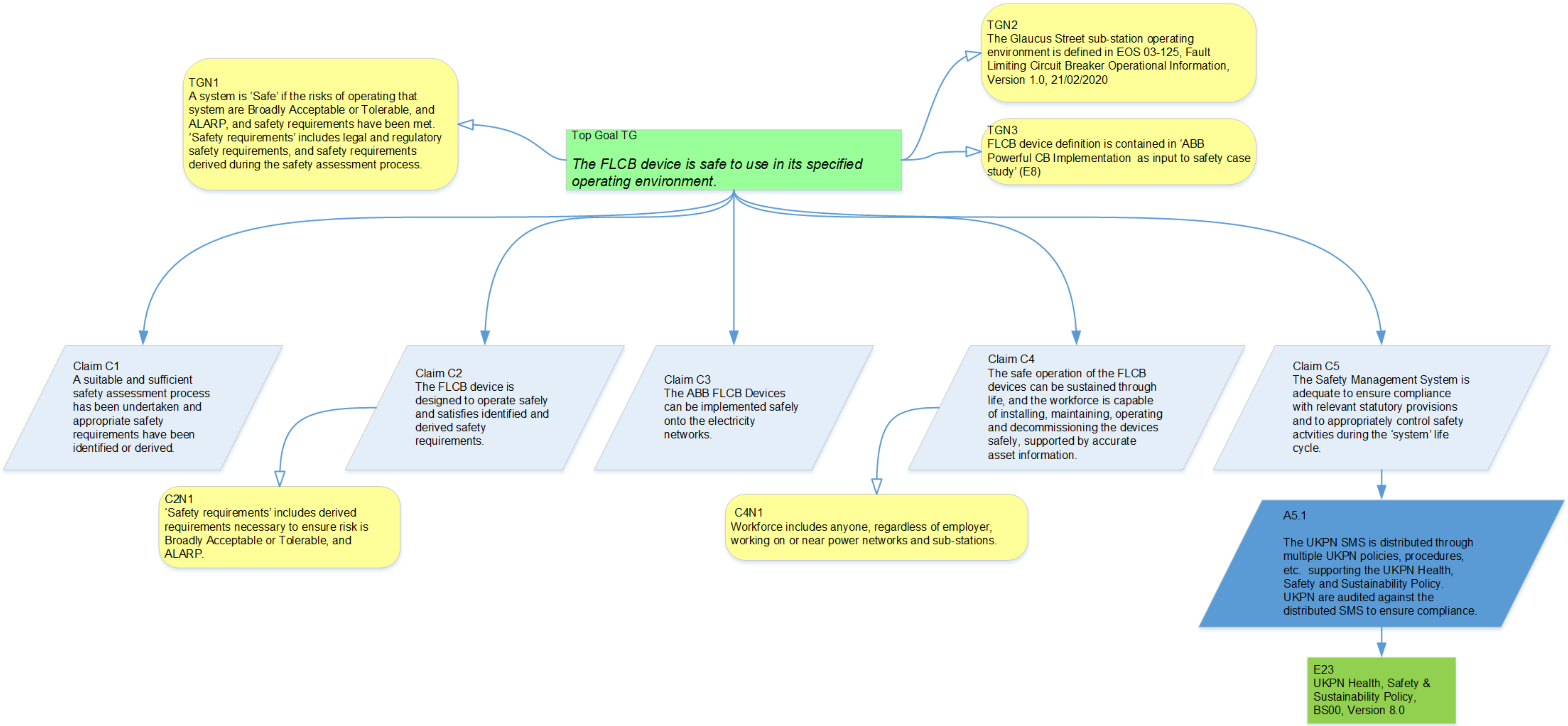
ABB	ABB Group
ALARP	As Low As Reasonably Practicable
AMAT	Applied Materials Inc.
BAU	Business As Usual
CAE	Claims, Arguments and Evidence
CB	Circuit Breaker
CBA	Cost Benefit Analysis
DG	Distributed Generation
DNO	Distribution Network Operator
EPN	Eastern Power Networks
FCS	Fast Commuting Switch
FLCB	Fault Limiting Circuit Breakers
FMEA	Failure Mode and Effects Analysis
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HSE	Health and Safety Executive
IBGT	Insulated Bipolar Gate Transistor
LPN	London Power Networks
NIC	Network Innovation Competition
PFD	Probability of Failure on Demand
PHI	Preliminary Hazard Identification
PSCR	Preliminary Safety Case Report
RA	Risk Assessment
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrence
RMS	Root Mean Square
SCP	Safety Case Principles
SCR	Safety Case Report
SFAIRP	So Far As Is Reasonably Practicable
SPN	South Eastern Power Networks
SQEP	Suitably Qualified and Experienced Personnel
UKPN	UK Power Networks

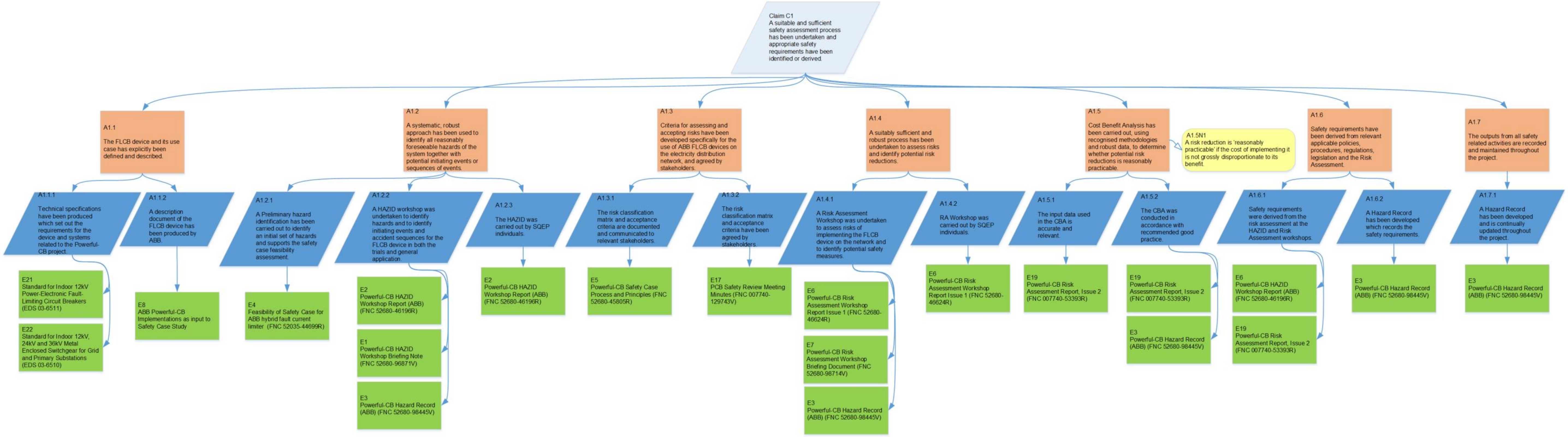
8.2 Glossary

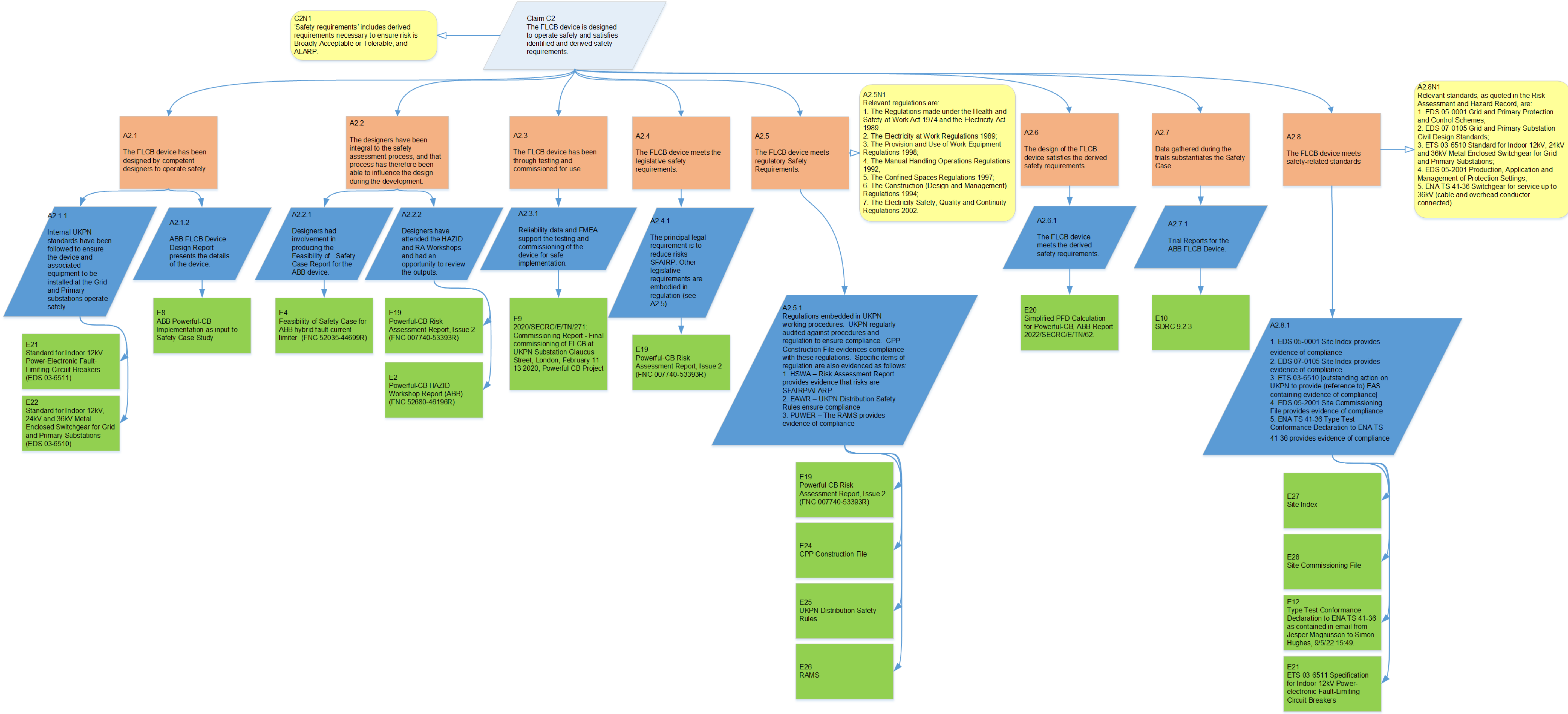
For consistency and ease of reference the following terminology is defined below:

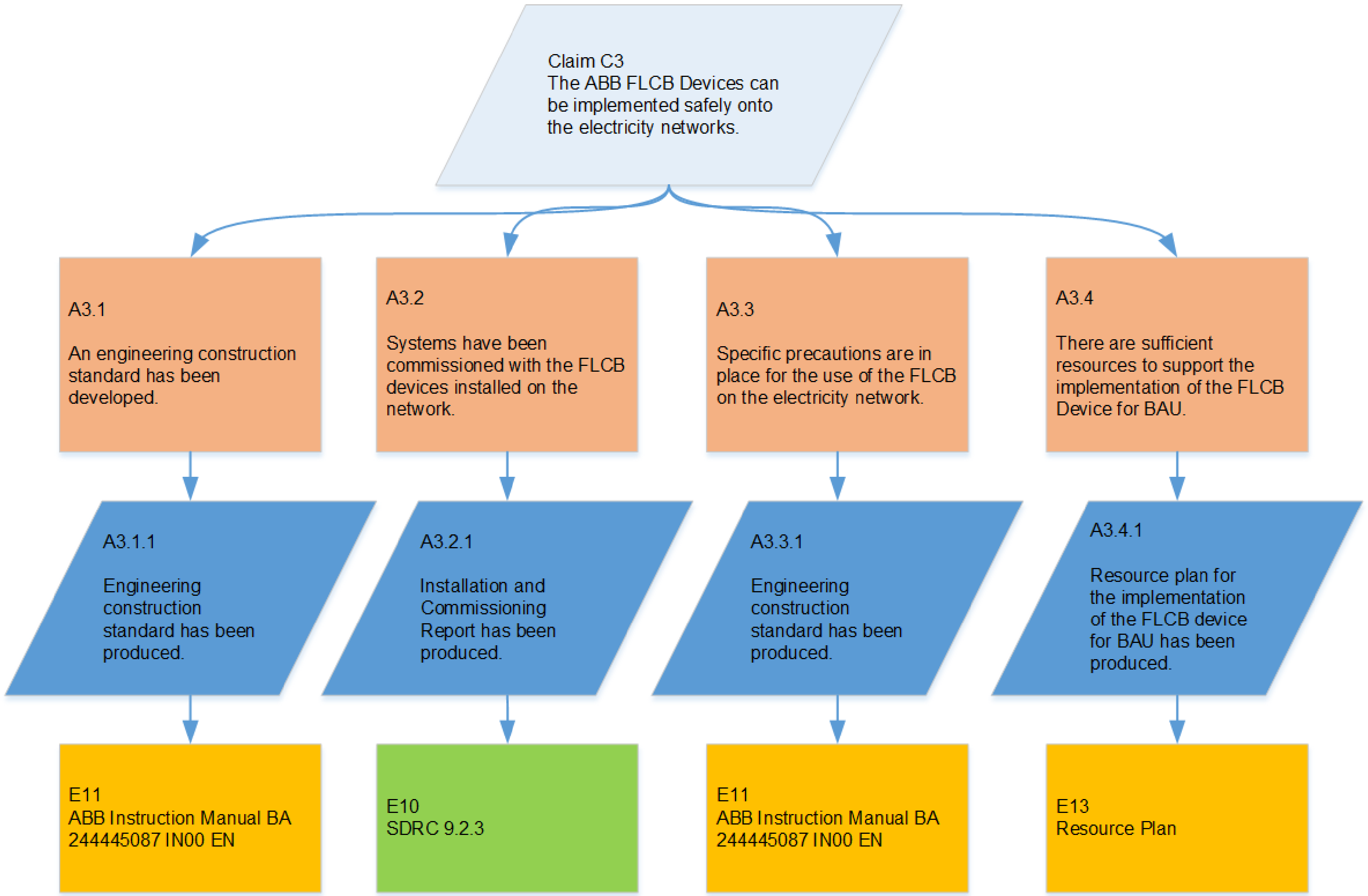
Accident	An unintended event, or sequence of events, that causes harm.
ALARP	A risk is As Low As reasonably Practicable when it has been demonstrated that the cost of any further risk reduction is grossly disproportionate to the safety benefit obtained from that risk reduction.
Claim	An assertion that contributes to the safety argument.
Consequence	The outcome, or outcomes, resulting from an event.
Evidence	Records, statements, facts or other information, which are relevant to the audit criteria and verifiable.
Harm	Death, physical injury or damage to the health of people.
Hazard	A physical situation or state of a system, often following from some initiating event that may lead to an accident. Anything presenting the 'possibility of danger' is also regarded as a 'hazard'.
Hazard Identification	The process of identifying and listing the hazards and accident sequence associated with a system.
Lost Time Incident	Where any person at work is incapacitated for routine work for more than one day (excluding the day of the accident) because of an injury resulting from an accident arising out of or in connection with that work. If this period exceed seven consecutive days then this is reportable under RIDDOR.
Medical Treatment Injury	Work-related injury resulting in treatment from a professional medical person e.g. nurse or a doctor in a hospital, from their own GP or paramedic etc. but does not result in a Lost Time Incident.
Personal Injury	A work-related injury of a minor nature and where the injured person receives no more than first aid treatment either whilst at work or from a medical professional but does not result in a lost time injury.
Risk	Combination of the likelihood of harm and the severity of that harm.
Risk Reduction	The systematic process of reducing risk.
Safety Case	A structured argument, together with a supporting body of evidence, that provides a compelling, comprehensible and valid case that a system is safe for a given application in a given operating environment.
Safety Case Report	A report that summarises the arguments and evidence of the Safety Case at a given point in time.
Tolerability Limits	The boundaries of individual risk, between which the level of risk may be tolerated when it has been demonstrated that the risk is ALARP and is not unacceptable. Different individual risk limits are set for workers and the general public.

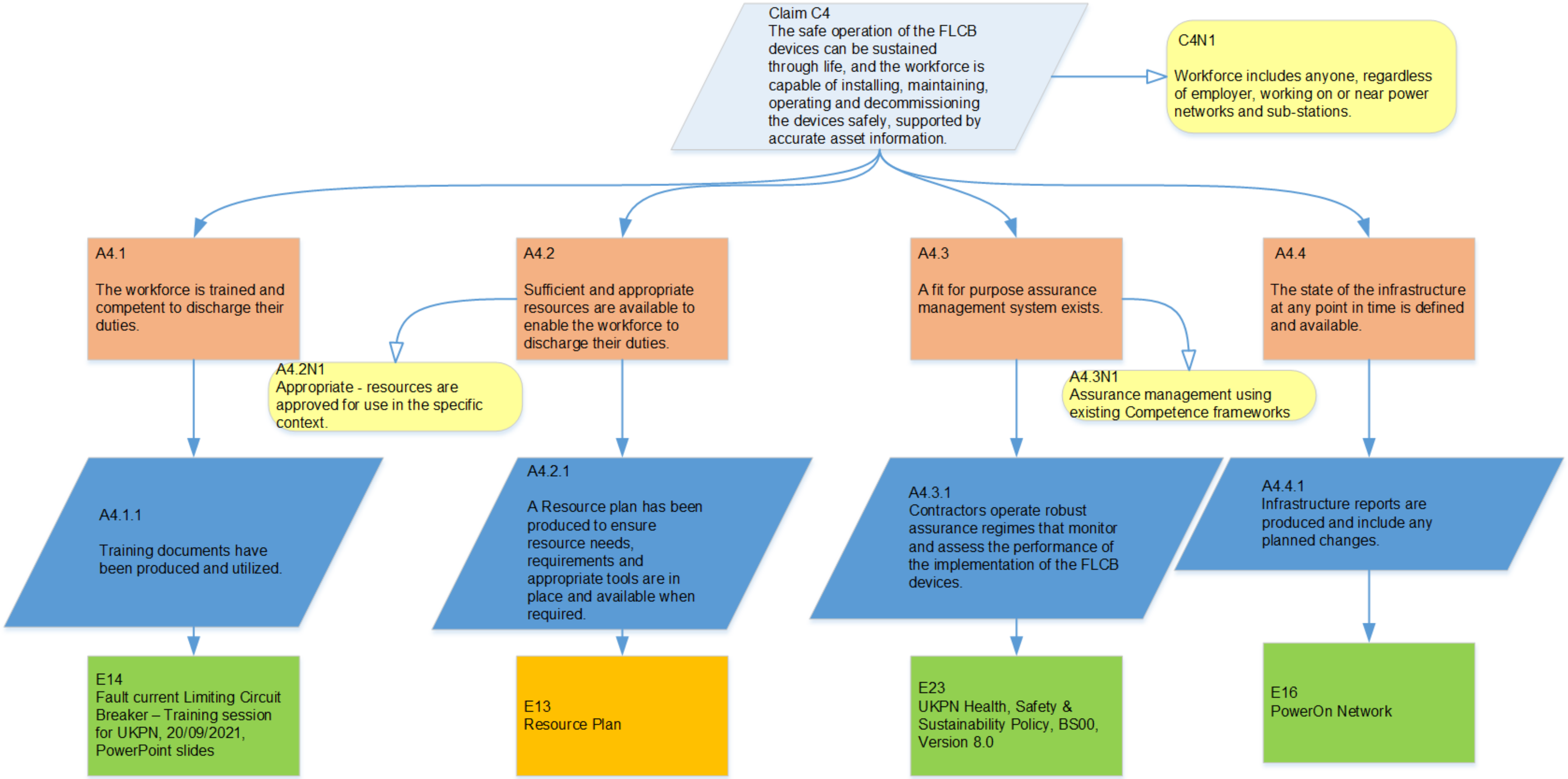
Annex A – Safety Argument Diagrams




Claim C1
A suitable and sufficient safety assessment process has been undertaken and appropriate safety requirements have been identified or derived.
A1.1
The FLCB device and its use case has explicitly been defined and described.
A1.2
A systematic, robust approach has been used to identify all reasonably foreseeable hazards of the system together with potential initiating events or sequences of events.
A1.3
Criteria for assessing and accepting risks have been developed specifically for the use of ABB FLCB devices on the electricity distribution network, and agreed by stakeholders.
A1.4
A suitably sufficient and robust process has been undertaken to assess risks and identify potential risk reductions.
A1.5
Cost Benefit Analysis has been carried out, using recognised methodologies and robust data, to determine whether potential risk reductions is reasonably practicable.
A1.5N1
A risk reduction is 'reasonably practicable' if the cost of implementing it is not grossly disproportionate to its benefit.
A1.6
Safety requirements have been derived from relevant applicable policies, procedures, regulations, legislation and the Risk Assessment.
A1.7
The outputs from all safety related activities are recorded and maintained throughout the project.
A1.1.1
Technical specifications have been produced which set out the requirements for the device and systems related to the Powerful-CB project.
A1.1.2
A description document of the FLCB device has been produced by ABB.
A1.2.1
A Preliminary hazard identification has been carried out to identify an initial set of hazards and supports the safety case feasibility assessment.
A1.2.2
A HAZID workshop was undertaken to identify hazards and to identify initiating events and accident sequences for the FLCB device in both the trials and general application.
A1.2.3
The HAZID was carried out by SQEP individuals.
A1.3.1
The risk classification matrix and acceptance criteria are documented and communicated to relevant stakeholders.
A1.3.2
The risk classification matrix and acceptance criteria have been agreed by stakeholders.
A1.4.1
A Risk Assessment Workshop was undertaken to assess risks of implementing the FLCB device on the network and to identify potential safety measures.
A1.4.2
RA Workshop was carried out by SQEP individuals.
A1.5.1
The input data used in the CBA is accurate and relevant.
A1.5.2
The CBA was conducted in accordance with recommended good practice.
A1.6.1
Safety requirements were derived from the risk assessment at the HAZID and Risk Assessment workshops.
A1.6.2
A Hazard Record has been developed which records the safety requirements.
A1.7.1
A Hazard Record has been developed and is continually updated throughout the project.
E21
Standard for Indoor 12kV Power-Electronic Fault-Limiting Circuit Breakers (EDS 03-6511)
E22
Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations (EDS 03-6510)
E8
ABB Powerful-CB Implementations as input to Safety Case Study
E4
Feasibility of Safety Case for ABB hybrid fault current limiter (FNC 52035-44699R)
E2
Powerful-CB HAZID Workshop Report (ABB) (FNC 52680-46196R)
E1
Powerful-CB HAZID Workshop Briefing Note (FNC 52680-96871V)
E3
Powerful-CB Hazard Record (ABB) (FNC 52680-98445V)
E2
Powerful-CB HAZID Workshop Report (ABB) (FNC 52680-46196R)
E5
Powerful-CB Safety Case Process and Principles (FNC 52680-45805R)
E17
PCB Safety Review Meeting Minutes (FNC 007740-129743V)
E6
Powerful-CB Risk Assessment Workshop Report Issue 1 (FNC 52680-46624R)
E7
Powerful-CB Risk Assessment Workshop Briefing Document (FNC 52680-98714V)
E3
Powerful-CB Hazard Record (ABB) (FNC 52680-98445V)
E6
Powerful-CB Risk Assessment Workshop Report Issue 1 (FNC 52680-46624R)
E19
Powerful-CB Risk Assessment Report, Issue 2 (FNC 007740-53393R)
E19
Powerful-CB Risk Assessment Report, Issue 2 (FNC 007740-53393R)
E3
Powerful-CB Hazard Record (ABB) (FNC 52680-98445V)
E6
Powerful-CB HAZID Workshop Report (ABB) (FNC 52680-46196R)
E19
Powerful-CB Risk Assessment Report, Issue 2 (FNC 007740-53393R)
E3
Powerful-CB Hazard Record (ABB) (FNC 52680-98445V)
E3
Powerful-CB Hazard Record (ABB) (FNC 52680-98445V)


C2N1
'Safety requirements' includes derived requirements necessary to ensure risk is Broadly Acceptable or Tolerable, and ALARP.
Claim C2
The FLCB device is designed to operate safely and satisfies identified and derived safety requirements.
A2.1
The FLCB device has been designed by competent designers to operate safely.
A2.2
The designers have been integral to the safety assessment process, and that process has therefore been able to influence the design during the development.
A2.3
The FLCB device has been through testing and commissioned for use.
A2.4
The FLCB device meets the legislative safety requirements.
A2.5
The FLCB device meets regulatory Safety Requirements.
A2.5N1
Relevant regulations are:
1. The Regulations made under the Health and Safety at Work Act 1974 and the Electricity Act 1989.
2. The Electricity at Work Regulations 1989;
3. The Provision and Use of Work Equipment Regulations 1998;
4. The Manual Handling Operations Regulations 1992;
5. The Confined Spaces Regulations 1997;
6. The Construction (Design and Management) Regulations 1994;
7. The Electricity Safety, Quality and Continuity Regulations 2002.
A2.6
The design of the FLCB device satisfies the derived safety requirements.
A2.7
Data gathered during the trials substantiates the Safety Case
A2.8
The FLCB device meets safety-related standards
A2.8N1
Relevant standards, as quoted in the Risk Assessment and Hazard Record, are:
1. EDS 05-0001 Grid and Primary Protection and Control Schemes;
2. EDS 07-0105 Grid and Primary Substation Civil Design Standards;
3. ETS 03-6510 Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations;
4. EDS 05-2001 Production, Application and Management of Protection Settings;
5. ENA TS 41-36 Switchgear for service up to 36kV (cable and overhead conductor connected).
A2.1.1
Internal UKPN standards have been followed to ensure the device and associated equipment to be installed at the Grid and Primary substations operate safely.
A2.1.2
ABB FLCB Device Design Report presents the details of the device.
A2.2.1
Designers had involvement in producing the Feasibility of Safety Case Report for the ABB device.
A2.2.2
Designers have attended the HAZID and RA Workshops and had an opportunity to review the outputs.
A2.3.1
Reliability data and FMEA support the testing and commissioning of the device for safe implementation.
A2.4.1
The principal legal requirement is to reduce risks SFAIRP. Other legislative requirements are embodied in regulation (see A2.5).
A2.5.1
Regulations embedded in UKPN working procedures. UKPN regularly audited against procedures and regulation to ensure compliance. CPP Construction File evidences compliance with these regulations. Specific items of regulation are also evidenced as follows:
1. HSWA – Risk Assessment Report provides evidence that risks are SFAIRP/ALARP.
2. EAWR – UKPN Distribution Safety Rules ensure compliance
3. PUWER – The RAMS provides evidence of compliance
A2.6.1
The FLCB device meets the derived safety requirements.
A2.7.1
Trial Reports for the ABB FLCB Device.
A2.8.1
1. EDS 05-0001 Site Index provides evidence of compliance
2. EDS 07-0105 Site Index provides evidence of compliance
3. ETS 03-6510 [outstanding action on UKPN to provide (reference to) EAS containing evidence of compliance]
4. EDS 05-2001 Site Commissioning File provides evidence of compliance
5. ENA TS 41-36 Type Test Conformance Declaration to ENA TS 41-36 provides evidence of compliance
E21
Standard for Indoor 12kV Power-Electronic Fault-Limiting Circuit Breakers (EDS 03-6511)
E22
Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations (EDS 03-6510)
E8
ABB Powerful-CB Implementation as input to Safety Case Study
E4
Feasibility of Safety Case for ABB hybrid fault current limiter (FNC 52035-44699R)
E19
Powerful-CB Risk Assessment Report, Issue 2 (FNC 007740-53393R)
E2
Powerful-CB HAZID Workshop Report (ABB) (FNC 52680-46196R)
E9
2020/SECRC/E/TN/271: Commissioning Report - Final commissioning of FLCB at UKPN Substation Glaucus Street, London, February 11-13 2020, Powerful CB Project
E19
Powerful-CB Risk Assessment Report, Issue 2 (FNC 007740-53393R)
E20
Simplified PFD Calculation for Powerful-CB, ABB Report 2022/SECRC/E/TN/62.
E10
SDRC 9.2.3
E19
Powerful-CB Risk Assessment Report, Issue 2 (FNC 007740-53393R)
E24
CPP Construction File
E25
UKPN Distribution Safety Rules
E26
RAMS
E27
Site Index
E28
Site Commissioning File
E12
Type Test Conformance Declaration to ENA TS 41-36 as contained in email from Jesper Magnusson to Simon Hughes, 9/5/22 15:49.
E21
ETS 03-6511 Specification for Indoor 12kV Power-electronic Fault-Limiting Circuit Breakers


Claim C3
The ABB FLCB Devices can be implemented safely onto the electricity networks.
A3.1
An engineering construction standard has been developed.
A3.2
Systems have been commissioned with the FLCB devices installed on the network.
A3.3
Specific precautions are in place for the use of the FLCB on the electricity network.
A3.4
There are sufficient resources to support the implementation of the FLCB Device for BAU.
A3.1.1
Engineering construction standard has been produced.
A3.2.1
Installation and Commissioning Report has been produced.
A3.3.1
Engineering construction standard has been produced.
A3.4.1
Resource plan for the implementation of the FLCB device for BAU has been produced.
E11
ABB Instruction Manual BA 244445087 IN00 EN
E10
SDRC 9.2.3
E11
ABB Instruction Manual BA 244445087 IN00 EN
E13
Resource Plan


Claim C4
The safe operation of the FLCB devices can be sustained through life, and the workforce is capable of installing, maintaining, operating and decommissioning the devices safely, supported by accurate asset information.
C4N1
Workforce includes anyone, regardless of employer, working on or near power networks and sub-stations.
A4.1
The workforce is trained and competent to discharge their duties.
A4.2
Sufficient and appropriate resources are available to enable the workforce to discharge their duties.
A4.3
A fit for purpose assurance management system exists.
A4.4
The state of the infrastructure at any point in time is defined and available.
A4.2N1
Appropriate - resources are approved for use in the specific context.
A4.3N1
Assurance management using existing Competence frameworks
A4.1.1
Training documents have been produced and utilized.
A4.2.1
A Resource plan has been produced to ensure resource needs, requirements and appropriate tools are in place and available when required.
A4.3.1
Contractors operate robust assurance regimes that monitor and assess the performance of the implementation of the FLCB devices.
A4.4.1
Infrastructure reports are produced and include any planned changes.
E14
Fault current Limiting Circuit Breaker – Training session for UKPN, 20/09/2021, PowerPoint slides
E13
Resource Plan
E23
UKPN Health, Safety & Sustainability Policy, BS00, Version 8.0
E16
PowerOn Network

Annex B – Safety Case Evidence

The status of each piece of evidence is defined as:

- Green- A complete issued version of the evidence is held;
- Yellow – A draft version or a reference to the evidence is held;
- Red – No evidence currently exists.

In some cases, full document configuration is not known (as indicated by "TBC" in the table). The missing details should be established to firm up the evidence record for the Safety Case.

Table 1: Safety Case Evidence Table

ID	Reference	Document Title	Issue / Date	Status
E1	FNC 52680-96871V	Powerful-CB HAZID Workshop Briefing Note	Issue 1 June 2017	G
E2	FNC 52680-46196R	Powerful-CB HAZID Workshop Report (ABB)	Issue 1 August 2017	G
E3	FNC 52680-98445V	Powerful-CB Hazard Record (ABB)	Issue 3 May 2022	G
E4	FNC 50235-44699R	Feasibility of safety case for ABB hybrid fault current limiter	Issue 1 August 2016	G
E5	FNC 52680-45804R	Powerful-CB Safety Case Process and Principles	Issue 2.1 February 2020	G
E6	FNC 52680-46624R	Powerful-CB Risk Assessment Workshop Report	Issue 1 November 2017	G
E7	FNC 52680-98714V	Powerful-CB Risk Assessment Workshop Briefing Document	Issue 1 September 2017	G
E8	Non Specific	ABB Powerful CB Implementation as input to safety case study	Rev 1 Apr-18	G
E9	2020/SECRC /E/TN/271	Commissioning Report - Final commissioning of FLCB at UKPN Substation Glaucus Street, London, February 11-13 2020, Powerful CB Project"	2020	G
E10	N/A	SDRC 9.2.3: Demonstration of solution at an 11 kV substation	May 2022	G
E11	Instruction Manual BA 244445087 IN00 EN	Fault Limiting Circuit-Breaker mounted in ZS-P panel	Rev 1	O

ID	Reference	Document Title	Issue / Date	Status
E12	N/A	Type Test Conformance Declaration to ENA TS 41-36	Issue 3 2012	G
E13	TBC	Resource Plan for BAU	TBC	O
E14	N/A	Fault current Limiting Circuit Breaker – Training session for UKPN	20 September 2021	G
E15		not used		
E16	N/A	PowerOn network	N/A	G
E17	FNC 007740-129743V	Minutes of the Powerful CB Safety Review Meeting, 13/4/22	9 May 2022	G
E18		not used		
E19	FNC 007740-53393R	Powerful-CB Risk Assessment Report	Issue 2 May 2022	G
E20	2022/SECRC/E/TN/62	Simplified PFD Calculation for Powerful-CB	May 2022	G
E21	ETS 03-6511	Standard for Indoor 12kV Power-Electronic Fault-Limiting Circuit Breakers	Version 1.1 June 2017	G
E22	ETS 03-6510	Standard for Indoor 12kV, 24kV and 36kV Metal Enclosed Switchgear for Grid and Primary Substations	Version 5.0 August 2017	G
E23	BS00	UKPN Health, Safety & Sustainability Policy	Version 8.0	G
E24	N/A	CPP Construction File	N/A	G
E25	N/A	UKPN Distribution Safety Rules	2016	G
E26	N/A	Risk Assessment Method Statements	N/A	G
E27	N/A	Site Index	N/A	G
E28	2020/SECRC/E/TN/271	Commissioning Report	October 2020	G

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