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Wind Turbine Switchgear Safety

High Voltage and Low Voltage Switchgear – A Concise Guide

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Contents

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Disclaimer

The contents of this guide are intended for information and general guidance only, do not constitute advice, are not exhaustive and do not indicate any specific course of action. Detailed professional advice should be obtained before taking or refraining from action in relation to any of the contents of this guide or the relevance or applicability of the information herein.

Introduction

Properly designed, installed and maintained switchgear is a vital prerequisite for any safe, secure and successful wind turbine installation.

This guidance is primarily aimed at designers, developers, operators and owners of wind turbines that may incorporate all switchgear with voltage ratings >1000 volts alternating current and 1500 volts direct current (normally referred to as High Voltage or HV) and voltage ratings of up to and including 1000 volts alternating current and 1500 volts direct current (normally referred to as Low Voltage or LV). It is intended as a basic overview of the key issues and arrangements for preventing and managing electrical risks associated with currently installed and new switchgear. The guidance only applies to switchgear subject to the jurisdiction of UK Health and Safety legislation.

The information in this document should only be regarded as generic advice. It represents industry good practice for switchgear safety operated on UK operational wind farms and arrays ('the industry'). It does not aim to address general safety issues for switchgear for which there is already an extensive range of standards and guidance in the public domain. In addition, site, location, turbine and switchgear specific assessments must still be performed to determine the most effective approach to managing switchgear.

This guide aims to set out the:

- Critical safety issues with particular consideration of the specification of switchgear and competence issues;
- Legislation, standards and policies relevant to switchgear;
- Measures to consider in the management of existing switchgear;
- Measures to take into account when determining the suitability of new switchgear; and
- Additional advice representing good practice based on operational experiences in the UK.

Note: Where LV switchgear is quoted this relates to all LV switchgear, circuit breakers, isolators, disconnectors and MCB's

Critical safety issues

All electrical switchgear must be considered a potentially serious safety risk. The principal risks associated with switchgear include electrocution, burns, explosions and fire. The failure to manage these can lead to death or serious injury. A major switchgear failure could also have consequential impacts including criminal liability, contractual/warranty claims, business continuity and/or damage to corporate reputation.

The Health and Safety Executive (HSE) has identified a number of common failure modes associated with the operation of switchgear. These include failures relating to a lack of knowledge, modifications, maintenance, inappropriate resets, inappropriate operation and anti-reflex handles. This guide does not consider these in detail as the issues are already clearly set out in HSE guidance and associated switchgear standards (see references).

To date there is insufficient evidence or data detailing any common safety trends across the industry for switchgear. However the risk of safety failures will increase where there is a poor understanding of the operational interface between the selected switchgear, the specific site/turbine operational arrangements and the network. In addition, two key issues have been identified of particular relevance to the industry with regard to the safe use of switchgear. These relate to the specification of the equipment and the competence of personnel operating on or adjacent to switchgear.

Specification

Understanding and achieving the correct specification of switchgear that is suitable and safe for the specific operational circumstances of the installation is vital. Examples of how this can be achieved include:

- Ensuring that adequate design risk assessments are carried out to ensure that the switchgear is adequate for its intended use
- Ensuring that the installed switchgear incorporates sufficient contactors to minimise maintenance overheads;
- Ensuring that the environment in which the switchgear is installed is compliant with applicable legislation;
- Taking into account the risks to personnel for access and maintenance during the operational life of the switchgear (e.g. access to switchgear in wind turbine sub-basements);
- Ensuring the switchgear is suitable for the installed location taking account of working space and access for operation and maintenance;
- Performing relevant testing that is appropriate for the specific location/application and ensuring that there are adequate risk-based procedures in place to support the correct use of switchgear;
- Ensuring there are robust access control procedures for competent personnel in place, which are specific to the classification of the turbine or enclosure when operated as a sub-station;
- Ensuring there are robust access control procedures for competent personnel in place to prevent inadvertent operation of switchgear,
- Aiming to prevent and minimise risks, including the requirement for local live switching, through access prevention and the use of remote operational techniques;
- Providing adequate provision for arc venting and dissipating energy during a fault condition within the area/enclosure in which the HV switchgear is located in accordance with the switchgear requirements;
- Agreeing and applying common standards for labelling and the annotation of electrical and mechanical diagrams;
- Agreeing and applying common standards for warnings and warning notices;
- Knowing who can control the system via remote SCADA access, and;
- Knowing who can provide overriding measures to allow safe isolation (e.g. password protection systems).

Competence

Anyone working on or adjacent to HV or LV switchgear must be competent for the tasks to be undertaken in order to prevent danger or injury. Determining the level of competence required, needs to consider both the organisational arrangements and the individual capabilities of anyone working on or around switchgear. These together must be risk assessed taking into account the specific operational circumstances of the installation. Examples of competence issues to consider include:

- Understanding the need to determine and apply a multiple-level approach to assigning and achieving competence (e.g. basic awareness to fully authorised);
- Segregating equipment and personnel that reflect competence levels;
- Using suitable mechanical protection measures to prevent and minimise human error (e.g. anti-reflex handles, interlocking devices, physical controls, barriers, PPE etc.); and;
- Consideration of Live or Dead switching with measures being implemented in accordance with a suitable and sufficient risk assessment.

It should also be stated that consideration should also be given to the competence of anyone involved in the procurement, installation and commissioning of switchgear. Furthermore, clients need to consider the issue of competence when engaging any contractor or third party involved with operating or maintaining the relevant switchgear.

Legislation, standards and policies

Legislation

The principal legislation relevant to the selection and use of switchgear operated in the UK includes the:

- Health and Safety at Work etc. Act 1974 (‘HSW’) – places duties on employers to ensure the safety of employees and others so far as reasonably practicable. Duties also extend to designers, manufacturers, importers or suppliers of any article for use at work;
- Management of Health and Safety at Work Regulations 1999 – absolute duty to carry out suitable and sufficient risk assessments;
- Electricity at Work Regulations 1989 - require electrical equipment for use at work to be constructed, maintained and operated by persons deemed competent in such a way as to prevent danger so far as is reasonably practicable; and
- Electricity Safety, Quality and Continuity Regulations 2002 – apply to electricity generation, generators, networks, suppliers and distributors regarding aspects of supply and distribution.
- The Dangerous Substances and Explosive Atmospheres Regulations 2002 – duties setting out an assessment approach to require employers to control the risks to safety from fire and explosions.

This legislation listed above is far from exhaustive. The Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 2013 came into effect on 6 April 2013. The Order revoked the previous 2001 and 2011 orders and extends the HSW Act to work activities such as the construction, repair and operation of energy structures and related structures within a renewable energy zone (REZ).

Duty holders will also need to review the significance of other legislation which may be relevant to the selection, installation, commissioning and use of switchgear (e.g. Construction Design and Management Regulations 2015 (‘CDM 2015’). See the references, and contact and links sections below for more details.

The principal duty holder for the determination of suitability of the switchgear will normally reside with the designer of the system. They will be responsible for the integration of the specific switchgear and allied equipment into the particular network. Clients are recommended to request a copy of the design risk assessment to demonstrate a robust process has validated that the design is safe, that the design has taken into account the switchgear location and the design allows for practical and reliable through life operation and maintenance.

Standards

There are a number of potential BS/EN or equivalent standards that apply to switchgear. The most relevant standards applicable to High Voltage equipment being:

- EN 62271-200:2012 – High-voltage switchgear and control gear – Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1kV and up to and including 52kV;
- BS 6626:2010 Code of practice for maintenance of electrical switchgear and control gear for voltages above 11kV and up to and including 36kV;
- ENA Technical Specification (TS) 41-36 Issue 3 2012: Distribution Switchgear for Service up to 36kV (cable and overhead cable connected); and
- ENA Technical Specification (TS) 41-37 Issue 1 2004: Distribution Switchgear for Service up to 66kV– 132kV – Parts 1, 2 &3

Further examples are detailed in the references.

In the first edition of this guide the advice from HSE was that full compliance with EN 62271-200:2004 was considered the minimum acceptable standard for switchgear in the UK. It also stated that HSE had further indicated that there was an obligation to upgrade any equipment to be compliant with that standard. Standards are regularly revised and the current version of BS EN62271 was published in 2012. It is regarded as good industry practice for switchgear to endeavour to meet the design safety and operational requirements of ENA TS 41-36 or TS 41-37. Certification to ENA standards is regarded as an optional protocol that duty holders may choose to perform to demonstrate additional confidence in assurance arrangements.

The most relevant standard applicable to Low Voltage equipment being:

- BS 7671:2008 (2015) Requirements for Electrical Installations: - 17th Edition
- BS EN 60947-1: 2007 – Low Voltage Switchgear and Control Gear - General
- BS EN 60947-2: 2006 – Low Voltage Switchgear and Control Gear – Circuit Breakers
- BS EN 60947-3: 2009 – Low Voltage Switchgear and Control Gear – Switches, Disconnector; Switch-Disconnector and Fused Combination Units
- BS 6423: 2014 - Code of Practice for maintenance of low-voltage switchgear and control gear

Further examples are detailed in the references.

The HSE have stated that full compliance with BS EN 60947 is considered the minimum acceptable standard for LV switchgear in the UK. They have further indicated that there is an obligation to upgrade any equipment not compliant with this standard. It is regarded as good industry practice for LV switchgear to endeavour to meet the design safety and operational requirements of BS EN 60947. Certification against BS EN standards is regarded as an optional protocol that duty holders may choose to adopt for supporting confidence in the compliance assurances stated by product manufacturers.

Drawing 1 below depicts the standard symbol applied to LV circuit breakers meeting the requirements of IEC60947-2 ‘Suitable for isolation’.

Suitability for isolation:

Indication of open position:

Indication of closed position:

Suitable for d.c. operation:

Protective earth terminal:

As detailed within the policies and presented below, it is recommended that users have management processes in place to assure themselves of the continued fitness for purpose of all switchgear Particular emphasis is placed on these combined devices, the critical condition of which could stand to be degraded through cumulative effects of circuit breaker switching unless monitored proactively.

Note: standards have no stand-alone legal status. However, an enforcing authority or court may apply and recognise standards as evidence of good practice in applying the principle of ALARP (as low as reasonably practicable) to a particular risk or activity.

Policies and procedures

Anyone responsible for existing and new switchgear should have suitable arrangements in place to ensure the safe operation of switchgear to minimise the risk of injury. As a minimum this would include:

- Policies and procedures covering the design, specification, installation, commissioning, operation, maintenance, modifications and decommissioning of the equipment;
- An appropriate system of records and document control;
- Definition of responsibilities, training and competence requirements; and
- Audit and review of protocols to demonstrate the effectiveness of procedures.

These represent what are regarded as minimum industry practice, but are nonetheless important to reiterate in view of safety risks concerned. These arrangements can be incorporated into existing Health and Safety management systems, including those required under statute and/or voluntary schemes.

Existing switchgear

All switchgear users should determine what arrangements are necessary by conducting appropriate risk assessments with the support of suitable electrically competent personnel. Specific issues identified as good practice for equipment utilised in the UK include:

- Drawing up an asset register detailing site and equipment-specific technical information and recording this in a suitable format;
- Checking any safety non-compliances against the minimum electrical safety standards and, where applicable, with any specification or technical standards agreed;
- Provision of adequate High Voltage (HV) and Low Voltage (LV) safety rules[1] suitable for the operational risks;
- Taking into account location-specific safety issues, including consideration of spacing, environmental conditions (e.g. temperature), security and access;
- Robust procedures and rules to provide a safe system of work (SSOW) using authorised competent persons and controlling access;
- Confirming that manufacturers operational and maintenance documentation is available for review;
- Confirmation that existing switchgear commissioning documentation is available for review;
- Confirmation that existing switchgear maintenance documentation is available for review;
- Confirmation that the means of generating electricity at the site and/or the manner in which the grid is connected to the site has not been changed or modified since commissioning;
- Confirming that where the means of generating electricity at the site and/or the manner in which the grid is connected to the site has been changed and/or modified since commissioning that any original switchgear fulfils the requirements of the new electrical infrastructure;
- Evidence of suitable risk assessment to fulfil duties under the Dangerous Substances and Explosive Atmospheres Regulations 2002, and;
- Confirming compliance with regards SF6 environmental management (e.g. EC F-Gas Regulations);
- Confirming compliance with relevant industry statute and guidance

Although of a more general nature it is important to reiterate other areas that may need to be addressed. These could include:

- Carrying out a planned programme of upgrading or retrofitting suitable controls where safety shortfalls have been identified;
- Reviewing the need for authorised persons and others to undergo refresher training;
- Updating policies and procedures taking account of any new information, installed controls or safe systems of work;
- Ensuring all changes are recorded and communicated to employees, contractors and others who may be at risk;
- Conducting a planned programme of inspection and maintenance; and
- performing periodic auditing of procedures and controls to ensure the safety and integrity of the switchgear.

1 These may be covered by two sets of safety rules if required.

New switchgear

The principal duty holder responsible for determining the suitability of switchgear is the designer. This could also include the client where their decisions influence the final design or specification. Due to the variety of routes to market, all parties concerned with the design and specification of switchgear should fully cooperate and communicate with each other. This should include clarification of their particular role and responsibilities for the project concerned.

A prudent client and where necessary other duty holders (as defined under CDM 2015) are recommended to consider:

- having a suitable procurement policy setting out the relevant design, technical and operational safety requirements for the project;
- Early communication with original equipment manufacturers (‘OEMs’) and switchgear manufacturers to allow the opportunity to consider relevant safety issues; and
- Agreeing the selection criteria for the switchgear, taking account of design features, applicable standards and statutory requirements.

Specifically this should include requesting a copy of the design risk assessment to demonstrate a robust process has validated the design.

The location of switchgear should be assessed from a safety perspective.

Note: The HSE has advised that switchgear should ideally be located in a separate building (i.e. rather than the base of the turbine). Where this is not possible, e.g. due to planning or other restrictions, suitable precautions should be taken to restrict access to switchgear from unauthorised personnel.

Additional commentary

Experience within the UK gained in recent years has identified a number of practical measures that can be taken to ensure that installed switchgear is safe for anyone working on or adjacent to it. The principal examples include:

General

1. **Competence:** Turbines containing LV equipment should be controlled and when access is required only competent and authorised persons are given access which is controlled through a SSOW.
2. **Procedures:** A procedure for dealing with electrical equipment in distress is to be in place before LV switchgear can be operated.
3. **Labelling:** Many electrical incidents are due to poor labelling and information. All equipment must be clearly and accurately labelled and a check must be conducted after maintenance/work when components are replaced. This will often include referring to / production of mimic diagrams. Statutory warning signs need to be displayed as required by legislation. Where there are two sources of electrical supply to a given switchgear (switchboards/components etc), signs should be used to identify this arrangement.
4. **Environment:** Generally, switchgear used in this application is classed as indoor equipment and the design should ensure that the equipment specification is suitable for both the intended location and actual location of LV switchgear. The overriding principle is therefore to ensure that either the switchgear is made to a standard that suits the installation OR the installation is designed to suit the constraints of the switchgear.
5. **Isolation:** Procedures to ensure effective electrical isolation are essential. Turning off an electrical supply will not make the system safe. Steps must be taken to prevent re-energisation and ensure that the electrical isolation is an adequate point of isolation. Locks shall be applied to points of isolation where possible and in accordance with the implemented safe system of work.
6. **Maintenance:** No equipment is maintenance free. A suitable and comprehensive maintenance programme for the equipment should be implemented to cover the operational life of the equipment in line with manufacturer’s recommendations. Relevant operational & maintenance manuals should clarify both routine operational checks as well as more significant overhaul maintenance where necessary.

7. **Electrical Protection:** Records should be maintained for any installed protection relays. This should include details of the protection scheme design (including the facility to install additional earth protection redundancy and protection equipment with fault recording capabilities), protection settings applied, the calculations used to demonstrate the settings are adequate. These points should be signed off by a competent person during the commissioning phase.
8. **Records:** Clear, accurate and up-to-date records are essential. Records must include a signed and dated as built single line diagram. These must be easily available to all persons working on switchgear. This would normally include records detailing operational diagrams and the electrical arrangements of the switchgear (e.g. circuit breakers, MCB's); LV switchgear rating plate information and serial numbers; electrical schematics and wiring diagrams and commissioning records. This information must interface with maintenance data in order to respond to product defect notices and identify any serial defects in the equipment. Operational restrictions should be controlled with signed and dated clearance certifications that should include the date of withdrawal from, and return to, service.
9. **Fault Operations:** Any electrical fault / trip that is experienced by the switchgear must be recorded and dealt with, in line with the switchgear Manufacturer's recommendation.
10. **Routine Operations:** To understand the rated capability for short circuit operations and the maximum permissible before replacement or refurbishment is recommended in accordance with the manufacturer's recommendations.
11. **Proving dead:** It is a statutory requirement in the UK to prove dead at the point of work before working on electrical equipment. Furthermore, the HSE consider the act of proving dead to be live work and as such regulation 14 of the Electricity at Work Regulations must be adhered to.Test points on the switchgear may allow this testing, depending on the design. If they are not available testing can prove difficult or dangerous. A written procedure that has been approved must be adopted to prove the switchgear is dead. Precautions should be taken to avoid any sole reliance on capacitive coupled voltage presence indicators/test points as proof of disconnection.

Additional HV specific measures

1. **Competence:** Turbines containing HV equipment are considered as sub-stations. It is a legal requirement that minimum levels of competence are determined for access. This should cover simple access for tasks inside a turbine for working on the HV system.
2. **Anti-reflex handles:** It is commonly accepted that anti-reflex handles are the minimum level of equipment provision for switchgear in the UK. It is necessary that designers consider the provision of either proprietary bespoke handles or, with the agreement of the manufacturer, to retrofit suitable handles to the equipment.
3. **Location:** Switchgear should ideally be located in a separate building. If this is not practicable due to planning or other restrictions, suitable precautions should be taken to restrict access to switchgear from unauthorised personnel.
5. **Isolation and earthing:** Procedures to ensure effective electrical isolation and earthing are essential. Turning off an electrical supply will not make the system safe. Steps must be taken to prevent re-energisation.
6. **Interlocking:** These systems provide a safe environment to operate switchgear and are included to mitigate against operator error. For example, interlocking systems can provide an effective method of preventing access to a live transformer by only allowing access when the transformer is isolated and earthed. Interlocking is provided by both mechanical and electrical means.
7. **Remote operation:** Internal switchgear failures can result in an explosive release of energy. Specific consideration should be given to using suitable remote switching, umbilical or lanyard devices, to minimise the risks to operators. This could extend to the use of supervisory control and data acquisition (SCADA) techniques to facilitate remote testing and inspection.

Reference sources

The following references are only intended as an indicative summary.

HSE

- HSG 85 Electricity at Work Safe Working Practices
- INDG 372 Electrical Switchgear Safety: A guide for owners and users
- INDG 354 Safety in electrical testing at work: general guidance
- EIS 37 Safety in electrical testing: switchgear and control gear. Engineering Information Sheet 37
- HSG 230 Keeping Electrical Switchgear Safe
- HSR 25 Memorandum of Guidance on the Electricity at Work Regulations 1989

BSI

- BS EN 50308:2004 Wind Turbines – Protective measures – requirements for design, operation and maintenance
- BS EN 61400-1:2005 Wind turbines – Design requirements
- BS EN 61400-3:2009 Wind Turbines -Design requirements for offshore wind turbines
- BS EN 62271-1:2008 High-voltage switchgear and control gear – Common specifications
- BS 7671:2008 (2015) Requirements for Electrical Installations; - 17th Edition
- BS EN 60947-1: 2007 – Low Voltage Switchgear and Control Gear - General
- BS EN 60947-2: 2006 – Low Voltage Switchgear and Control Gear – Circuit Breakers
- BS EN 60947-3: 2009 – Low Voltage Switchgear and Control Gear – Switches, Disconnector, Switch-Disconnectors and Fused Combination Units
- BS 6423: 2014 - Code of practice for maintenance of low-voltage switchgear and control gear
- BS 6626:2010 Code of practice for maintenance of electrical switchgear and control gear for voltages above 11kV and up to and including 36kV
- BS EN 50187:1997 Gas-filled compartments for a.c. switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV
- BS EN 60480:2004 Guidelines for the checking and treatment of sulphur hexafluoride (SF6) taken from electrical equipment and specification for its re-use
- BS EN 62271-4:2013 High-voltage switchgear and control gear. Handling procedures for sulphur hexafluoride (SF6) and its mixtures

CEN

- EN 62271-200:2012 – High-voltage switchgear and control gear – Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1kV and up to and including 52kV

IEC

- IEC 62271-200: 2003 – High-voltage switchgear and control gear – Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1kV and up to and including 52kV

EC

- Low Voltage Directive – 2006/95/EC
- Machinery Directive – 2006/42/EC
- F Gas Regulation (EC) No 842/2006
- F Gas Regulation (EU) No 517/2014 (Effective January 2015)

ENA

- Technical Specification (TS) 41-36 Issue 3 2012: Distribution Switchgear for Service up to 36kV (cable and overhead cable connected)
- Technical Specification (TS) 41-37 Issue 1 2004: Distribution Switchgear for Service up to 66kV–132kV, Parts 1, 2 & 3.

RenewableUK

- Offshore Wind & Marine Health and Safety Guidelines 2014
- Onshore Health and Safety Guidelines 2015
- Wind Turbine Safety Rules - Version 3: 2015 and supporting Guidance & Procedures

BEAMA

- Guide to Verification of Low Voltage Power Switchgear and Control Gear Assemblies (PSC) in Accordance with BS EN 61439-2. (October 2009)

There are numerous additional references that may be relevant to switchgear safety. The majority are likely to be available via the contacts and links below.

Contacts and Links

- British Electrotechnical and Allied Manufacturers Association (BEAMA)
  http://www.beama.org.uk/
- British Standards Institute (BSI)
  http://www.bsi-global.com/
- RenewableUK
  http://www.renewableuk.com
- Health and Safety Executive (HSE)
  http://www.hse.gov.uk/
- European Committee for Standardisation
  http://www.cen.eu/cenorm/homepage.htm
- European Community (EC) Directives
  http://eur-lex.europa.eu/en/index.htm
- International Electrotechnical Commission (IEC)
  http://www.iec.ch/
- The Institution of Engineering and Technology (IET)
  http://www.theiet.org/
- UK Health and Safety Legislation
  HSE http://www.hse.gov.uk/legislation/
  Legislation.gov.uk http://www.legislation.gov.uk/

RenewableUK
Greencoat House, Francis Street
London SW1P 1DH, United Kingdom

Tel: +44 (0)20 7901 3000
Fax: +44 (0)20 7901 3001
Web: www.RenewableUK.com
Email: info@RenewableUK.com

Our vision is for renewable energy to play a leading role in powering the UK.

RenewableUK is the UK's leading renewable energy trade association, specialising in onshore wind, offshore wind, and wave & tidal energy. Formed in 1978, we have a large established corporate membership, ranging from small independent companies to large international corporations and manufacturers.

Acting as a central point of information and a united, representative voice for our membership, we conduct research, find solutions, organise events, facilitate business development, advocate and promote wind and marine renewables to government, industry, the media and the public.