# Base Load Power Hub (BLPH)

## Electrical Protection Philosophy

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# 1 INTRODUCTION

## 1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

### 1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

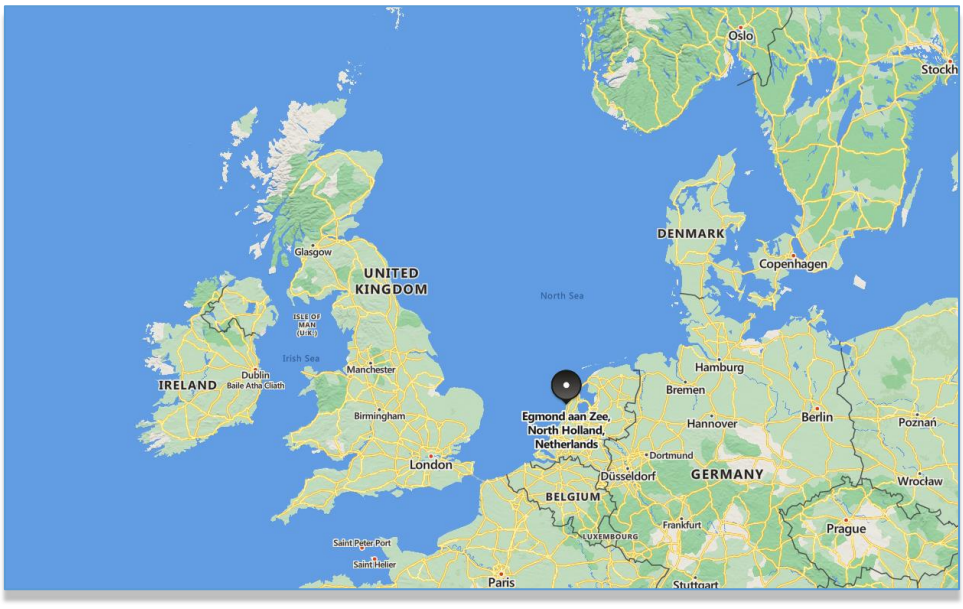



*Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map*

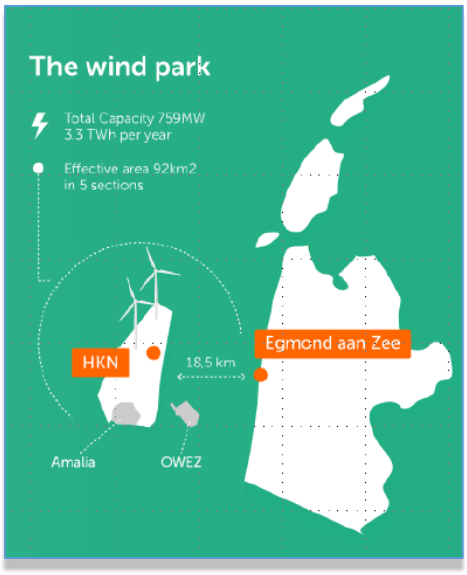



*Figure 2 - Wind Park Details*

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

### 1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

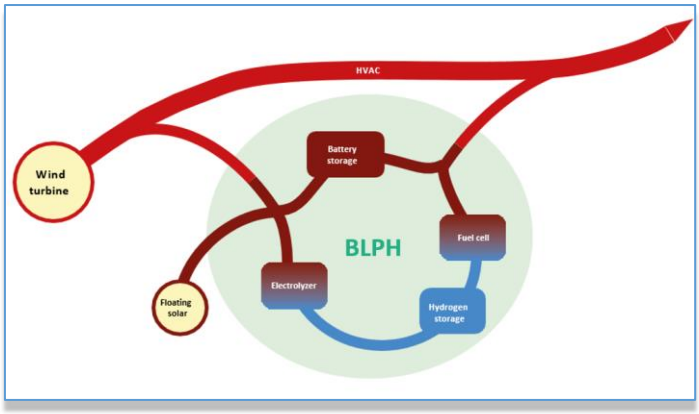



*Figure 3 – BLPH Concept*

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

# 2 DOCUMENT SCOPE

This document defines the high-level electrical protection philosophy proposed for electrical equipment to be installed for the BLPH project. This is based on the document K559-2254-EL-PHI-001 from the FEED phase.

## 2.1 REFERENCES

| Doc. No. | Description |
|---|---|
| 123A90-DDL-EL-DG-20158 | Overall/Key Single Line Diagram |
| 123A90-DDL-EL-DG-20185 | Electrical Single Line Diagram HV Systems |
| 123A90-DDL-EL-DG-20015 | Electrical Single Line Diagram 6.6kV Systems |
| 123A90-DDL-EL-SP-20039 | Functional and Technical Design Specification, IDS and DDS for Electrical Monitoring and Control System (EMCS) |
| 123A90-DDL-EL-DG-20014 | Electrical Control, Protection and Metering Diagrams |
| 123A90-DDL-EL-RE-20170 | Electrical System Study Report - Load Flow |
| 123A90-DDL-EL-RE-20171 | Electrical System Study Report – Short Circuit |
| 123A90-DDL-EL-RE-20172 | Electrical System Study Report - Arc Flash Energy Calculation |
| IEC 60255-51 | Measuring relays and protection equipment - Part 151: Functional requirements for over/under current protection |
| IEC 60255-26 | Measuring relays and protection equipment - Part 26: Electromagnetic compatibility requirements |
| IEC 60947-4-1 | Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters |
| IEC 61000-4-12 | Electromagnetic Compatibility (EMC) Part 4-12: Testing and Measurement Techniques - Ring Wave Immunity Test |
| IEC 61000-4-18 | Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test |
| IEC 61000-6-4 | Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments |
| IEC 61000-6-5 | Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment |
| IEC/TR 61000-3-6 | Electromagnetic compatibility (EMC) - Part 3-6: |

| Doc. No. | Description |
|---|---|
| | Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems |
| IEC 61850-1 | Communication networks and systems for power utility automation - Part 1: Introduction and overview |
| IEC 61869 | Instrument transformers - Part 1: General requirements |
| IEC 61869-2 | Instrument transformers - Part 2: Additional requirements for current transformers |
| IEEE 1584-2018 | IEEE Guide for Performing Arc-Flash Hazard Calculations |
| IEEE C37.2 | Electrical power system device function numbers, acronyms, and contact designations |

*Table 1 - Reference Documents*

## 2.2 DEFINITIONS AND ABBREVIATIONS

| | |
|---|---|
| AC | Alternating Current |
| A/D | Analogue/Digital |
| BESS | Battery Energy Storage System |
| BLPH | Base Load Power Hub |
| CB | Circuit Breaker |
| CCS | Central Control System |
| CCT | Critical Clearance Time |
| COMPANY or Client (CPY): | Crosswind |
| CONTRACTOR (CTR): | ROSETTI MARINO S.p.A. |
| CT | Current Transformer |
| DT | Definite Time |
| EFA | Electrical Frame Agreement |
| ELI | Earth Loop Impedance |
| EMCS | Electrical Monitoring and Control System |
| EPC | Engineering Procurement Construction |

| | |
|---|---|
| FCT | Fault Clearance Time |
| FEED | Front End Engineering Design |
| HMI | Human Machine Interface |
| HRC | High Rupture Capacity |
| HV | High Voltage |
| IAC | Inter Array Cable |
| IDMT | Inverse Definite Mean Time |
| IEC | International Electrotechnical Commission |
| IED | Intelligent Electronic Device |
| LLL | Line to Line to Line |
| LL | Line to Line |
| LLG | Line to Line to Ground |
| LG | Line to Ground |
| LV | Low Voltage |
| MCB | Miniature Circuit Breaker |
| MCC | Motor Control Centre |
| MCCB | Moulded Case Circuit Breaker |
| MV | Medium Voltage |
| MW | Mega Watt |
| NER | Neutral Earth Resistor |
| NUI | Normally Unmanned Installation |
| N/A | Not Applicable |
| PF | Power Factor |
| PROJECT: | HOLLANDSE KUST NOORD WIND PARK Project |
| RCBO | Residual Current operated Circuit Breaker |
| RCD | Residual Current Device |
| REF | Restricted Earth Fault |
| SLD | Single Line Diagram |
| SoC | State of Charge |
| TAMAP | Shell's Approved Vendor List |

*Table 2 - Definitions and Abbreviations*

| Term | Definition |
|---|---|
| 25 | Synchro-check |
| 26OT | Transformer oil temperature indicator |
| 26WT | Transformer winding temperature indicator |
| 27 | Under-voltage protection |
| 46 | Single phasing, or phase unbalance protection |
| 49 | Thermal overload protection |
| 49T | Winding temperature thermal imagie relay |
| 50 | Instantaneous overcurrent protection |
| 50N | Instantaneous earth fault protection |
| 50TD | Short time overcurrent protection |
| 51 | AC inverse time overcurrent protection |
| 51G | AC inverse time earth fault protection |
| 51N | AC inverse time earth fault protection - unbalanced |
| 59 | Overvoltage protection |
| 59N | Neutral overvoltage relay |
| 63 | Pressure Relief Device |
| 64 (or 87NT) | Restricted Earth Fault |
| 67 | Directional overcurrent protection |
| 67N | Directional earth fault protection |
| 71 | Transformer Oil Level Switch |
| 74 | Trip circuit supervision |
| 86 | Lockout relay |
| 87 | Differential protection |
| 94B | Buchholz protection - Auxiliary alarm and trip relay |
| 94L | Oil level alarm auxilairy relay |
| 94OT | Transformer oil temperature element - Auxiliary alarm and trip relay |
| 94WT | Transformer winding temperature element - Auxiliary alarm and trip relay |
| 94P | Pressure Relief protection - Auxiliary alarm and trip relay |
| 94x | Transformer Protection auxiliary alarm and trip |

| Term | Definition |
|---|---|
| 97T | Buchholz relay |
| 98T.1 | Bladder rupture relay |
| 98T.2 | Self dehydrating breather |

*Table 3: ANSI power system device function numbers*

# 3 POWER SYSTEM FUNCTIONALITY

BLPH is a Normally Unmanned Installation (NUI) platform and will operate autonomously as a pilot for the potential upscaling of a 'round trip' (battery with water electrolysis & fuel-cell) process located off-shore.

BLPH will be capable of operating as a self-sustaining plant for a limited period (whilst not connected to either the wind or solar farms) due to unfavourable weather or due to any other operational or maintenance driven requirement and have minimal planned maintenance.

The BESS is rated 1 MW/ 5 MWh and low voltage cut-off shall be provided to prevent the battery from continuously draining after the maximum acceptable discharge time. Battery capacity is selected to supply fully the inverter's input power requirement when the inverter delivers rated kVA output at <0.95 PF.

The various operation modes of BLPH will cause the 0.4 kV and 6.6 kV system power demands to vary significantly (BESS charging / discharging and fuel-cell running or electrolyser running) and the electrical system shall be adequate for the worst-case, for example, highest demand (import or export).

## 3.1 CONNECTION MODES AND OPERATION MODES

The Central Control System (CCS) will be a single control system (single Operator) that monitors and controls the entire BLPH electrical system inclusive of BESS, electrolyser, fuel cell and solar farm (power in-feed). Communication with electrical equipment (HV and LV switchgear / MCC) shall use the IEC 61850 or Modbus TCP/IP protocols to be capable of switching circuit breakers sufficiently quickly for load-shedding purposes.

BLPH - CONNECTION MODES (Refer to 123A90-DDL-EL-SP-20039)

A. Connected – Wind Farm (only).

B. Connected – Solar Farm (only).

C. Connected – both.

D. Neither – (Island).

CCS - OPERATION MODES (Refer to 123A90-DDL-EL-SP-20039)

1. Mode 0 – Idle.
2. Mode 1 – Charging (power import).
3. Mode 2 – Discharging (power export).
4. Mode 3 – Hot Standby (power import / export not required).
5. Mode 4 – Cold Standby (power import / export not possible).
6. Mode 4A – Emergency (Island).

7. Mode 5 – Power Out (Blackout).
8. Mode 6 – Maintenance Access.
9. Mode 7 – Research.

## 3.2 WIND FARM CONNECTION

The wind farm operates at 66 kV AC and 50 Hz. The 66 kV power connection will be transformed down to 6.6 kV and 0.4 kV for use onboard BLPH.

At BLPH the IAC will be connected to a single bus bar 66 kV (non-$SF_6$) type switchgear.

## 3.3 SOLAR FARM CONNECTION

The solar farm will be designed by 'Others' with all necessary inverters located at the solar platform. The nominal operating voltage and frequency of the in-feed will be 800 V, 50Hz, with the two winding transformer TR-200ED1 included at BLPH to step-up the in-feed voltage for connection to the 6.6 kV bus at BLPH.

The solar farm in-feed power circuit breaker panel SG-200D2 is situated inside LV switchroom (B-200) that are selected to be capable of both making & breaking the worst-case prospective fault current that originates at both BLPH and the solar farm (contributions combined). The 6.6 kV feeder latched fused contactor shall intertrip both LV side circuit breaker and the package itself, through serial link. The in-feed cable and transformer shall be adequately protected at each end.

# 4 GENERAL PROTECTION REQUIREMENTS

## 4.1 GENERAL

The design of the protection system for the electrical installation shall be based on the provision of a safe and reliable supply of electricity at all times. Safe conditions shall be ensured under all operation modes, including those associated with start-up and shutdown of plant and equipment throughout the intervening shutdown periods. The design of electrical protection systems and equipment shall ensure that all operating and maintenance activities can be performed safely.

A system of automatic protection shall be provided to protect equipment and personnel. The protection system shall be able to automatically detect the abnormality and isolate the fault, with minimum delay and minimum danger to equipment and personnel. The protection system shall include redundancy or backup such that if a single protection device or circuit fails then there is independent secondary method for fault identification and isolation.

### 4.1.1 Compliance

The electrical protection system shall comply with the relevant international standards and this philosophy.

### 4.1.2 Safety of Personnel

Safety of personnel shall be considered paramount. The design of electrical installation /network and protection systems shall aim at eliminating or minimising the dangers of electric arcs and touch voltages. Measures to be incorporated shall include:

- Effective system earthing and equipment frame earthing.
- Dead fronted (safe to touch in normal operation) switchgear frames.
- The use of 30mA / 100mA / 300mA or traditional overcurrent protection (with sufficiently low Earth Loop Impedance (ELI)) should be evaluated to ensure package certification will not be compromised. Additionally, each Vendor should be consulted about the need for specific RCD/RCBO operating current values to ensure item certification will not be compromised.
- Isolation of the faulty parts of the network with minimum delay.
- Remote operation of switchgear via IEC 61850 (66 kV switchgear, 6.6 kV switchgear and incoming on 400 V switchgear) or Modbus TCP/IP (LV switchgears) from the CCS.

### 4.1.3 Safety of Equipment

The isolation of the faulty parts of the installation shall be achieved automatically by the combined actions of the protective devices and switching devices within a time limit that does not exceed the short circuit current withstand capability or thermal withstand capability of the equipment involved.

### 4.1.4 Safety of Operations

To always ensure overall safety of the system and reliable supply of electricity, the design of the protection system shall also include the following features to avoid widespread system tripping:

- Fast and selective response of primary protective devices.
- The provision of correctly located and coordinated back-up protection.
- Minimum fault clearance time (FCT) to ensure equipment and personnel safety.

The critical clearance time (CCT) will be established from protection coordination report. Grading times will be estimated based in best practices according to the CB equipment described in 123A90-DDL-EL-DG-20158.

NOTE: The BLPH system fault levels will vary dependent upon the status of the wind and solar farm connections, solar in-feed power, BESS SoC and/or fuel-cell operating load point, according to the results shown in the short circuit report.

### 4.1.5 Standardization of Protection Equipment and Relay Settings

For reasons of cost effectiveness, ease of operation (programming, settings, and change control) and maintenance, the protection system design shall use standardised protection equipment (same make and model) throughout where possible.

### 4.1.6 System Communications

Protection relays and other protective devices shall be provided with facilities capable of communicating with other relays and systems as follows:

- All the multifunction protection relays shall comply with IEC 61850 communication requirements.
- With upstream and downstream relays on the same radial branch to ensure effective protection and back up protection of that branch.
- With the CCS for alarms, status reporting, circuit parameter reporting (current, voltage, power, power factor etc.), events recording and control commands.
- With an operator, either locally via the HMI for information gathering and parameter setting, or by using a laptop with appropriate software, or remotely from the CCS HMI panel.

## 4.2 PROTECTION PRINCIPLES

This philosophy describes the detection and automatic disconnection requirements of electrical distribution equipment in the event of a fault or system disturbance.

The following criteria will be adhered to:

- The electrical protection system shall be designed to operate for the full range of anticipated system fault levels considering all connection and operation modes (refer to Chapter 3.1).
- Minimum fault clearance time (FCT) to ensure equipment and personnel safety.
- The electrical protection system shall be designed to permit stable operation for overloads (allowed overload within the safe limit of equipment) and normal system transients, such as transformer magnetizing inrush currents, switching surges.
- The electrical protection system shall include redundancy or backup such that if a single protection device or circuit fails then there is independent secondary method for fault identification and isolation.
- Load shedding is managed by EMCS.
- The possibility of dormant, un-revealed faults in protection systems will be minimized by design, for example, use of trip circuit supervision, self-checking relays etc.

Automatic protective systems shall be designed to achieve selective isolation of faulted equipment with minimum delay. In any event this will be within a time corresponding to the short circuit current withstand capability of equipment, system stability limits and the maximum fault clearance times. Adequate and selective phase short circuit and earth fault protection will be provided, due regard being given to the magnitude of short circuit currents (maximum (LLL or LLG) and minimum (LL or LG)) based on having maximum fault contribution (wind, solar, BESS and fuel-cell) or minimum contribution (BESS) and the method of system earthing.

Protection systems will be selective, and the settings will be coordinated so that upstream protection provides enough time to afford fault clearance back-up protection, in the event of protective system and / or switching device failure downstream.

For circuit breakers/ contactors operating across potentially unsynchronized supplies, circuit close commands will be via the associated protection relay integral synchro check (25).

## 4.3 ELECTRICAL SYSTEM STUDIES

### 4.3.1 Protection Co-ordination (Grading) Study

A protection co-ordination (grading) study shall be performed during the EPC phase to determine the optimum time/current characteristic to be used for phase and earth fault protection relays to achieve full discrimination and rapid fault clearance whilst still maintaining sufficient sensitivity to protect equipment from sustained overloading.

The Protection Coordination Study report shall include:

- A description of the system and of the system operating modes on which the settings have been based.

- Relevant short circuit current calculations for the specified minimum and maximum supply conditions.
- Single line diagrams for each part of the system.
- The philosophy applied in selecting the relay settings, highlighting any areas where necessary compromises have been made.
- Tabulated settings of the individual devices, for example, setting range, steps, CT ratio, type of relay curve, all relay parameter settings.
- Coordinated characteristics of the protective devices, fuses, dynamic and thermal withstand curves.
- The protection co-ordination (grading) curve shall clearly show the points related to fault current at various bus locations to show the relay operation time for the faults at these locations. In addition, the grading curves shall include transformer inrush and equipment damage curves.

A separate protection schedule shall be provided in vendor specific parameters format for each protection relay.

### 4.3.2 Arc Flash Study

An arc flash incident energy study shall be completed (Refer to 123A90-DDL-EL-RE-20172), in accordance with IEEE 1584-2018, to assess the maximum prospective arc flash incident energy for 6.6 kV and 400 V switchgear. In addition, the arc flash protection boundary shall be calculated, which is the distance from exposed live parts within which a person could receive a second-degree burn.

The study shall determine the incident energy for switchgear without arc flash detection and estimated maximum protection setting time for maximum and minimum short circuit cases based on the short circuit calculations.

If the results show the incident energy release exceeds 8 calories/cm$^2$ the arc flash incident energy study shall be repeated for switchgear with arc flash detection and a recommendation of mitigation measures shall be proposed to the Company for consideration.

## 4.4 APPLICATION OF RELAYS

Multifunction numerical protection relays incorporating features such as self-checking, programmable scheme logic, communication, measured value display and disturbance / fault recording facilities shall be applied.

The self-check feature for multifunction relays will include the following minimum continuous self-monitoring features:

- Auxiliary supply supervision.
- Checksum on all protection algorithms.

- Memory checks.
- Checks on input modules (A/D converter).
- Watchdog supervision on program execution.

Only relays with the above self-supervision / diagnostic features will be considered for integrating multiple protection functions into one relay. However main and back-up protection will not be combined into one relay and will use separate CTs.

To ensure maximum integrity and minimum fault clearance times, protection trips will be direct acting, from the protection relay, without intermediate relaying.

Lock out relays (86) shall be used to reinforce all protection trips and inhibit re-closure. The reset mechanism of the lockout relay should be electrically operated to facilitate both local and remote resetting.

# 5 BASIS OF COORDINATION

Device settings will be selected to give the optimum practical operating times.

## 5.1 GRADING MARGIN

To achieve the selective isolation of the faulty section, there should be a time interval between the operation of the protection relays based on the following factors:

- Circuit breaker breaking time.
- Relay overshoot time (for protection relays this is not valid).
- Errors of relays and CTs.
- Safety margin.

The following total margins are recommended as the minimum margins to be used for the relay coordination exercise based on industry practice recommendation:

- Between Inverse Tholdime Relays - The minimum grading interval between inverse time relays will be set at 250 ms.
- Between Definite Time Relays - The minimum grading interval between relays with a definite time characteristic will be set at 200 ms.
- Between Relays and Fuses - The minimum recommended grading interval between upstream relays and downstream fuses will be set to 150 ms.
- Between Fuses - Grading between fuses in series will be checked for the total operating $I^2t$ of the smaller downstream fuse to be less than the pre-arcing $I^2t$ of the larger upstream fuse. The melting time and clearing time are of significance as the upstream feeder fuse must not melt during the clearing time of the downstream outgoing fuse when a common fault current passes.
- Between Relay and MCCB - The recommended grading margin is 200 ms, between an upstream IDMT curve and the upper tolerance of the MCCB trip curve. The recommended grading margin is 100 ms, between an upstream DT curve and the upper tolerance of the MCCB trip curve.
- Between MCCBs in Series - The recommended grading margin between MCCB trips in series is 100 ms, without overlap of respective tolerance bands.
- Between MCCB and MCB - The philosophy for setting upstream MCCB is to grade with downstream thermal magnetic MCBs and operating no faster than 100 ms, to allow the instantaneous MCB magnetic trip to clear first.
- Between MCCB and Fuse - The recommended grading margin between an MCCB and a downstream fuse is a minimum of 100 ms.

## 5.2 BASIS FOR PHASE OVER-CURRENT DISCRIMINATION

Protection discrimination and operational sensitivity will be established for the maximum and minimum three phase fault currents.

The rated short circuit withstand capacities for the various switchgears are as detailed in Table 4.

| Tag number | Switchgear Description | Rated short circuit current (kA rms) | Time withstand (s) |
|---|---|---|---|
| HNA6-AFA70 | 66 kV switchgear | 31.5 | 1 |
| SG-100D1-MV1 | 6.6 kV switchgear | 25 | 1 |
| SG-200N1-LV1& ELV1 | 0.4 kV switchgear | 50 | 1 |

*Table 4: Rated short circuit capacities for various switchgears*

- The operating time of the relay on the incomer at the respective switchgear will be such that the operating time of the immediate backup relay, considered together with its breaker opening time, does not exceed the short time rating of the switchgear as stated above.
- Discrimination between the primary and secondary side protection across a transformer is not considered obligatory since both protection schemes will remove the transformer from service and grading between the two schemes will not increase the continuity of supply.
- The protection provided against damage to cables shall be such that short circuit protection operation time is shorter than the cable short time withstand.
- The protection provided against transformer damage shall be such that short circuit protection operation time is shorter than the transformer short time withstand.
- Transformer primary side overcurrent relay is set so that it does not operate during short duration of transformer magnetizing inrush current. Transformer inrush current and duration shall be as per transformer data sheets / vendor data.
- The instantaneous element (50) of the overcurrent relays at the primary side of a transformer should be set to higher than 150% of the calculated secondary fault current to ensure that the instantaneous element will operate for a transformer fault, but not for a downstream secondary fault.
- The relay current settings for over-current relays at motor feeders shall be selected in such a way that it permits continuous rated full load current flow and ensures that the relay does not operate during the starting of the motor.

## 5.3 BASIS FOR EARTH FAULT DISCRIMINATION

Protection discrimination and operational sensitivity will be established for the maximum and minimum single phase earth fault currents.

Earth fault protection (51G) schemes at 6.6 kV, where earth fault currents are limited by Neutral Earthing Resistors (NERs) are set, where possible, to a pick-up setting of 10% to 20% of the CT rating.

For restricted earth fault (REF) schemes, relays and matching CTs shall be selected to afford the sufficient sensitivity to detect earth faults within the equipment winding.

Distribution transformers utilize Delta / Star (earthed) configuration for their primary and secondary winding connections. This arrangement permits the earth fault relays on either side of the transformer to be set independently of each other, resulting in minimum FCTs for primary side earth faults being achieved.

LV earth faults can be expected to occur as arcing faults as well as solid faults. Where arcing faults occur, the fault current will be significantly reduced by the opposition of the arc voltage to the system voltage and clearance times would increase for inverse time schemes. Definite time schemes maintain a good sensitivity to low level earth faults without increasing operating time and are used in preference to inverse time schemes for earth fault protection.

Typical studies of arcing earth faults for solidly earthed LV three phase systems have indicated that arcing faults can reduce fault currents to 38% of solid faults. Earth fault relays will, therefore, be set to achieve sensitivities better than this level to respond to arcing earth faults.

Backup earth fault protection schemes will have the CT in the earth leg of the transformer earth circuit. To mitigate spurious tripping due to normal neutral current return path, the relay's threshold set-point current will be set above the maximum unbalanced current in the neutral return. This can be within 5% to 20% CT rating, based on the percentage of single phase loads from the switchgear. Further optimization during commissioning may be required in the event of spurious tripping.

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# 6 EQUIPMENT PROTECTION

This section covers the electrical protection of the following:

- Distribution Transformers
  - TR-100AD1
  - TR-200DE1
- Solar package transformer (TR-200ED1) including in-feed cable
- 6.6 kV latched fused contactor feeder to a vendor package:
  - Battery Energy Storage System (BESS)
  - Fuel cell
- 6.6 kV circuit breaker feeder to a vendor package:
  - Electrolyser
- Busbar Protection
- LV Induction Motor
- LV Feeder Circuit

The electrical protection and settings for packaged equipment will be completed by the package vendor, the Contractor shall be responsible for the selection and setting for the protections on the feeders to each package.

## 6.1 DISTRIBUTION TRANSFORMERS

The distribution transformers are equipped with switching devices listed in Table 5.

| Tag number | Distribution transformer description | Primary side switching device | Secondary side switching device |
|---|---|---|---|
| TR-100AD1 | o 7 MVA<br>o 66/6.9 kV<br>o Oil immersed | Circuit breaker (A6) | Circuit breaker |
| TR-200DE1 | o 1.6 MVA<br>o 6.6/0.42 kV<br>o Oil immersed | Latched fused contactor (A4) | Circuit breaker |

*Table 5: Information on distribution transformers*

Each of the switching devices shall be equipped with a multifunction protection relay (IED) to perform the following protection functions.

Transformer Primary Winding:

- Differential protection (87) covering the primary side feeder cable, transformer windings and secondary side connections. For transformer TR-100AD1only.
- Instantaneous overcurrent (50) and earth fault (50N) protection, for the primary side power cables and transformer primary winding. For transformer TR-200DE1 instantaneous overcurrent protection (50) is managed by the protection relay acting on the contactor, while HRC fuses will trip as backup.
- IDMT overcurrent protection (51), for the transformer overload protection and secondary side short circuit protection. This will also act as a backup protection for the secondary side switchgear busbars.
- Directional overcurrent (67) and earth fault (67N) protection for detection of electrical faults during power export mode. For transformer TR-100AD1only.
    - These functions shall be subjected to further evaluation after the selectivity study is performed.
- Check synchronization (25). For transformer TR-100AD1 only.

Transformer Secondary Winding:

- Instantaneous overcurrent (50) and earth fault (50N) protection, to provide protection for the secondary switchgear busbars.
- IDMT overcurrent (51) and earth fault (51N) protection, to provide backup protection for the switchgear outgoing feeders.
- DT earth fault protection (51G), for transformers TR-100AD1 and TR-200DE1 secondary side earth faults. The earth fault protection function will also act as a backup protection for the secondary side switchgear busbars.
- Transformer secondary side restricted earth fault protection (64 or 87NT) to cover earth fault in both the secondary winding and connections. For transformer TR-100AD1 only.
- Check synchronization (25). For Transformer TR-100AD1 only.

Other Transformer Protection Functions:

- Transformer Liquid Temperature Device (26OT).
- Transformer Winding Image relay (49TT).
- Transformer Oil Level Switch (71).
- Buchholz Relay (97).

- Pressure Relief Device (63).
- Bladder rupture relay (98T.1). For Transformer TR-100AD1 only.
- Self dehydrating breather (98T.2). For Transformer TR-100AD1 only.
- Transformer OLTC Oil Level Switch (71OLTC). For Transformer TR-100AD1 only.
- Transformer OLTC protection relay (97OLTC). For Transformer TR-100AD1 only.

All transformer alarm are acquired directly on the 6.6 kV incoming multifunction protection relay, while transformer trip are duplicated on interposing relays (94x), in order to act on the lock out relay and to be acquired by the 6.6 kV incoming multifunction protection relay.

### 6.1.1 Differential Protection (87)

Differential protection for transformer TR-100AD1 shall be used to detect internal winding faults. The protected zone shall include the transformer and the connections between the transformer and the switchgear on both sides.

The operating characteristic of the bias protection shall ensure stability on any transformer tap position under maximum through-fault conditions. The harmonic restraint characteristics of the relay shall be used to ensure the relay does not operate for transformer inrush currents. High accuracy CTs shall be selected for use with the differential system and, in all cases, the design of the CTs shall be based on the recommendations of the relay manufacturer.

### 6.1.2 Transformer Primary Instantaneous Overcurrent (50)

Transformer and the associated primary cables which are supplied via a circuit breaker shall be protected against both three phase and two-phase short circuits using instantaneous overcurrent relay elements connected to suitably rated CTs installed in each phase. The transformer instantaneous relay elements shall be set not to trip under the transformer magnetising current inrush conditions and be set approximately 1.5 times the calculated secondary fault current to ensure that the instantaneous element will operate for a transformer internal fault, but not for a downstream secondary fault.

### 6.1.3 Transformer Primary Instantaneous Earth Fault Protection (50N)

Transformer primary side earth fault protection shall be provided with an instantaneous earth fault current element to provide rapid disconnection in the event of a transformer primary earth fault. The earth fault relay element is set to approximately 5% to 10% of the system earth fault current and will be supplied using three residually connected CTs or from a dedicated core balance CT.

### 6.1.4 Transformer Primary IDMT Overcurrent Protection (51)

The transformers and the associated cables shall be protected against system overload currents using three IDMT overcurrent relay elements, one located in each phase. The transformer IDMT relay elements shall be set to discriminate with the largest secondary outgoing feeder circuit. The relay elements shall be set close to the full load current of the transformer with a suitable grading margin as described in Chapter 5.1.

For TR-200DE1, primary IDMT overcurrent (51) and earth fault (51N) protection shall be provided on the transformer primary side circuit switching device to provide backup protection for the secondary switchgear busbar.

### 6.1.5 Transformer Primary Directional overcurrent (67) and earth fault (67N)

Directional overcurrent (67) and earth fault (67N) protection shall be provided for transformer TR-100AD1 for detection of electrical faults during power export mode.

The export of solar power and/or release of the energy stored onboard BLPH will be approximately 1 MW and will require a lower setting than non-directional overcurrent and earth fault for rapid disconnection of an upstream fault during this export mode.

These functions shall be subjected to further evaluation after the selectivity study is performed.

### 6.1.6 Transformer Primary Check Synchronization (25)

Check synchronization (25) for transformer TR-100AD1 shall be included to verify the voltage, phase angle and frequency are within acceptable limits prior to closing the circuit breaker. The check synchronization shall include the facility for dead bus closing.

### 6.1.7 Transformer Secondary Instantaneous Overcurrent (50)

The three-phase short circuits in the switchgear busbar on the secondary side of transformer shall be cleared by the circuit breaker on the secondary side using instantaneous overcurrent 50 protection from the CTs on the secondary side of the transformer.

### 6.1.8 Transformer Secondary Instantaneous Earth Fault Protection (50N)

The earth faults in the switchgear busbar on the secondary side of transformer shall be cleared by the circuit breaker on the secondary side using instantaneous overcurrent 50N protection from the CBCT on the secondary side of the transformer.

### 6.1.9 Transformer Secondary IDMT Overcurrent (51) and Earth Fault (51N) Protection

IDMT overcurrent and earth fault protection shall be provided on the transformer secondary side circuit switching device to provide backup protection for the switchgear outgoing feeders.

### 6.1.10 Transformer Secondary DT Earth Fault Protection (51G)

DT earth fault protection (51G) is applicable for TR-100AD1 as well as TR-200DE1. Transformer secondary side DT earth fault protection relay element (51G) shall be connected to a suitably rated CT located in the transformer secondary winding neutral star point connection.

These protection relays will detect all earth faults located on the transformer secondary side including the transformer secondary winding, associated switchgear busbar and outgoing feeder earth faults. The earth fault relay element shall be set to discriminate with the largest secondary outgoing feeder circuit earth fault protection.

### 6.1.11 Transformer Secondary Restricted Earth Fault Protection (64 or 87NT)

Restricted earth fault relays shall be provided for the secondary, star connected windings of transformer TR-100AD1. The restricted earth fault relay protection will provide rapid fault clearance in the event of a transformer winding earth fault where discriminating earth fault protection is required with downstream devices.

Protection shall be low impedance (biased) type. The current transformer connections shall compare the resultant current from the three phases with the current flowing in the star winding neutral which for normal operation should sum to zero.

### 6.1.12 Transformer Secondary Check Synchronization (25)

Refer to Chapter 6.1.6.

### 6.1.13 Transformer Oil Temperature Device (26OT)

Oil temperature protection (26OT) shall be provided to raise an alarm when the transformer oil temperature reaches a pre-set level and to initiate a trip (94OT) should a further increase in oil temperature occur.

### 6.1.14 Transformer Winding Temperature Device (26WT) or Thermal image relay (49T)

Winding temperature protection (26WT) or thermal image relay (49T) shall be provided to raise an alarm when the transformer winding temperature reaches a pre-set level and to initiate a trip (94WT) should a further increase in winding temperature occur.

### 6.1.15 Transformer Oil Level Switch (71OT)

Transformer oil level switch is installed on the oil conservator to raise an alarm when the oil level reaches a lower level and to initiate a trip (94L) when the level should be further reduced. Trip due to very low oil level is provided only for transformer TR-100AD1.

### 6.1.16 Buchholz Relay (97T)

Each transformer has a conservator tank and it shall be provided with a Buchholz relay with contacts arranged to alarm in the event of a slow gas accumulation and trip (94B) for a rapid liquid surge in the event of a winding fault.

### 6.1.17 Pressure Relief Device (63T)

Each transformer has a pressure relief device fitted to prevent the transformer tank reaching excessive over pressure in the event of a winding or internal fault. A contact is fitted which provides a trip (94P) when the overpressure device operates.

### 6.1.18 Bladder rupture relay (98T.1)

TR-100AD1 transformer is equipped with a sensor inside the oil conservator tank to detect any problem will occur to the membrane which is installed to avoid the atmosphere to touch the transformer oil. The Bladder rupture relay (98T.1) has an alarm for remote signalling purpose.

### 6.1.19 Self dehydrating breather (98T.2)

TR-100AD1 transformer is equipped with a self dehydrating breather (98T.2), which allows regeneration of sylicagel inside one breather while the other one is in operation. The self dehydrating breather has an alarm for remote signalling purpose in case of not proper operation.

### 6.1.20 Transformer OLTC Oil Level Switch (71OOLTC)

TR-100AD1 transformer is also equipped with an oil level switch installed on the oil conservator for the OLTC to raise an alarm when the oil level reaches a lower level and to initiate a trip (94L-OLTC) when the level should be further reduced.

### 6.1.21 Protection relay on OLTC (97OLTC)

TR-100AD1 transformer OLTC oil circuit is equipped with a relay that can detect any gas presence in the oil that could generate over pressure in the oil itself. This relay has a contact that provides a trip (94P-OLTC) when the overpressure device operates

### 6.1.22 Tripping Requirements (86)

Transformer protection trips shall be via local or remote reset, lockout relay functions (86).

All alarms should be able to be reset/acknowledged remotely.

One lockout relay shall lock out the primary switching device and the other lockout relay shall lockout the secondary switching device (only for transformer TR-100AD1).

Protection trips associated with a transformer primary shall operate the lockout relay for the primary switching device, and similarly, protection trips associated with a transformer secondary shall operate the lockout relay for the secondary switching device (only for transformer TR-100AD1).

Logic based inter trips will be performed between the primary and secondary switching devices to isolate the fault.

The following trips shall operate the relevant lockout relays and inter trip upstream/ downstream:

- Primary side lockout relay (86):
  - Differential protection (87). Transformer TR-100AD1 only.
  - Instantaneous overcurrent (50).
  - Instantaneous earth fault (50N).
  - IDMT overcurrent (51).
  - DT earth fault (51G).
  - Directional overcurrent (67) and earth fault (67N). Transformer TR-100AD1 only.

– These functions shall be subjected to further evaluation after the selectivity study is performed.

- Restricted earth fault (64). Transformer TR-100AD1 only.

- Secondary side lockout relay (86) (only for transformer TR-100AD1):
  - Instantaneous overcurrent (50) and earth fault current (50N).
  - IDMT overcurrent (51) and earth fault (51N).

For internal transformer faults, and feeder cable faults, both primary and secondary side switching devices shall trip.

## 6.2 SOLAR PACKAGE TRANSFORMER (TR-200ED1) – INCLUDING IN-FEED CABLE

TR-200ED1 is equipped with the switching devices listed in Table 6.

| Tag number | Distribution transformer description | Primary side switching device | Secondary side switching device |
|---|---|---|---|
| TR-200ED1 | o 0.5 MVA<br>o 6.6/0.8 kV<br>o Oil immersed | Latched fused contactor (A2) | Circuit breaker (SG-200D2) |

*Table 6: Information on solar package transformer*

Each of the switching devices shall be equipped with a multifunction protection relay (IED) to perform the following protection functions.

Transformer Primary Winding:

- Instantaneous overcurrent (50) and earth fault (50N) protection, for the primary side power cables and transformer primary winding. Instantaneous overcurrent protection (50) is provided via protection relay and HRC fuses on the primary side switching devices.
- IDMT overcurrent protection (51), for the transformer overload protection and secondary side short circuit protection. This will also act as a backup protection for the secondary side of the transformer, including the secondary side in-feed cable.
- Check synchronization (25).

Transformer Secondary Winding:

- Instantaneous overcurrent protection (50), instantaneous earth fault protection (50N) and IDMT overcurrent protection (51), for the in-feed cable protection.

- Any earth fault on the in-feed cable will be detected and cleared by the instantaneous earth fault protection (50N) of SG-200D2. The backup is provided by primary IDMT earth fault protection (51N).

- Any earth fault between the transformer secondary and SG-200D2 will be cleared by the primary switching device with either instantaneous earth fault protection (50N) or IDMT earth fault protection (51N).

Other Transformer Protection Functions:

- Transformer Liquid Temperature Device (26OT).
- Transformer Winding Temperature Device (26WT).
- Pressure Relief Device (63).

All transformer alarm and trip functions shall be via auxiliary alarm and trip relays (94x).

### 6.2.1 Transformer Primary Instantaneous Overcurrent (50)

Transformer TR-200ED1 and the associated primary cables are to be protected against short circuit currents by protection relay and suitably rated HRC fuses.

### 6.2.2 Transformer Primary Instantaneous Earth Fault Protection (50N)

Transformer primary side earth fault protection shall be provided with an instantaneous earth fault current element to provide rapid disconnection in the event of a transformer primary earth fault. The earth fault relay element is set to approximately 5% to 10% of the system earth fault current and will be supplied using three residually connected CTs or from a dedicated core balance CT.

### 6.2.3 Transformer Primary IDMT Overcurrent (51) and Earth Fault (51N) Protection

IDMT overcurrent and earth fault protection shall be provided on the transformer primary side circuit switching device to provide backup protection for the in-feed cable.

### 6.2.4 Transformer Primary Check Synchronization (25)

Check synchronization (25) shall be included to verify the voltage, phase angle and frequency are within acceptable limits prior to closing the contactor. The check synchronization shall include the facility for dead bus closing.

### 6.2.5 Transformer Secondary Instantaneous Overcurrent (50)

The three-phase short circuits in the in-feed cable on the secondary side of TR-100ED1 shall be cleared by the circuit breaker on the secondary side (SG-200D2) with in-built protection (50) in SG-200D2.

### 6.2.6 Transformer Secondary Instantaneous Earth Fault Protection (50N)

The earth faults in the in-feed cable on the secondary side of TR-100ED1 shall be cleared by the circuit breaker on the secondary side (SG-200D2) with in-built protection (50N) in SG-200D2.

### 6.2.7 Transformer Secondary IDMT Overcurrent (51) and Earth Fault (51N) Protection

IDMT overcurrent and earth fault protection shall be provided on the transformer secondary side circuit switching device (SG-200D2) to provide protection for overload on the in-feed cable.

### 6.2.8 Transformer Oil Temperature Device (26OT)

Oil temperature protection (26OT) shall be provided to raise an alarm when the transformer oil temperature reaches a pre-set level and to initiate a trip (94OT) should a further increase in oil temperature occur.

### 6.2.9 Transformer Winding Temperature Device (26WT)

Winding temperature protection (26WT) shall be provided to raise an alarm when the transformer winding temperature reaches a pre-set level and to initiate a trip (94WT) should a further increase in winding temperature occur.

### 6.2.10 Pressure Relief Device (63T)

Transformer TR-200ED1 has a pressure relief device fitted to prevent the transformer tank reaching excessive over pressure in the event of a winding or internal fault. A contact is fitted which provides a trip (94P) when the overpressure device operates.

### 6.2.11 Tripping Requirements (86)

Transformer protection trips shall be via local or remote reset, lockout relay functions (86).

All alarms should be able to be reset/acknowledged remotely.

One lockout relay shall lock out the primary switching device.

Protection trips associated with a transformer primary shall operate the lockout relay for the primary switching device.

Hardwired inter trips will be performed between the primary and secondary switching devices to isolate the fault.

The following trips shall operate the relevant lockout relays and inter trip upstream/ downstream:

- Primary side lockout relay (86):
  - Instantaneous overcurrent (50).
  - Instantaneous earth fault (50N).
  - IDMT overcurrent (51) and earth fault (51N).

For internal transformer faults, the primary switching device shall trip and should send an inter trip signal to the package (via serial communication). Trip form transformer protections are managed by auxiliary trip relays as described in the previous paragraphs.

For primary feeder cable faults, the primary switching device shall trip and should send an inter trip signal to the package (via serial communication). For secondary feeder cable faults, the secondary switching device shall trip and should send an inter trip signal to the package (via serial communication).

## 6.3 6.6 KV LATCHED FUSED CONTACTOR FEEDER TO A VENDOR PACKAGE

The vendor packages shown in Table 7 below are supplied from the 6.6 kV switchgear SG-100D1 via 6.6 kV latched fused contactor. Each feeder supplies a vendor package comprising of a transformer complete with a rectifier/ inverter unit.

This section considers the feeder protection to the transformers only as the vendor will advise the package electrical protection requirements.

| Tag number | Transformer description | Primary side switching device |
|---|---|---|
| 18T1 | o To BESS (A3)<br>o 1.25 MVA<br>o 7/0.62 kV<br>o Dry type | Latched fused contactor |
| TA30 | o To fuel cell (A7)<br>o 1.25 MVA<br>o 6.6/0.4 kV<br>o Dry type | Latched fused contactor |

*Table 7: Information on vendor package transformers - BESS and fuel cell*

Each of the primary side switching devices shall be equipped with a HRC fuse and a multifunction protection relay (IED) to perform the following protection functions.

Transformer Primary Winding:

- Instantaneous overcurrent protection (50) provided via protection relay and HRC fuses.
- Instantaneous earth fault protection (50N), for the primary side power cables and transformer primary winding.
- IDMT overcurrent (51) and earth fault (51N) protection, for the transformer overload protection and secondary side short circuit protection.
- Directional overcurrent (67) and earth fault (67N) protection for detection of electrical faults during power export mode. These functions shall be subjected to further evaluation after the selectivity study is performed.
- Check synchronization (25).

### 6.3.1 Transformer Primary Instantaneous Overcurrent (50)

Each unit transformer and the associated primary cables are to be protected against short circuit currents by suitably rated HRC fuses.

### 6.3.2 Transformer Primary Instantaneous Earth Fault Protection (50N)

Transformer primary side earth fault protection shall be provided with an instantaneous earth fault current element to provide rapid disconnection in the event of a transformer primary earth fault. The earth fault relay element be set to approximately 5% to 10% of the system earth fault current and will be supplied using from a dedicated core balance CT.

### 6.3.3 Transformer Primary IDMT Overcurrent (51) and Earth Fault (51N) Protection

The transformers and the associated cables shall be protected against system overload currents using three IDMT overcurrent relay elements, one located in each phase. The relay elements shall be set close to the full load current of the transformer with a suitable grading margin with the 6.6 kV switchgear incomer. Refer to Chapter 5.1 for grading margin.

### 6.3.4 Transformer Primary Directional overcurrent (67) and earth fault (67N)

As the fuel cell only exports power it is recommended directional overcurrent (67) and earth fault (67N) protection be considered for transformer TA30, to provide early detection and disconnection in case of a fault on the circuit being fed from upstream.

The requirement for directional overcurrent (67) and earth fault (67N) protection for the Battery Energy Storage System (BESS) to be confirmed, during the EPC phase, taking into consideration the system rate of charge/discharge.

These functions shall be subjected to further evaluation after the selectivity study is performed.

### 6.3.5 Transformer Primary Check Synchronization (25)

Check synchronization (25) shall be included to verify the voltage, phase angle and frequency are within acceptable limits prior to closing the contactor. The check synchronization shall include the facility for dead bus closing.

### 6.3.6 Tripping Requirements (86)

The feeder protection trips to the Vendor Package shall be via hand or remote reset, lockout relay functions (86).

A lockout relay shall lockout the primary switching device.

All alarms should be able to be reset/acknowledged remotely.

Protection trips associated with a transformer primary shall operate the lockout relay for the primary switching device.

Logic based inter trips will be performed between the primary and secondary switching devices to isolate the fault.

The following trips shall operate the relevant lockout relays and inter trip upstream/ downstream:

- Primary side lockout relay (86):
  - Instantaneous overcurrent (50).
  - Instantaneous earth fault current (50N).
  - IDMT overcurrent (51).
  - Directional overcurrent (67) and earth fault (67N).
    - These functions shall be subjected to further evaluation after the selectivity study is performed.

For the package transformer internal faults, and feeder cable faults, the primary switching device shall trip and should send an inter trip signal to the package (via serial communication).

## 6.4 6.6 KV CIRCUIT BREAKER FEEDER TO A VENDOR PACKAGE

The vendor package shown in Table 8 below are supplied from the 6.6 kV switchgear SG-100D1-MV1 via 6.6 kV circuit breaker. Each feeder supplies a vendor package comprising of a transformer complete with a rectifier/ inverter unit.

This section considers the feeder protection to the transformers only as the vendor will advise the package electrical protection requirements.

| Tag number | Transformer description | Primary side switching device |
|---|---|---|
| T4 | o To electrolyser (A1)<br>o 3.2 MVA<br>o 6.6/0.36/0.36 kV<br>o Oil type | Circuit breaker |

*Table 8: Information on vendor package transformer - electrolyser*

Each of the primary side switching devices shall be equipped with a multifunction protection relay (IED) to perform the following protection functions.

Transformer Primary Winding:

- Instantaneous overcurrent (50) and earth fault (50N) protection, for the primary side power cables and transformer primary winding.
- IDMT overcurrent (51) and earth fault (51N) protection, for the transformer overload protection and secondary side short circuit protection.

### 6.4.1 Transformer Primary Instantaneous Overcurrent (50)

Transformer and the associated primary cables which are supplied via a circuit breaker shall be protected against both three phase and two-phase short circuits using instantaneous overcurrent relay elements connected to suitably rated CTs installed in each phase. The transformer instantaneous relay elements shall be set not to trip under the transformer magnetising current inrush conditions and be set approximately 1.5 times the calculated secondary fault current to ensure that the instantaneous element will operate for a transformer internal fault, but not for a downstream secondary fault.

### 6.4.2 Transformer Primary Instantaneous Earth Fault Protection (50N)

Transformer primary side earth fault protection shall be provided with an instantaneous earth fault current element to provide rapid disconnection in the event of a transformer primary earth fault. The earth fault relay element be set to approximately 5% to 10% of the system earth fault current and will be supplied using from a dedicated core balance CT.

### 6.4.3 Transformer Primary IDMT Overcurrent (51) and Earth Fault (51N) Protection

The transformers and the associated cables shall be protected against system overload currents using three IDMT overcurrent relay elements, one located in each phase. The relay elements shall be set close to the full load current of the transformer with a suitable grading margin with the 6.6 kV switchgear incomer. Refer to Chapter 5.1 for grading margin.

### 6.4.4 Tripping Requirements (86)

The feeder protection trips to the Vendor Package shall be via hand or remote reset, lockout relay functions (86).

A lockout relay shall lockout the primary switching device.

All alarms should be able to be reset/acknowledged remotely.

Protection trips associated with a transformer primary shall operate the lockout relay for the primary switching device.

Hardwired inter trips will be performed between the primary and secondary switching devices to isolate the fault.

The following trips shall operate the relevant lockout relays and inter trip upstream/ downstream:

- Primary side lockout relay (86):
  - Instantaneous overcurrent (50).
  - Instantaneous earth fault (50N).
  - IDMT overcurrent (51) and earth fault (51N).

For the internal package transformer faults, detected inside the package, vendor will provide an hardwired trip signal for the primary switching device trip. The open status of the primary switching device will be sent to the package as hardwired intertrip.

## 6.5 BUSBAR PROTECTION

Overcurrent (51) and Earth Fault (51N) protective devices shall be applied for the 6.6 kV switchgear SG-100D1 and 0.4 kV SG-200N1 incomers.

These protective devices will serve as incomer protection, as protection of switchgear busbars, and as back-up to switchgear outgoing circuit protection.

## 6.6 LOW VOLTAGE INDUCTION MOTOR

400 V motor circuits shall be controlled by suitably rated fused contactors, with no volt release, and be provided with the following protection functions, depending upon their ratings:

- Thermal overload protection (49)
- Single phasing, or phase unbalance, protection (46)
- Earth fault protection using CBCT (51N with time delay) for motors ≥ 30 kW

Short circuit protection shall be provided by circuit breaker.

Earth fault protection shall have a time delay setting facility to prevent any attempt to open the contactor beyond its breaking capacity. In addition, any relay short circuit function (50) shall be disabled.

## 6.7 LOW VOLTAGE FEEDER CIRCUIT

Typical low voltage feeder circuits will comprise of Moulded Case Circuit Breaker (MCCB) feeders. All MCCBs shall be provided with LSIG protection release.

- L = Long Time (overload protection).
- S = Short Time (short circuit protection of low-level faults).
- I = Instantaneous (short current protection of high-level faults).
- G = Ground Fault (equipment earth fault protection).

Settings shall be selected to protect downstream equipment and cabling whilst also grading with downstream devices. Where a MCCB feeds electrical equipment with an incoming MCCB, for example, a distribution board, discrimination between the upstream and downstream MCCB is not considered obligatory, however both MCCBs shall have full discrimination with any sub distribution protective device.

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# 7 ISLAND OPERATION

In case of island operation, once the BLPH platform is disconnected from the wind farm, the 6.6 kV will be disconnected from the transformer TR-100AD1 and the relevant NER so that the 6.6 kV neutral status will change from grounded with resistance to ungrounded.

Moreover, the power sources connected to the 6.6kV system are with inverters/IGBT, which means low contributions in case of short circuit; so the short circuit currents on the 6.6 kV system, while in island, will be very low, in the same range of the rated current.

Due to these considerations, it is not possible to detect faults on the 6.6 kV system with protective functions working on currents.

During island operation it is necessary to work on the 59N protective function, looking at the zero sequence voltage.

59 N settings and actions will be finalized within the protection coordination study.

# 8 INTERLOCKING

Extensive electrical and mechanical interlocks shall be provided throughout the electrical power system to ensure safety of personnel and equipment. The final selection of the type of interlock shall be determined during the EPC phase after equipment selection.

BLPH 66 kV switchgear, HNA6-AFA70, will be under Crosswind's authority and the interlocking (intertrips and inhibits) with the wind farm will be managed through HV SCADA (via serial interface).

The following is a summary of the interlocks that shall be provided:

- Both 66 kV and 6.6 kV switchgear circuit breakers shall be provided with integral earthing switches which will be interlocked with the:
  - Associated circuit breaker/ disconnector.
  - Downstream / upstream circuit breaker and associated earthing switches.

  It shall be ensured that earthing switches can only be closed if both circuit breakers / disconnectors are locked open. Conversely the circuit breakers / disconnectors cannot be re-closed unless the earthing switches are locked open.
- The 6.6 kV bus-bar earth switch interlock will be both electrical and hardwired.
- The 66 kV switchgear circuit breaker shall be electrically interlocked with the 6.6 kV switchgear downstream incoming circuit breaker to ensure that when both circuit breakers are open the upstream circuit breaker must be closed first before the downstream circuit breaker can be closed.
- The 6.6 kV switchgear transformer latched fused contactor feeder shall be electrically interlocked with the 400 V switchgear downstream incoming circuit breaker to ensure:
  - Both 6.6 kV and 400 V switching devices are locked open before the upstream earth switch can be applied. Conversely the switching devices cannot be re-closed unless the upstream earthing switch is locked open.
  - When both 6.6 kV and 400 V switching devices are open the upstream switching device must be closed first before the downstream switching devices can be closed.

The interlocking (intertrips and inhibits) required between the 6.6 kV switchgear and each package, for example, BESS, fuel cell and solar farm shall be managed via serial link, as described in the previous paragraphs.

Intertrips required between the 6.6 kV switchgear and electrolyser package will be hardwired, as described in the previous paragraphs.

# 9 ATTACHMENTS

Attachment 1 PROTECTION SUMMARY TABLE

| Circuit type | Protective functions | | | | | | | | | | | | | | | | | | | | | | | Refer to 123A90-DDL-EL-DG-20014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25 | 26 OT | 26 WT | 27 | 46 | 49 | 50 | 50 N | 50 TD | 51 | 51 G | 51 N | 59 N | 63 | 64 (87 NT) | 66 | 67 | 67 N | 71 | 74 | 86 | 87 | 94 x | 97 | |
| 66 kV CB incomer feeder to TR-100AD1 | X | | | X | | | X | X | | X | X | | | | X | | X | X | | X | X | X | X [d] | | Sheet 2 |
| TR-100AD1* | | X [b] | X [b] | | | | | | | | | | | X [b] | | | | | X [b] | | | | | X [b] | |
| 6.6 kV CB outgoing feeder from TR-100AD1 | X | | | | | | X | X | | X | | X | | | | | | | | X | X | | | | |
| 6.6 kV latched fused contactor incomer feeder to TR-200DE1 | | | | | | | X | X | | X | X | X | X | | | | | | | X | X | | X [d] | | Sheet 6 |
| TR-200DE1* | | X [b] | X [b] | | | | | | | | | | | X [b] | | | | | X [c] | | | | | X [b] | |
| 0.4 kV CB incomer feeder from TR-200DE1 | | | | | | | X | X | | X | | X | | | | | | | | | | | | | |
| 6.6 kV latched fused contactor feeder to TR-200ED1 | X | | | | | | X | X | | X | | X | X | | | | X | X | | X | X | | X [d] | | Sheet 7 |
| TR-200ED1** | | X [b] | X [b] | | | | | | | | | | | X [b] | | | | | X [b] | | | | | X [b] | |
| SG-200D2 (0.8 kV CB incomer feeder from solar package) | | | | | | | X [e] | X [e] | | X [e] | | X [e] | | | | | | | | | | | | | |

| | Circuit type | Protective functions | | | | | | | | | | | | | | | | | | | | | | Refer to 123A90-DDL-EL-DG-20014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 25 | 26 OT | 26 WT | 27 | 46 | 49 | 50 | 50 N | 50 TD | 51 | 51 G | 51 N | 59 N | 63 | 64 (87 NT) | 66 | 67 | 67 N | 71 | 74 | 86 | 87 | 94 x | 97 | |
| 6.6 kV | latched fused contactor feeder to BESS | X | | | | | | X | X | | X | | X | X | | | | X | X | | X | X | | X [d] | | Sheet 3 |
| 6.6 kV | latched fused contactor feeder to fuel cell | X | | | | | | X | X | | X | | X | | | | | X | X | | X | X | | X [d] | | Sheet 5 |
| 6.6 kV | CB feeder to electrolyser | | | | | | | X | X | | X | | X | | | | | | | | X | X | | X [d] | | Sheet 4 |
| 0.4 kV | motor feeder*** | | | | | X | X | X | | | | | X | | | | | | | | | | | | | N/A |
| 0.4 kV | MCCB feeder | | | | | | | X | | X | X | | X | | | | | | | | | | | | | N/A |

[a] deleted [b] transformer protection alarm signals sent to multifunction relay and trp signals sent to 94x auxiliary trip relay.

[c] Transformer protection alarm signals sent to multifunction relay [d] Based on the transformer protection trip signals via 94x auxiliary trip relay .

[e] deleted