| Eskom | Standard | Technology |
|---|---|---|

Title: **STANDARD PHILOSOPHY FOR THE BREAKER-AND-A-HALF DIAMETER INTERFACE**

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## Content

**Tables**

# 1. Introduction

This document describes Eskom's Extra High-Voltage (EHV) breaker-and-a-half transmission line protection and control philosophy.

# 2. Supporting clauses

## 2.1 Scope

### 2.1.1 Purpose

The purpose of this standard is to describe Eskom's philosophy for breaker-and-a-half line protection schemes.

### 2.1.2 Applicability

This standard shall apply to PTM&C within Eskom Group Technology.

## 2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

### 2.2.1 Normative

[1] Cigré Working Group B5.27: Implications and Benefits of Standardised Protection and Control Schemes

[2] Cigre SC34: "Eskom's certification testing requirements for EHV numerical transmission line protection relays" 1999

[3] IEC 50: International Electrotechnical Vocabulary; Chapter 448 Power system protection

[4] Cigre SC34-WG04: Application Guide on protection of complex transmission network configurations

[5] Network Code: The South African Grid Code (Revision 8.0)

[6] TST41-689: Standard for the Protection and Control of Extra High Voltage Transmission Lines on the Eskom Power System

### 2.2.2 Informative

[7] 32-9: Definition of Eskom documents

[8] 32-644: Eskom documentation management standard

[9] 474-65: Operating manual of the Steering Committee of Technologies (SCOT)

## 2.3 Definitions

### 2.3.1 General

| Definition | Description |
|---|---|
| **Auxiliary functions** | Non-measuring functions which augment the required tripping system capability. |
| **Back-up protection** | Protection functions which are called on to operate to ensure fault clearance as a result of failure of the primary protection or of circuit-breaker failure. |

| Definition | Description |
|---|---|
| **Dependability** | The probability of not having a failure to operate under given conditions for a given time interval [IEC 50 - 448]. |
| **Duplication** | Doubling-up of equipment to provide redundancy (local back-up). The equipment could be identical or diverse. Each would serve the same purpose and have the same level of importance. |
| **Fault clearance system** | The Fault Clearance System comprises the two Tripping Systems, plus the circuit-breaker. |
| **Non-intrusive** | Without intruding on, changing the properties of, or compromising the integrity of a piece of equipment, especially when testing such equipment. |
| **Primary protection** | The main element of the Tripping System which consists of primary protection functions and supplementary protection functions. |
| **Primary protection function** | The most important protection function within the primary protection. It operates in the fastest time possible, removes the least amount of equipment from service, and is expected to have priority over supplementary protection in initiating fault clearance. |
| **Protection and control scheme** | A composite arrangement of protection functions as well as control and information systems put together to isolate system disturbances and to minimise damage to items of plant. The Protection and Control Scheme is that portion of the Fault Clearance System, Bay Closing System, and Bay Management System housed within the suite of cubicles within the control room building or kiosk. Replace with CIGRE B5.27 Definition. |
| **Protection function** | The basic conceptual component of a Protection System |
| **Protection system** | The Protection System is that part of the Tripping System which provides the requisite primary, back-up, system and auxiliary protection functions. |
| **Security** | The probability of not having an unwanted operation under given conditions for a given time interval [IEC50-448]. |
| **Selectivity** | The ability to detect a fault within a specified zone of a network and to trip the appropriate circuit-breaker(s) to clear this fault with a minimum disturbance to the rest of that network. |
| **Single failure criterion** | A design criterion whereby a system must not fail to operate even if one component fails to operate. With respect to the primary protection relay, Eskom's interpretation of the single failure criterion caters primarily for a failed or defective relay, and not a failure to operate as a result of a performance deficiency inherent within the design of the relay. |
| **Supplementary protection function** | A protection function which augments the primary protection function by enhancing dependability and/or security. |
| **System protection** | Protection which is required to respond to a system condition as opposed to a system fault e.g. overvoltage, underfrequency or power swing conditions. |
| **Teleprotection dependability** | The ability of the teleprotection system to issue a valid command in the presence of interference and/or noise (IEC 834-1) |
| **Teleprotection security** | The ability of the teleprotection system to prevent interference and noise from generating a command state at the receiving end when no command signal is transmitted (IEC 834-1). |

| Definition | Description |
|---|---|
| **Tripping system** | A Tripping System comprises the Protection System, an independent d.c. source, a dedicated CT core, a separately fused input from a shared VT core (where applicable), dedicated teleprotection equipment, and dedicated trip-coil of the line circuit-breaker (or transfer circuit-breaker). |

### 2.3.2 Disclosure classification

**Controlled disclosure:** controlled disclosure to external parties (either enforced by law, or discretionary).

## 2.4 Abbreviations

| Abbreviation | Description |
|---|---|
| **Ω** | Ohm |
| **μs** | Micro second |
| **°C** | Degrees celsius |
| **52a** | Breaker normally open auxiliary contact |
| **52b** | Breaker normally closed auxiliary contact |
| **A** | Ampere(s) |
| **AC** | Alternating Current |
| **B#SIS** | Bay 1/2 supervisory isolating switch |
| **BB** | Bay breaker |
| **B-N** | Blue to neutral |
| **B-R** | Blue to red |
| **CAD** | Computer aided design |
| **CALH** | Alarm handling |
| **CL** | Closing |
| **CSWI** | Switch Controller |
| **CT** | Current transformer |
| **CTTB** | Current transformer test block |
| **CVT** | Capacitive voltage transformer |
| **d** | Depth |
| **DC** | Direct current |
| **DCD** | Diameter Control Device |
| **DCI** | Direct current isolation |
| **DIP** | Diameter interface panel |
| **EHV** | Extra high voltage |
| **ETHSW** | Ethernet switch |
| **F** | Frequency |

| Abbreviation | Description |
|---|---|
| **FACTS** | Flexible AC Transmission System |
| **GGIO** | Generic process Inputs/Outputs |
| **GOOSE** | Generic Object Oriented Substation Event |
| **h** | Height |
| **HMI** | Human machine interface |
| **Hz** | Frequency |
| **IDMT** | Inverse definite minimum time |
| **IEC** | International Electrotechnical Committee |
| **IED** | Intelligent electronic device |
| **IEEE** | Institute of Electrical and Electronic Engineers |
| **IHMI** | Human machine interface |
| **IND** | Indication |
| **JB** | Junction box |
| **JBNH** | Junction box not healthy |
| **KHTR** | Cubicle heater |
| **Km** | Kilometre |
| **kV** | Kilo volt |
| **M** | Isolator normally open auxiliary contact |
| **MΩ** | Mega Ohm |
| **MCB** | Miniature Circuit-Breaker |
| **mm** | Millimetre |
| **MMS** | Manufacturing Message Specification |
| **MMXU** | Measurement |
| **MPS** | Model Power System Simulator Testing |
| **ms** | Millisecond |
| **N** | Isolator normally closed auxiliary contact |
| **nm** | Nano metre |
| **P** | Active power |
| **PDIF** | Differential protection |
| **PDIR** | Distance zone directional element |
| **PDIS** | Distance protection |
| **PF** | Power factor |
| **PIOC** | Instantaneous overcurrent |
| **PIU** | Process interface unit |
| **POR** | Permissive overreach |

| Abbreviation | Description |
|---|---|
| **PSCH** | Scheme communication |
| **PSNH** | Protection system not healthy |
| **PTOC** | Time overcurrent |
| **PTOV** | Overvoltage protection |
| **PTRC** | Trip conditioning |
| **PTUC** | Undercurrent |
| **PTUV** | Undervoltage |
| **PUR** | Permissive underreach |
| **PVC** | Polyvinyl chloride |
| **Q** | Reactive power |
| **QA** | Quality assurance |
| **R** | Resistance |
| **r.m.s.** | Rout mean square |
| **RADR** | Disturbance recorder channel analogue |
| **RBDR** | Disturbance recorder channel binary |
| **RBRF** | Breaker failure protection |
| **RDIR** | Distance zone directional element |
| **RDIS** | Distance zone |
| **RDRE** | Disturbance recorder function |
| **RFLO** | Fault locator name |
| **R-N** | Red to neutral |
| **RPSB** | Power swing blocking |
| **R-W** | Red to white |
| **SANS** | South African National Standard |
| **SCADA** | Supervisory Control And Data Acquisition |
| **SCD** | Substation Configuration Description |
| **SED** | System Exchange Description |
| **SIS** | Supervisory Isolate Switch |
| **SOTF** | Switch-onto-fault |
| **SS** | Secure supply |
| **TB** | Tie bay |
| **TBSIS** | Tie bay supervisory isolating switch |
| **TNS** | Test Normal Selection |
| **TPIS** | Teleprotection isolating switch |
| **TST** | Transmission standard |

| Abbreviation | Description |
|---|---|
| **V** | Voltage |
| **VAC** | AC voltage |
| **VDC** | DC voltage |
| **VT** | Voltage transformer |
| **VTTB** | Voltage transformer test block |
| **w** | Width |
| **W-B** | White to blue |
| **W-N** | White to neutral |
| **XCBR** | Circuit breaker |
| **XSWI** | Circuit switch |

## 2.5 Roles and responsibilities

Protection technology and support shall utilise this document as basis for the breaker-and-a-half line protection specification.

## 2.6 Process for monitoring

The protection technology & support manager and the custodian will monitor the compliance to this standard.

## 2.7 Related/supporting documents

Not applicable.

# 3. Requirements

## 3.1 Introduction

This standard describes the diameter control requirements for breaker-and-a-half diameter interface scheme solutions. The diameter interface scheme shall interface with the two object protection schemes (line and/or transformer) to provide for the required protection and control of the diameter and the lines. The diameter interface scheme shall be capable of single pole auto-reclosing (bay breaker) and three pole auto-reclosing (bay breaker and tie bay breaker), manual closing and single pole trip testing. The scheme permutations shall cater for application to stations with a single station HMI and stations with a dual station HMI.

The diameter control device shall be capable of accepting both single-pole and three-pole initiations from both object protection devices depending upon the auto-reclose mode selection. Additional single pole initiations shall be derived from the trip testing functions and additional three pole initiations shall be derived from an external source. Single pole reclose initiation from the single pole trip testing function (bay 1 breaker, tie bay breaker and bay 2 breaker) shall only be possible when the diameter control device is ready and selected for a single pole reclose cycle and that the adjacent breaker is three pole closed.

The auto-reclose mode selections (single pole, three pole single and three pole) and the cycle selection (three or five cycle) shall select the required reclose sequence. The diameter control device shall, depending on the chosen program, control the tripping mode of both the object line protection devices. The object 1 and 2 line protection devices shall be forced to trip three pole, irrespective of the type of fault, when their ‘3 Pole Trip Select’ inputs are activated by the diameter control device. The activation of these signals shall be dependent on the reclose program selected.

Additional diameter interface device functions (inputs/GOOSE) shall include block reclosing, inhibit reclosing and block manual closing. The block reclosing input shall be initiated by:

- Object 1 line protection device;
- Object 2 line protection device;
- SF6 gas low (block manual closing); or,
- Start of the second object tie bay breaker auto-reclose cycle following an in progress auto-reclose cycle.

All manual close commands shall be executed via the diameter control device. The diameter control device shall therefore perform all manual and auto-reclosing. The relevant breaker close coils shall be controlled by the diameter control device.

All the diameter control, auto-reclose and synchronism check functions shall be fully integrated within a single hardware device.

### 3.1.1 General statement

The diameter interface functionality is required to automatically or manually restores the diameter equipment following transmission related network faults, and following maintenance activities thereby ensuring optimal quality of supply to customers and to sustain the stability and integrity of the power system.

Quality of supply to customers:

- The duration of the disconnection must be kept to a minimum, implying the necessity for automatic reclosure (single and three-pole) with synchronism check.

Stability and integrity of the power system:

- The ability of the transmission system is to transport power in a stable manner such that the integrity of the power system is not compromised.

The requirement is to have more cost effective Diameter Control Systems to reduce the overall cost of the Diameter Control Scheme. In any modern business environment, cost is a focal issue. In Eskom, business imperatives have, over time, been biased either towards engineering / superior performance issues, or towards financial issues. It has now become necessary to seek an optimal balance between the two, with equipment cost being a priority issue. It is now necessary to engineer schemes smarter by better understanding and designing for the associated risks, and by eliminating unnecessary cost premiums by applying suitable functionality and performance capability to meet the specific requirements.

### 3.1.2 Scope of application

The breaker-and-a-half substation layouts used on the Eskom transmission system vary in different diameter combinations and with/without a busbar reactor transfer busbar. The range of protection and control schemes employed must be capable of protecting the various diameters and objects combinations which include the following combinations:

- Line – line;
- Line – transformer;
- Line only (object 1);
- Line only (object 2);
- Transformer only (object 1);
- Transformer only (object 2); and,
- Busbar reactor.

The breaker-and-a-half layout has three main components to protect and control the primary plant within the diameter and the objects connected to the diameter:

- Diameter interface;
- Line protection; and,
- Transformer protection

The diameter interface solution shall interface with the object protection solutions to provide for the required control, auto-reclosing and synchronism check. The diameter interface scheme shall permit for single pole tripping (bay breaker) and three pole tripping (bay breaker and tie bay breaker), auto-reclosing (single and three-pole for the bay breaker and three-pole for the tie bay breaker), manual closing and single pole trip testing. The scheme permutations shall cater for application to stations with a single station HMI and stations with a dual station HMI.

## 3.2 Composition

### 3.2.1 Philosophy

For all breaker-and-a-half EHV transmission line protection applications, the diameter interface solution shall comprise of a closing control and management system.

The diameter interface solution shall comprise two independent and galvanically isolated closing control and management systems, plus the bay 1 circuit-breaker, tie bay circuit-breaker and bay 2 circuit-breaker. Each diameter interface solution shall comprise a closing control and management system, supplied from an independent DC source, receive its analogue inputs from separate CT cores and separately protected VT cores (busbar 1, connector 1, line 1, connector 2, line 2 and busbar 2, 3 phase VTs) and be directly connected (via the process interface unit) to one trip-coil of the bay 1 circuit-breaker, to one trip-coil of the tie bay circuit breaker, one trip-coil of the bay 2 circuit-breaker, closing-coil of the bay 1 circuit-breaker, closing-coil of the tie bay circuit-breaker, closing-coil of the bay 2 circuit-breaker and open and close coils of all the isolators associated with that diameter. The two bay closing and bay management systems shall operate in a one-out-of-two mode. The auto-reclosing functions within the two systems shall operate in a master / slave mode.

The diameter control system shall be capable of performing both single- and three-pole automatic reclosing. The allowed closing modes/conditions shall be determined by the required auto-reclose mode selections. The permitted closing conditions for manual closing and automatic reclosing shall be separately settable, allowing different closing conditions to apply.

### 3.2.2 Rationale

Two independent and galvanically isolated diameter interface systems operating in a one-out-of-two mode are required to satisfy the single failure criterion. Furthermore, the provision of two diameter interface systems allows routine maintenance and refurbishment to be carried out on one diameter interface system without taking the object or diameter out of service. When necessary, the relevant diameter interface system can be isolated, keeping the objects and diameter in service with the other diameter interface system still operational.

Fully integrating all closing control and management functions for each diameter interface system into one hardware device is required as this does not compromise the expected reliability of the overall scheme design due to the dual closing control and management system philosophy. The closing control and management systems are biased towards dependability (dual one-out-of-two mode of operation).

The closing control and management system interface with the primary plant equipment through the IEC61850 process interface units is to minimise copper interfacing between the relay room and the primary plant equipment, and between different closing control and management system within the relay room.

### 3.2.3 Design requirements

The breaker-and-a-half diameter interface scheme shall comprise all the required diameter control functions, manual closing, auto-reclose and synch check functions, ethernet switch, MCBs, test blocks, switches, pushbuttons and indications. The IED(s), MCBs, switches, indications, test blocks, indications and pushbuttons shall be located at the front of the panel. The management system shall provide for the required primary plant equipment controls (local and remote), primary plant equipment status indications (local and remote) and data logging and display (local and remote). All the equipment shall have the capability to be mounted in a flush mount 19” rack system. The breaker-and-a-half diameter interface control system shall not adversely affect the availability and performance of any other in-service diameter interface control system.

Within a single closing control and management system, all the required functions shall reside within a single hardware device. This hardware device shall comprise the single node through which all controls and auto-reclosing shall occur for all internally generated commands, as well as through which all externally generated commands shall be routed. The closing control and management systems will be housed within a cubicle within the control room building. The closing control and management system shall interface with the diameter primary equipment through IEC61850 process interface units located in close proximity to the primary plant equipment. The closing control and management system shall interface with object 1 and object 2 protection systems through IEC61850 for the purpose of auto-reclosing and control of the primary plant equipment.

The breaker-and-a-half diameter interface scheme shall have one IED with all the required closing control and management functions integrated within a single IED. A separate IED for the closing control and management of the transformer MV side (double busbar interface) primary plant equipment is permissible.

The breaker-and-a-half diameter interface scheme shall be designed that the two object panels can be mounted on either the left hand or right hand or both sides of the diameter interface panel. The breaker-and-a-half diameter interface scheme shall be an independent design with an own set of scheme diagrams.

The breaker-and-a-half diameter interface system shall include:

- Main # Diameter Interface Panel Not Healthy Indication (230 VAC);
- Main # Bay 1 JB Not Healthy Indication (230 VAC);
- Main # Bay 2 JB Not Healthy Indication (230 VAC);
- Main # Tie Bay JB Not Healthy Indication (230 VAC);
- Main # MV Bay JB Not Healthy Indication (230 VAC);
- Main # Diameter Control Device with all the required control functions integrated within a single hardware device;
- Ethernet Switch;
- Main # Bay 1 Breaker Current Transformer Test Block;
- Main # Bay 1 Breaker Current Transformer Test Block;
- Main # Tie Bay Breaker Current Transformer Test Block;
- Main # MV Bay Breaker Current Transformer Test Block;
- Main # Line 1 Voltage Transformer Test Block;
- Main # Line 2 Voltage Transformer Test Block;
- Main # Busbar 1 Voltage Transformer Test Block;
- Main # Busbar 2 Voltage Transformer Test Block;
- Main # Connector 1 Voltage Transformer Test Block;
- Main # Connector 2 Voltage Transformer Test Block;

- Main # MV Side Busbar 1 Voltage Transformer Test Block;
- Main # MV Side Busbar 2 Voltage Transformer Test Block;
- Main # MV Side Transformer Voltage Transformer Test Block;
- Lamp Test push button;
- Main # 230 VAC Isolating MCB;
- Main # DCD DC Isolating MCB;
- Main # Ethernet Switch DC Isolating MCB;
- Main # DC Isolating MCB;
- Main # Bay 1 Closing DC Isolating MCB;
- Main # Bay 1 Indication DC Isolating MCB;
- Main # Bay 2 Closing DC Isolating MCB;
- Main # Bay 2 Indication DC Isolating MCB;
- Main # Tie Bay Closing DC Isolating MCB;
- Main # Tie Bay Indication DC Isolating MCB;
- Main # MV Bay Closing DC Isolating MCB;
- Main # MV Bay Indication DC Isolating MCB;
- Main # Bay 1 Supervisory Isolating Switch;
- Main # Bay 2 Supervisory Isolating Switch;
- Main # Tie Bay Supervisory Isolating Switch;
- Main # MV Bay Supervisory Isolating Switch; and,
- Diode Units.

The breaker-and-a-half diameter interface scheme shall provide for the following DC voltage options to meet the station requirements:

- 110 VDC; and,
- 220 VDC

The scheme solutions shall have the capability interface and integrate with legacy diameter interface solutions.

The process interface units, in close proximity to the primary plant equipment, shall include all the required IEC61850 logical nodes required to represent each item of primary plant equipment. Each of the breaker bays shall have two process interface units to interface with the two independent diameter interface systems and protection systems.

A secure supply, derived from the main 1 and main 2 DC systems, shall be available to power the singular primary plant interface items that are connected to the main 1 and main 2 process interface units.

## 3.3 Diameter control device

### 3.3.1 Philosophy

The breaker-and-a-half diameter interface scheme shall have all the required diameter control functions integrated within a single IED. Process interface units (PIU) are required to be located in close proximity to the primary plant equipment and to provide the interface (binary inputs and outputs via IEC61850) between the primary plant equipment and the diameter control IEDs.

The LPHD (Logical Physical Device Information) Logical Node models the common issues for physical devices (diameter control IED). This Logical Node and associated Data Attributes such as physical description, physical health, communications, and power supply, shall be available to the Eskom System Configurator for modelling issues.

All intelligent electronic devices shall have built-in self-monitoring features. The built-in self-monitoring features shall not in any way compromise the operational status of any one of the functions (logical nodes).

### 3.3.2 Rationale

For the diameter interface system, maximum integration of functions within a single hardware device is required to reduce complexity, DC supply burden and to achieve the maximum cost benefit.

The PIUs located within the relevant breaker bay JB, shall broadcast and receive IEC61850 messages from the diameter control devices and the protection devices. The utilisation of IEC61850 minimise the copper interface between the control room equipment and the primary plant.

Self-monitoring functions in IEDs are provided to avoid and control internal failures that can occur in these devices. Self-monitoring improves the availability of the diameter interface scheme and also enables the reduction of the frequency and duration of relay maintenance visits. This in turn enables a reduction in the overall life-cycle cost of the diameter interface system.

### 3.3.3 Design requirements

The LPHD (Logical Physical Device Information) detailed requirements are within document 240-42066934 section 6.2.

The circuit breaker PIUs (breaker, isolator and earth switches) are required as interface (IEC61850) between the primary plant equipment within the diameter and the diameter control IED.

The breaker-and-a-half diameter control IED shall include the following functions:

| | **Function** | **Logical Node** |
|---|---|---|
| 1) | Object 1 thermal overload detection | PTTR 1 |
| 2) | Object 2 thermal overload detection | PTTR 2 |
| 3) | Bay 1 breaker trip testing | PTRC 1 |
| 4) | Bay 2 breaker trip testing | PTRC 2 |
| 5) | Tie Bay breaker trip testing | PTRC 3 |
| 6) | Bay 1 breaker three pole trip selected | |
| 7) | Bay 2 breaker three pole trip selected | |
| 8) | Bay 1 breaker trip counting | |
| 9) | Bay 2 breaker trip counting | |
| 10) | Tie Bay breaker trip counting | |
| 11) | MV Bay breaker trip counting | |
| 12) | Disturbance recorder function | RDRE |
| 13) | Disturbance recorder channel analogue (per analogue quantity) | RADR |
| 14) | Disturbance recorder channel binary (per binary signal) | RBDR |
| 15) | Auto-reclose master and slave modes | CSWI |
| 16) | Auto reclose mode selections | CSWI |
| 17) | Auto reclosing, bay 1 breaker, line 1 | RREC 1 |

| | **Function** | **Logical Node** |
|---|---|---|
| 18) | Auto reclosing, tie bay breaker, line 1 | RREC 3 |
| 19) | Auto reclosing, bay 2 breaker, line 2 | RREC 2 |
| 20) | Auto reclosing, tie bay breaker, line 2 | RREC 4 |
| 21) | Synchronism-check bay 1 breaker | RSYN 1 |
| 22) | Synchronism-check bay 2 breaker | RSYN 2 |
| 23) | Synchronism-check tie bay breaker | RSYN 3 |
| 24) | Synchronism-check breaker MV side of transformer | RSYN 4 |
| 25) | Synchronising VT supply monitoring | |
| 26) | Bay 1 breaker spring charging fail time | |
| 27) | Bay 2 breaker spring charging fail time | |
| 28) | Tie Bay breaker spring charging fail time | |
| 29) | MV Bay breaker spring charging fail time | |
| 30) | Measurements | MMXU |
| 31) | IEC61850 communications failure | |
| 32) | Tie bay breaker red phase trip circuit supervision | |
| 33) | Tie bay breaker white phase trip circuit supervision | |
| 34) | Tie bay breaker blue phase trip circuit supervision | |
| 35) | Bay 1 breaker SF6 gas supervision | SIMG 1 |
| 36) | Bay 2 breaker SF6 gas supervision | SIMG 2 |
| 37) | Tie Bay breaker SF6 gas supervision | SIMG 3 |
| 38) | MV Bay breaker SF6 gas supervision | SIMG 4 |
| 39) | Bay 1 breaker busbar 1 side CT SF6 gas supervision | SIMG 5 |
| 40) | Bay 1 breaker connector 1 side CT SF6 gas supervision | SIMG 6 |
| 41) | Bay 2 breaker busbar 2 side CT SF6 gas supervision | SIMG 7 |
| 42) | Bay 2 breaker connector 2 side CT SF6 gas supervision | SIMG 8 |
| 43) | MV Bay breaker CT SF6 gas supervision | SIMG 9 |
| 44) | Indications | IHMI |
| 45) | Bay 1 breaker status | CSWI 1 |
| 46) | Bay 2 breaker status | CSWI 2 |
| 47) | Tie bay breaker status | CSWI 3 |
| 48) | MV bay breaker status | CSWI 4 |
| 49) | Object 1 isolator status | CSWI 5 |
| 50) | Object 1 isolator discrepancy | CSWI 6 |
| 51) | Object 2 isolator status | CSWI 7 |
| 52) | Object 2 isolator discrepancy | CSWI 8 |

| | **Function** | **Logical Node** |
|---|---|---|
| 53) | Line 1 reactor transfer isolator status | CSWI 9 |
| 54) | Line 1 reactor transfer isolator discrepancy | CSWI 10 |
| 55) | Line 2 reactor transfer isolator status | CSWI 11 |
| 56) | Line 2 reactor transfer isolator discrepancy | CSWI 12 |
| 57) | Bay 1 Busbar 1 isolator status | CSWI 13 |
| 58) | Bay 1 Busbar 1 isolator discrepancy | CSWI 14 |
| 59) | Bay 1 isolator busbar 2 side status | CSWI 15 |
| 60) | Bay 1 isolator busbar 2 side isolator discrepancy | CSWI 16 |
| 61) | Bay 2 busbar 2 isolator status | CSWI 17 |
| 62) | Bay 2 busbar 2 isolator discrepancy | CSWI 18 |
| 63) | Bay 2 isolator busbar 1 side status | CSWI 19 |
| 64) | Bay 2 isolator busbar 1 side discrepancy | CSWI 20 |
| 65) | Tie Bay isolator busbar 1 side status | CSWI 21 |
| 66) | Tie Bay isolator busbar 1 side discrepancy | CSWI 22 |
| 67) | Tie Bay isolator busbar 2 side status | CSWI 23 |
| 68) | Tie Bay isolator busbar 2 side discrepancy | CSWI 24 |
| 69) | MV Bay busbar 1 isolator status | CSWI 25 |
| 70) | MV Bay busbar 2 isolator discrepancy | CSWI 26 |
| 71) | MV Bay busbar 2 isolator status | CSWI 27 |
| 72) | MV Bay busbar 2 isolator discrepancy | CSWI 28 |
| 73) | DC supply monitoring | |
| 74) | AC supply monitoring | |
| 75) | Alarm handling | CALH |
| 76) | Interlocking | CILO |
| 77) | Switch Controllers | CSWI |
| 78) | Generic process I/O | GGIO |
| 79) | Generic Security Application | GSAL |
| 80) | Heaters | KHTR |
| 81) | GOOSE receive functional blocks | |
| 82) | GOOSE broadcast functional blocks | |
| 83) | GOOSE broadcast functional blocks | |
| 84) | Human machine interface | IHMI |
| 85) | Binary inputs (quantity as per the required scheme design) | |
| 86) | Binary outputs (quantity as per the required scheme design) | |
| 87) | Analogue inputs (quantity as per the required scheme design) | |

## 3.4 Security

### 3.4.1 Philosophy

Security is defined as the probability of not having an unwanted operation under given conditions for a given time interval. The diameter interface system should have as high a security as possible.

### 3.4.2 Rationale

Security of the diameter interface system is very important because incorrect reported data, incorrect controls, incorrect auto-reclosing and incorrect synchronism check could lead to primary plant equipment and rotating plant damage. Poor security would manifest itself in damage of equipment and safety of personnel. Because of the principle of applying duplicate diameter interface systems in a 1 out of 2 tripping arrangement security is adversely affected as poor security of any of the two systems will result in poor security of the whole scheme.

Diameter interface system security can be influenced by software, incorrect settings and failure of hardware e.g. VT secondary supply failure, etc.

### 3.4.3 Design requirements

None

## 3.5 Dependability

### 3.5.1 Philosophy

Dependability is defined as the probability of not having a failure to operate under given conditions for a given time interval. The diameter interface system should have as high dependability as possible.

### 3.5.2 Rationale

Dependability of the diameter interface system is very important because failure to auto-reclose or manual close following system faults could threaten system stability and integrity. Because of the undesirable consequences of failure of the diameter interface system to control and report it is Eskom's philosophy to duplicate the control and auto-reclosing systems in a 1 out of 2 arrangement.

Diameter interface system dependability can be influenced by software (configuration), incorrect settings, IED availability, d.c. supply health and failure of hardware e.g. VT secondary supply failure, etc.

### 3.5.3 Design requirements

None

## 3.6 Accuracy

### 3.6.1 Philosophy

IED accuracy is a measure of an IED's ability to conform to its applied settings within a specified level of tolerance (excluding any errors introduced by current and voltage transformers). IED functions applied on EHV transmission line breaker-and-a-half protection schemes shall conform to the specified accuracy levels under all system operating scenarios.

### 3.6.2 Rationale

In EHV breaker-and-a-half diameter interface applications IED accuracy is important to ensure no incorrect operations occur due to measurement and/or timing errors. Accuracy is therefore closely coupled to the security and dependability of all the diameter interface functions within the closing control and management systems that make up the IED.

### 3.6.3 Design Requirements

Overall protection accuracy needs to take into account the accuracy of the current and voltage transformers used.

## 3.7 Duplication

### 3.7.1 Philosophy

For all EHV breaker-and-a-half applications, the closing control and management system shall be duplicated and independent. The failure of any one of the two systems shall not adversely affect the healthy system.

### 3.7.2 Rationale

In order to satisfy the single failure criterion, dual closing control and management systems are employed. Eskom's interpretation of the single failure criterion is that it shall cater for a failed component within one closing control and management system, and not a performance deficiency.

### 3.7.3 Design requirements

None

## 3.8 Analogue processing

### 3.8.1 Philosophy

The breaker-and-a-half diameter interface IED shall have the ability to independently interface with the bay 1 CTs (3 phases and neutral), tie bay CTs (3 phases and neutral) and bay 2 CTs (3 phases and neutral). The bay 1 CT and tie bay CT quantities shall be independently and summated available, the bay 2 CT and tie bay CT quantities shall be independently and summated available within the diameter interface IED, for the required functions. The independent and summated CT quantities are also required to be connected to the internal disturbance recorder.

The breaker-and-a-half diameter interface IED shall interface with the busbar 1 CVT (3 phases), connector 1 CVT (3 phases), connector 2 CVT (3 phases) and busbar 2 CVT (3 phases).

The MV side, double busbar interface, closing control and management IED (if independent) shall interface with the MV busbar 1 CVT (3 phases), MV busbar 2 CVT (3 phases) and transformer MV side CVT (3 phases).

All the analogue quantities shall be synchronised within the IED as not to influence the measured accuracy and dependability of the protection functions.

### 3.8.2 Rationale

The independent and summated current quantities are required for the bay 1, tie bay and bay 2 measurements quantities, open pole detection and thermal overload function.

Internal summation of the CTs is required to prevent magnetisation of a disconnected CT in the event of external summation.

The connections of the CVTs are required for measurements reporting and for synchronism check across all the breakers within the diameter and the MV side breaker (double busbar interface).

### 3.8.3 Design Requirements

The standard current transformer secondary inputs are 1 amp, with a continuous rating of 2 amp. The standard practice is to earth the neutral ($4^{th}$ wire) where the CT cable is connected to the terminals within the relay panel. $4mm^2$ wiring shall be used for all CT secondary connections within the panel. Each CT input shall have a dedicated current transformer test block with shorting strips to short the CT inputs.

The standard voltage transformer secondary inputs are 63.5 volt per phase (110 volt, phase-phase). The standard practice is to earth the neutral (4th wire) within the VT JB. 4mm2 wiring shall be used for all VT secondary connections within the panel.

The MCB protection of the VT circuits shall be located within each VT JB. The VT JBs will have three phase MCBs for connection to the diameter interface IED. The three phase MCBs, for all the required VT inputs, shall be fitted with normally closed auxiliary contacts connected to the PIU for blocking and alarming purposes.

The breaker-and-a-half diameter interface scheme will use one CT core from the bay 1 CT, one CT core from the bay 2 CT, one CT core from the tie bay CT and one CT core from the MV bay CT for measurements purposes, the following metering class cores shall be connected to the diameter control device:

- Bay 1 CT metering core;
- Bay 2 CT metering core;
- Tie bay metering CT core; and,
- MV bay metering CT core.

The bay 1 CT, bay 2 CT, tie bay CT and MV bay CT connections shall be routed through current transformer test blocks, CTTB(B1), CTTB(B2), CTTB(TB) and CTTB(MV), and independently connected to the diameter control IED. The standard practice is to earth the neutral (4th wire) within the diameter interface panel (incoming terminals).

The diameter control device shall report the measurement quantities to:

- Diameter control device HMI;
- Station HMI; and,
- Gateway for remote reporting.

The breaker-and-a-half diameter interface scheme will use one VT core from the busbar 1 VT, one VT core from the busbar 2 VT, one VT core from the connector 1 VT, one VT core from the connector 2 VT, one VT core from the line 1 VT, one VT core from the line 2 VT and one VT core from the MV bay VT for measurements purposes, the following metering class cores shall be connected to the diameter control device:

- Busbar 1 VT metering core;
- Busbar 2 VT metering core;
- Connector 1 VT metering core;
- Connector 2 VT metering core;
- MV bay metering VT core;
- Line 1 VT metering core; and,
- Line 2 VT metering core.

The busbar 1 VT, busbar 2 VT, connector 1 VT, connector 2 VT, line 1 VT, line 2 VT and MV bay VT connections shall be routed via voltage transformer test blocks, VTTB(BB1), VTTB(BB2), VTTB(CON1), VTTB(CON2), VTTB(LINE1), VTTB(LINE2) and VTTB(MV), and independently connected to the diameter control IED. The standard practice is to earth the neutral (4th wire) within the VT JBs.

The diameter control device shall report the measurement quantities to:

- Diameter control device HMI;
- Station HMI; and,
- Gateway for remote reporting.

Synchronism check for the bay 1 breaker, tie bay breaker, bay 2 breaker and MV bay breaker is located within the diameter control device. The measurements VT inputs shall also be used for synchronism check. The VT shall be used as follow:

- Bay 1 breaker synchronism check function shall use:
  - Busbar 1 VT; and,
  - Connector 1 VT.
- Bay 2 breaker synchronism check function shall use:
  - Busbar 2 VT; and,
  - Connector 2 VT
- Tie Bay breaker synchronism check function shall use:
  - Connector 1 VT; and,
  - Connector 2 VT
- MV bay breaker synchronism check function shall use:
  - MV bay VT;
  - MV busbar 1 VT; and,
  - MV busbar 2 VT

The MV busbar 1 and busbar 2 VTs for synchronism check shall be selectable within the diameter control device by the busbar 1 and busbar 1 isolator statuses.

## 3.9 Binary information processing

### 3.9.1 Philosophy

The diameter interface device shall constitute a single node through which all the control commands shall be routed (internal functions and from the external devices).

The GOOSE data shall be utilised to communicate plant information and control information between IEDs (and test equipment).

GOOSE data shall be utilised to communicate plant information, control and status information between the process interface units and the diameter interface device. The process interface units shall have the capability to be set either to the “Normal” mode or “Test” mode from the station HMI. The “Normal” mode shall permit the control commands the primary plant and the “Test” mode shall block the control command outputs to the primary plant. The PIU shall provide an acknowledgement to the diameter control device and the station HMI for each control being executed for both the “Normal” and “Test” modes.

The following data will in general be sent via a GOOSE message:

- Primary plant status;
- Control signals;
- Auto-reclose signals; and,
- Master and slave modes.

### 3.9.2 Rationale

The IEC61850 GOOSE data usage reduce the hardwire interfacing between IEDs within the bay, the primary plant equipment and interfacing with other bays.

The single node requirement for the diameter interface device provides for:

- Primary plant controls;
- Auto-reclosing;
- Synchronism check; and,
- Local and remote reporting.

### 3.9.3 Design Requirements

IEC 61850 shall be implemented as "purely" as possible (e.g. defined logical node names and data attributes). The vendor shall comply with the IEC61850 standards and Eskom's requirements as per document 240-42066934.

GOOSE data communication shall be between the diameter control device and:

- Other diameter control device;
- Object protection systems;
- Bay 1 breaker process interface unit;
- Tie bay breaker process interface unit;
- Bay 2 breaker process interface unit;
- Connected line reactor breaker process interface unit; and,
- Busbar reactor breaker process interface unit.

The diameter control device shall provide for the following binary inputs:

- Bay 1 closing no DC fail;
- Bay 1 manual close command;
- Bay 1 SIS selected to OFF;
- Bay 1 SIS selected to ON;
- Bay 1 SIS selected to MAINTENANCE;
- Tie Bay closing no DC fail;
- Tie Bay manual close command;
- Tie Bay SIS selected to OFF;
- Tie Bay SIS selected to ON;
- Tie Bay SIS selected to MAINTENANCE;
- Bay 2 closing no DC fail;
- Bay 2 manual close command;
- Bay 2 SIS selected to OFF;
- Bay 2 SIS selected to ON;
- Bay 2 SIS selected to MAINTENANCE;
- MV Bay closing no DC fail;
- MV Bay manual close command;
- MV Bay SIS selected to OFF;
- MV Bay SIS selected to ON;

- MV Bay SIS selected to MAINTENANCE;
- Bay 1 indication no DC fail;
- Tie Bay indication no DC fail;
- Bay 2 indication no DC fail; and,
- MV Bay indication no DC fail.

The diameter control device shall provide for the following binary outputs:

- Diameter interface panel unhealthy;
- Bay 1 breaker red phase open command and trip test signal;
- Bay 1 breaker white phase open command and trip test signal;
- Bay 1 breaker blue phase open command and trip test signal;
- Tie Bay breaker red phase open command and trip test signal;
- Tie Bay breaker white phase open command and trip test signal;
- Tie Bay breaker blue phase open command and trip test signal;
- Bay 2 breaker red phase open command and trip test signal;
- Bay 2 breaker white phase open command and trip test signal;
- Bay 2 breaker blue phase open command and trip test signal;
- Tie Bay breaker red phase trip circuit supervision;
- Tie Bay breaker white phase trip circuit supervision;
- Tie Bay breaker blue phase trip circuit supervision;
- MV Bay breaker red phase open command;
- MV Bay breaker white phase open command;
- MV Bay breaker blue phase open command;
- Bay 1 breaker unhealthy (Object 1 external disturbance recorder);
- Tie Bay breaker unhealthy (Object 1 external disturbance recorder);
- Bay 2 breaker unhealthy (Object 2 external disturbance recorder);
- Tie Bay breaker unhealthy (Object 2 external disturbance recorder); and,
- Diameter control device fail (normally closed contact).

#### 3.9.3.1 Breaker Process Interface Unit Module Composition

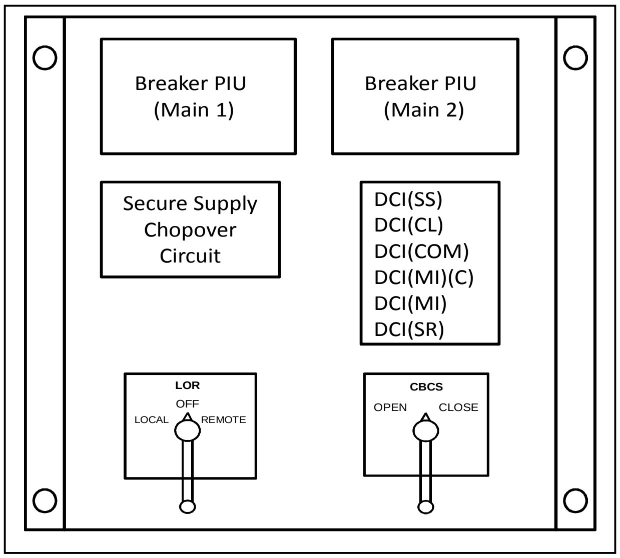
The breaker process interface unit module shall be 19” rack mount and will be fitted within the bay 1 breaker JB, bay 2 breaker JB, tie bay breaker JB and MV bay breaker JB in the close proximity to the breaker bay primary equipment. The breaker JB does not form part of this enquiry. The breaker process interface unit module shall include the following:

- Main 1 Breaker PIU;
- Main 2 Breaker PIU;
- Secure supply chop-over circuit;

Circuit-breaker control switch for local open and close of the breaker when the LOR is selected to “LOCAL”;

“LOCAL”, “OFF”, “REMOTE” (LOR) switch, and MCBs.

The main 1 breaker PIU shall be the interface (IEC61850) between the primary plant and the main 1 protection & control scheme/module IED(s) and the gateway. The main 2 breaker PIU shall be the interface (IEC61850) between the breaker bay primary plant and the main 2 protection & control scheme/module IED(s) and the gateway. The main 1 breaker PIU and Main 2 breaker PIU inputs and outputs shall be as per section 4.4.4.7. The breaker PIU IEC61850 data shall be as per section 4.4.4.4. The bay 1 breaker PIUs shall interface with the diameter interface scheme and with the object 1 protection scheme. The bay 2 breaker PIUs shall interface with the diameter interface scheme and with the object 2 protection scheme. The tie bay breaker PIUs shall interface with the diameter interface scheme and both object protection schemes. The MV bay breaker PIUs shall interface with the diameter interface scheme and with the transformer protection scheme. The breaker PIU shall meet the requirements as per the "Generic Specification for Protective Intelligent Electronic Devices (IEDs) Standard (240-64685228).




## 3.10 Local controls

### 3.10.1 Philosophy

Primary plant and diameter interface controls shall be made available, on a real time basis, locally on the diameter control IED and the diameter interface panel.

The primary local operator interface shall be provided via the substation HMI. Local controls will, however be required on the diameter interface scheme. The preferred method of providing local controls is via integrated programmable push buttons on the diameter control device, as an alternative, dedicated local control LCD/LED screen HMI. The control and selection shall be visually displayed and not hidden within the HMI menu structures. The main 1 and main 2 diameter control devices shall follow each other when a selection is made on any one of the diameter control devices.

Supervisory selections are required to select the source of control (local or remote) and the maintenance mode selection per breaker.

### 3.10.2 Rationale

Controls are required by the site operators and protection field staff, during commissioning and maintenance, to facilitate safe operation of the primary plant equipment within the diameter.

### 3.10.3 Design Requirements

The Human machine interface (IHMI) Logical Node shall be available as an operator interface to execute controls, display measurement quantities and to display visual alarms at diameter level as required by the Eskom System Configurator.

The preferred method of providing local controls is via integrated programmable push buttons on IEDs, as an alternative, dedicated local control LCD/LED screen HMI. All controls shall be routed via the diameter control system. However a circuit-breaker open command, per breaker, shall be connected directly to the relevant circuit-breaker trip coil, on the panel for purposes of safety. The required local controls are:

- Line 1 - Auto-reclose ON selected;
- Line 1 - Auto-reclose OFF selected;
- Line 1 - 1 Pole auto-reclose selected;
- Line 1 - 3 Pole auto-reclose selected;
- Line 1 - 1&3 Pole auto-reclose selected;
- Line 1 - 3 Cycle reclose selected;
- Line 1 - 5 Cycle reclose selected;
- Line 1 - 3 Pole slow auto-reclose selected;
- Line 1 - 3 Pole fast auto-reclose selected;
- Line 1 - TPK Normal;
- Line 1 - TPK Transfer;
- Line 2 - Auto-reclose ON selected;
- Line 2 - Auto-reclose OFF selected;
- Line 2 - 1 Pole auto-reclose selected;
- Line 2 - 3 Pole auto-reclose selected;
- Line 2 - 1&3 Pole auto-reclose selected;
- Line 2 - 3 Cycle reclose selected;
- Line 2 - 5 Cycle reclose selected;
- Line 2 - 3 Pole slow auto-reclose selected;
- Line 2 - 3 Pole fast auto-reclose selected;
- Line 2 - TPK Normal;
- Line 2 - TPK Transfer;
- Main # Master selected; and,
- Main 1 Slave selected.
- The following shall be a dedicated devices and independent from the IED HMI:
- Bay 1 Supervisory Isolating Switch;
- Bay 2 Supervisory Isolating Switch;
- Tie Bay Supervisory Isolating Switch;
- MV Bay Supervisory Isolating Switch;
- Bay 1 breaker control switch;

- Bay 2 breaker control switch;
- Tie Bay breaker control switch; and,
- MV Bay breaker control switch.

#### 3.10.3.1 Supervisory isolating switches

The supervisory isolating switch select between local control (HMI/scheme) and remote control (Station HMI and Control Centres). The circuit-breaker emergency open command shall be independent on the SIS position being selected. The SIS switches shall have three positions: ON, OFF and MAINTENANCE.

The Bay Supervisory Isolating Switch (B#SIS) and the Tie Bay Supervisory Isolating Switch (TBSIS) is located on the diameter interface panel and provides for the selection between local (OFF selected), remote (ON selected) controls and maintenance mode (breaker fail isolated). The Bay Supervisory Isolating Switch (B#SIS) maintenance mode selection shall be send from the diameter interface panel to the main # protection device to block the bay breaker fail function. The Tie Bay Supervisory Isolating Switch (TBSIS) maintenance mode selection shall be send from the diameter interface panel to the main # protection device to block the tie bay breaker fail function.

#### 3.10.3.2 Circuit-breaker control switch (emergency trip)

An emergency trip function, per breaker, shall always be provided for via a discrete control switch that is independent of any IED. The circuit-breaker control function (bay 1, bay 2, tie bay and MV bay) is used to electrically open and close the associated circuit-breaker(s) via the scheme front panel. The switches shall require a double action to operate (e.g. press and turn). It shall be possible to trip the applicable circuit-breaker via the scheme front panel, even in the event of an IED failure. The circuit-breaker control switches open command shall be independent on the SIS selection. The circuit-breaker emergency trip function shall be connected to the main # trip circuit of the scheme.

For schemes controlling multiple circuit-breakers (e.g. transformer protection schemes and breaker-and-a-half protection schemes), the control labels shall clearly and uniquely differentiate the functions (e.g. HV circuit-breaker trip, MV circuit-breaker trip, Bay # circuit-breaker trip, Tie Bay circuit-breaker trip, etc.).

The actuator(s) for local opening and closing of the circuit-breaker shall be identifiable by the following method:

- By colour coding: The colour green shall be associated with the trip control and red with the close control. The breaker status shall be via indication LED's operated by the Breaker auxiliary contacts and shall be independent on the health of the diameter control device.

***Note:*** The Eskom colour coding convention for trip/close actuators is opposite to that specified in IEC 60073 (i.e. IEC requires trip red and close green).

The circuit breaker control switches (bay 1, bay 2, tie bay and MV bay) shall have, for stations with a single station HMI, the capability to both open and close the circuit breaker. Closing shall be via the synchronism check function where applicable.

#### 3.10.3.3 Auto-reclose mode selections

The preferred method of providing local auto-reclose mode selection controls is via integrated programmable push buttons on IEDs. Alternately these controls with indications can be provided for on the scheme. The selection shall be latched within the IED and be retained even in the event that the IED restarts. The auto-reclose mode selections shall be independently selectable for each line. The following auto-reclose mode selections are required:

- ON and OFF;
- 1-Pole, 3-Pole and 1&3-Pole;
- 3-cycle and 5-cycle;
- Fast and Slow 3-pole reclose; and,
- Master and Slave

#### 3.10.3.4 Circuit-breaker trip testing

A trip test function shall be provided for so as to allow protection field technicians an easy means to test the operation of the ARC function on a scheme. A trip test function shall be provided on all schemes that include an ARC function. Trip testing on single pole circuit-breakers shall only be single pole and be dependent on the auto-reclose selected for single-pole and be ready for a 1-pole auto-reclose cycle. Trip testing shall be routed via the IED to the circuit-breaker.

For breaker-and-a-half applications, trip testing is also dependent on the adjacent circuit-breaker in the diameter to be closed. Trip testing, independent per breaker, shall be from the station HMIs.

#### 3.10.3.5 Transfer permission (TPK)

The preferred method of providing local TPK controls is via integrated programmable push buttons on IEDs. Alternately these controls with indications can be provided for on the scheme. The selection shall be latched within the IED and be retained even in the event that the IED restarts. When the line protection system is required to operate in the transfer/bypass mode, the transfer permission key relay (TPK) is switched from the "Normal" position to the "Transfer" position. The TPK function shall be switchable from remote when the relevant Supervisory Isolating Switch (SIS) is selected to the “ON” position. Operation of the TPK function shall enable control of the reactor transfer isolator.

#### 3.10.3.6 Isolator(s) controls

Isolator controls are required for stations with a single station HMI. A control per isolator, to open and close motorised isolators, shall be provided for and shall be independent of any IED. The isolator controls are used to electrically open and close the associated isolator via the LCD/LED screen HMI. The control shall be confirm before operate. It shall be possible to control all the isolators from the LCD/LED screen HMI, even in the event of an IED failure or station HMI failure. The isolator control labels shall clearly and uniquely differentiate between the different isolators. The isolator control switch shall have an indication for both open and close.

The isolators local control commands shall be supervised by the SIS selection, local isolator controls shall only be permitted with the SIS selected to “OFF”.

The motorised isolators shall have a dedicated DC supply with MCB protection.

## 3.11 Local indications

### 3.11.1 Philosophy

It is important to maintain high quality information relevant to the operation of protection equipment and abnormal operation of the power system.

Primary plant status, secondary control selection statuses and grouped alarms shall be made available, on a real time basis, both locally and remotely.

Essential alarms shall be presented locally and detailed sequence of events at bay level, on a non-real time basis, to be extractable both locally and remotely.

The IED mimic shall have a single line diagram representing the applicable bay, with the required controls, indications and display of analogue quantities. The IED HMI shall reflect the true status being selected, the most resent protection operational indications and the real time analogue quantities. The selected modes shall continuously be illuminated and health verified with a lamp check function.

### 3.11.2 Rationale

Information that is collected during operational or abnormal conditions of the power system can be used for a number of purposes:

- performance monitoring;
- fault finding;

- verification of settings;
- behaviour under abnormal system conditions;
- reliability centred maintenance;
- quality of supply monitoring; and,
- condition based monitoring.

The above information can assist in improving design of protection schemes, methods of calculating settings, economic evaluation of investments in new protection and protection upgrades. Obtained information is stored in various databases. Presently there is a trend to share information effectively on an organisation wide basis and this is achieved through the concentration of information in large databases and the provision of a communications infrastructure stretching from main offices to substations.

Intelligent essential alarms and control statuses are required by the system controllers and site operators to facilitate safe operation of the power system. However, at the same time, it is essential to protect them from information overload.

Detailed alarm and sequence of event information is required at bay level and at the Human Machine Interfaces (HMI's). These alarms would typically be accessible both locally and via remote devices, analysed and stored by various information systems to facilitate post fault analysis. Emphasis is being placed on making information available on a 'when needed' basis.

Alarms should satisfy certain basic conditions i.e. they should be relevant, available when needed and easy to read and interpret.

### 3.11.3 Design Requirements

All indications shall be visible by default, that is, no external influence shall be required to view any indication. The status of all locally and remotely controllable functions and power plant equipment shall be indicated on the scheme.

The required indications, selection statuses and measurements shall be displayed in real time on the IED HMI with the option to latch the indications.

On the panel mimic, red and green indicator lamps shall, at all times provide a visual indication of the status of the bay 1 breaker, bay 2 breaker and tie bay breaker. In addition to this, indications for all isolators shall be provided for on the IED mimic. The panel mimic control visual indications shall indicate the true status being selected by either the diameter control device (local or remote) or the panel mimic controls.

The following indications shall be available on the IED HMI or on the scheme:

- Circuit-breaker status;
- Isolator status;
- Auto-reclose mode selections;
- Transfer permission;
- Earth switches;
- Panel not healthy indication;
- Bay 1 JB not healthy indication;
- Bay 2 JB not healthy indication;
- Tie Bay JB not healthy indication; and,
- MV Bay JB not healthy indication.

The diameter control IED HMI shall be used for local measurements display without human intervention to view the values. Measurements quantities shall be provided as per the requirements of the detail functional specifications. The measurement for each quantity shall be measured separately and continuously.

Bay 1 - IED HMI Analogue quantities:

| | **Description** |
|---|---|
| 1 | Bay 1 Red phase current |
| 2 | Bay 1 White phase current |
| 3 | Bay 1 Blue phase current |
| 4 | Tie Bay Red phase current |
| 5 | Tie Bay White phase current |
| 6 | Tie Bay Blue phase current |
| 7 | Object 1 Red phase current |
| 8 | Object 1 White phase current |
| 9 | Object 1 Blue phase current |
| 10 | Connector 1 Red – White phase voltage |
| 11 | Connector 1 White – Blue phase voltage |
| 12 | Connector 1 Blue – Red phase voltage |
| 13 | Line 1 Red – White phase voltage |
| 14 | Line 1 White – Blue phase voltage |
| 15 | Line 1 Blue – Red phase voltage |
| 16 | Busbar 1 Red – White phase voltage |
| 17 | Busbar 1 White – Blue phase voltage |
| 18 | Busbar 1 Blue – Red phase voltage |
| 19 | Bay 1 Active Power |
| 20 | Bay 1 Reactive Power |
| 21 | Busbar 1 Frequency |
| 22 | Line 1 Active Power |
| 23 | Line 1 Reactive Power |
| 24 | Line 1 Frequency |
| 25 | Voltage difference (Busbar 1 and Connector 1) |
| 26 | Frequency difference (Busbar 1 and Connector 1) |
| 27 | Phase angle difference (Busbar 1 and Connector 1) |

Bay 2 - IED HMI Analogue quantities:

| | **Description** |
|---|---|
| 1 | Bay 2 Red phase current |
| 2 | Bay 2 White phase current |
| 3 | Bay 2 Blue phase current |
| 4 | Tie Bay Red phase current |
| 5 | Tie Bay White phase current |

| | **Description** |
|---|---|
| 6 | Tie Bay Blue phase current |
| 7 | Object 2 Red phase current |
| 8 | Object 2 White phase current |
| 9 | Object 2 Blue phase current |
| 10 | Bay 2 Active Power |
| 11 | Bay 2 Reactive Power |
| 12 | Busbar 2 Frequency |
| 13 | Line 2 Active Power |
| 14 | Line 2 Reactive Power |
| 15 | Line 2 Frequency |
| 16 | Connector 2 Red – White phase voltage |
| 17 | Connector 2 White – Blue phase voltage |
| 18 | Connector 2 Blue – Red phase voltage |
| 19 | Line 2 Red – White phase voltage |
| 20 | Line 2 White – Blue phase voltage |
| 21 | Line 2 Blue – Red phase voltage |
| 22 | Busbar 2 Red – White phase voltage |
| 23 | Busbar 2 White – Blue phase voltage |
| 24 | Busbar 2 Blue – Red phase voltage |
| 25 | Voltage difference (Busbar 2 and Connector 2) |
| 26 | Frequency difference (Busbar 2 and Connector 2) |
| 27 | Phase angle difference (Busbar 2 and Connector 2) |

Tie Bay - IED HMI Analogue quantities:

| | **Description** |
|---|---|
| 1 | Tie Bay Red phase current |
| 2 | Tie Bay White phase current |
| 3 | Tie Bay Blue phase current |
| 4 | Connector 1 Red – White phase voltage |
| 5 | Connector 1 White – Blue phase voltage |
| 6 | Connector 1 Blue – Red phase voltage |
| 7 | Connector 2 Red – White phase voltage |
| 8 | Connector 2 White – Blue phase voltage |
| 9 | Connector 2 Blue – Red phase voltage |
| 10 | Tie Bay Active Power |
| 11 | Tie Bay Reactive Power |

| | |
|---|---|
| 12 | Connector 1 Frequency |
| 13 | Connector 2 Frequency |
| 14 | Voltage difference (Connector 1 and Connector 2) |
| 15 | Frequency difference (Connector 1 and Connector 2) |
| 16 | Phase angle difference (Connector 1 and Connector 2) |

MV Bay - IED HMI Analogue quantities:

| | **Description** |
|---|---|
| 1 | MV Bay Red phase current |
| 2 | MV Bay White phase current |
| 3 | MV Bay Blue phase current |
| 4 | Transformer Red – White phase voltage |
| 5 | Transformer White – Blue phase voltage |
| 6 | Transformer Blue – Red phase voltage |
| 7 | Busbar 1 Red – White phase voltage |
| 8 | Busbar 1 White – Blue phase voltage |
| 9 | Busbar 1 Blue – Red phase voltage |
| 10 | Busbar 2 Red – White phase voltage |
| 11 | Busbar 2 White – Blue phase voltage |
| 12 | Busbar 2 Blue – Red phase voltage |
| 13 | MV Bay Active Power |
| 14 | MV Bay Reactive Power |
| 15 | Transformer MV Side Frequency |
| 16 | Voltage difference (Transformer and Selected Busbar) |
| 17 | Frequency difference (Transformer and Selected Busbar) |
| 18 | Phase angle difference (Transformer and Selected Busbar) |

Indication lamp colours shall be as follows:

- Red: Trip conditions, not healthy condition;
- Amber: Alarm conditions;
- White (or Amber): Earth applied, Automatic Voltage Control on Manual; and,
- Green: Health

The lamp check pushbutton shall be used to verify the health of the all the diameter interface panel lamps, this includes both DC and AC powered lamps. Where possible, this function shall also cause all IEDs' integrated indications to be illuminated.

## 3.12 Remote controls

### 3.12.1 Philosophy

Primary plant and secondary bay controls shall be made available, on a real time basis, both locally and remotely. The remote operator interface shall be provided via the substation gateway. The remote control commands shall be locally logged. Remote controls are required for all primary plant equipment and auto-reclose mode selections.

All remote controls (including the station HMI controls) shall be routed via the diameter control device. The main 1 and main 2 diameter control devices shall follow each other when a selection is made on any one of the diameter control devices.

Supervisory selections are required to select the source of control (local or remote) and the maintenance mode selection per breaker.

### 3.12.2 Rationale

Controls are required by the system controllers and site operators to facilitate safe operation of the power system.

### 3.12.3 Design Requirements

All remote controls shall be routed via the diameter control devices.

Open commands for all the circuit breakers shall interface directly to the circuit-breaker trip coil shall be provided on the panel for purposes of safety. The circuit-breaker open commands shall be independent on the health of the diameter control device

The detailed functional specifications will include the list of commands (Logical nodes and data attributes) to be executed and status reporting. The vendors shall use IEC 61850 as “purely” as possible (e.g. defined logical node names and data attributes).

## 3.13 Remote indications, info and status to be reported

### 3.13.1 Philosophy

It is important to maintain high quality information relevant to the operation of equipment and abnormal operation of the power system.

Primary plant status, secondary control selection statuses and grouped alarms shall be made available, on a real time basis, both locally and remotely.

Essential alarms shall be reported remotely.

### 3.13.2 Rationale

Remote information reporting is required for all mode selections, supply health, equipment health and control operations.

Information that is collected during operational or abnormal conditions of the power system can be used for a number of purposes:

- performance monitoring;
- fault finding;
- verification of settings;
- behaviour under abnormal system conditions;
- reliability centred maintenance;
- quality of supply monitoring; and,
- condition based monitoring.

The above information can assist in improving design of protection schemes, methods of calculating settings, economic evaluation of investments in new protection and protection upgrades.

Intelligent essential alarms and control statuses are required by the system controllers and site operators to facilitate safe operation of the power system. However, at the same time, it is essential to protect them from information overload.

Detailed alarm and sequence of event information is required at bay level and at the Human Machine Interfaces (HMI's). These alarms would typically be accessible both locally and via remote devices, analysed and stored by various information systems to facilitate post fault analysis. Emphasis is being placed on making information available on a 'when needed' basis.

Alarms should satisfy certain basic conditions i.e. they should be relevant, available when needed and easy to read and interpret.

The IED indications and alarms are required by the control centre staff and site operators to manage the network effectively by restoring tripped lines to service.

### 3.13.3 Design Requirements

The IED shall report all the active indications and alarms, when operated to the client(s). The indications and alarms shall be time stamped at the IED. The detailed functional specifications will include the list of MMS data points (Logical nodes and data attributes) for vertical communication. The vendors shall use IEC 61850 as "purely" as possible (e.g. defined logical node names and data attributes). Remote information reporting are required for all protection mode selections, supply health, equipment health and protection operations.

The indications and alarms of the required functions shall comply with the IEC61850 standards and Eskom's mandatory requirements as per document 240-42066934. The detailed functional specifications shall include the list of MMS data points (Logical nodes and data attributes) for vertical communication.

The IED shall report the protection operation and unhealthy conditions per data attribute and as grouped alarms.

#### 3.13.3.1 Alarm handlingName: CALH

The CAHL logical node shall be used for the creation of group alarms and group events. This logical node shall be used to calculate new data out of individual data from different logical nodes. The following grouped alarms are required for remote reporting purposes:

| **Grouped Alarm** | **Individual data points within grouped alarm** |
|---|---|
| **Bay 1 DC Failed** | Bay 1 Closing DC Failed |
| | Bay 1 Indication DC Failed |
| | Bay 1 Motorised Isolators DC Failed |
| **Grouped Alarm** | **Individual data points within grouped alarm** |
| **Bay 2 DC Failed** | Bay 2 Closing DC Failed |
| | Bay 2 Indication DC Failed |
| | Bay 2 Motorised Isolators DC Failed |
| **Grouped Alarm** | **Individual data points within grouped alarm** |
| **Tie Bay DC Failed** | Tie Bay Closing DC Failed |
| | Tie Bay Indication DC Failed |
| | Tie Bay Motorised Isolators DC Failed |

| **Grouped Alarm** | **Individual data points within grouped alarm** |
|---|---|
| **MV Bay DC Failed** | MV Bay Closing DC Failed |
| | MV Bay Indication DC Failed |
| | MV Bay Motorised Isolators DC Failed |
| **Grouped Alarm** | **Individual data points within grouped alarm** |
| **Bay 1 JB DC Failed** | Bay 1 JB Main 1 Secure Supply DC Failed |
| | Bay 1 JB Main 2 Secure Supply DC Failed |
| | Bay 1 JB Closing DC Failed |
| | Bay 1 JB Motorised Isolators DC Failed |
| | Bay 1 JB Common Circuits DC Failed |
| **Grouped Alarm** | **Individual data points within grouped alarm** |
| **Bay 2 JB DC Failed** | Bay 2 JB Main 1 Secure Supply DC Failed |
| | Bay 2 JB Main 2 Secure Supply DC Failed |
| | Bay 2 JB Closing DC Failed |
| | Bay 2 JB Motorised Isolators DC Failed |
| | Bay 2 JB Common Circuits DC Failed |
| **Grouped Alarm** | **Individual data points within grouped alarm** |
| **Tie Bay JB DC Failed** | Tie Bay JB Main 1 Secure Supply DC Failed |
| | Tie Bay JB Main 2 Secure Supply DC Failed |
| | Tie Bay JB Closing DC Failed |
| | Tie Bay JB Motorised Isolators DC Failed |
| | Tie Bay JB Common Circuits DC Failed |
| **Grouped Alarm** | **Individual data points within grouped alarm** |
| **MV Bay JB DC Failed** | MV Bay JB Main 1 Secure Supply DC Failed |
| | MV Bay JB Main 2 Secure Supply DC Failed |
| | MV Bay JB Closing DC Failed |
| | MV Bay JB Motorised Isolators DC Failed |
| | MV Bay JB Common Circuits DC Failed |

## 3.14 GOOSE data for testing

### 3.14.1 Philosophy

The IED(s) shall be cond with GOOSE data to verify each setting within the IED. The test equipment will also simulate test points for verification and fault playback purposes. The simulated GOOSE signals shall be enabled and disabled within the IED. All the protection functions to be tested shall be enabled and the bay breaker three pole trip selected condition removed from PTRC1 when selected to the test mode.

### 3.14.2 Rationale

The utilisation of GOOSE data for testing eliminates the need to switch off (disable) any function within the IED (non-intrusive testing).

The GOOSE testing information is required by the protection field staff to verify all the applied setting during commissioning and maintenance activities. The test equipment will subscribe to the GOOSE data being broadcasted by the IED under test to interrupt the test quantities for the function under test. The test equipment simulated GOOSE data attributes are required for verification and fault playback purposes. The simulated GOOSE signals shall be enabled and disabled within the IED, when selected to the test mode, to prevent any simulated GOOSE signal to remain high and hence adversely affect the in-service performance of the IED. The bay breaker three pole trip selected condition are required to be removed from PTRC1, when selected to the test mode, to enable verification of single pole tripping.

### 3.14.3 Design Requirements

The GOOSE data attributes required for testing shall comply with the IEC61850 standards and Eskom's mandatory requirements as per document 240-42066934. The detailed functional specifications shall include the list of the GOOSE data testing points (Logical nodes and data attributes).

## 3.15 Secondary injection testing test aids

### 3.15.1 Philosophy

Current and voltage testing facilities shall be available between the current & voltage transformers and the IED.

### 3.15.2 Rationale

The current and voltage testing facilities are required to isolate the interfaces between the current & voltage transformers and the IED. The testing facilities shall provide for:

- Automatic short circuiting of the incoming current transformer circuits;
- Measurement of the current in the incoming current transformer circuit of all three phases and the neutral individually;
- Measurement of the voltage in the incoming voltage transformer circuit of all three phases and the neutral individually; and,
- Injection of test currents and voltages into the panel circuits on all three phases and the neutral individually 9with the bay in, or out of service).

### 3.15.3 Design Requirements

Current transformer test interface shall be fitted with shorting strips to prevent open circuiting of current transformer secondary circuits when the IED is under test or out of service.

The current and voltage transformer circuit's connections to test facilities shall be consistent with legacy arrangements.

The testing interfaces shall be located on the front of the panel and be clearly labelled.

The following current transformer test blocks are required:

| | |
|---|---|
| CTTB(B1) | 4-way test block for the Bay 1 metering currents. Connected to the Bay 1 CT. One connection for each phase voltage, plus neutral. |
| CTTB(TB) | 4-way test block for the Tie Bay metering currents. Connected to the Tie Bay CT (CT on the busbar 2 side of the Tie Bay breaker). One connection for each phase voltage, plus neutral. |

| | |
|---|---|
| CTTB(B2) | 4-way test block for the Bay 2 metering currents. Connected to the Bay 2 CT. One connection for each phase voltage, plus neutral. |
| CTTB(MV) | 4-way test block for the MV Bay metering currents. Connected to the MV Bay CT. One connection for each phase voltage, plus neutral. |

The following voltage transformer test blocks are required:

| | |
|---|---|
| VTTB(BB1) | 4-way test block for the Busbar 1 measurements voltages. Connected to the Busbar 1 CVT metering class core. One connection for each phase voltage, plus neutral. |
| VTTB(BB2) | 4-way test block for the Busbar 2 measurements voltages. Connected to the Busbar 2 CVT metering class core. One connection for each phase voltage, plus neutral. |
| VTTB(CON1) | 4-way test block for the Connector 1 measurements voltages. Connected to the Connector 1 CVT metering class core. One connection for each phase voltage, plus neutral. |
| VTTB(CON2) | 4-way test block for the Connector 2 measurements voltages. Connected to the Connector 2 CVT metering class core. One connection for each phase voltage, plus neutral. |
| VTTB(LINE 1) | 4-way test block for the Line 1 measurements voltages. Connected to the Line 1 CVT metering class core. One connection for each phase voltage, plus neutral. |
| VTTB(LINE 2) | 4-way test block for the Line 2 measurements voltages. Connected to the Line 2 CVT metering class core. One connection for each phase voltage, plus neutral. |
| VTTB(MV)(T) | 4-way test block for the Transformer MV side measurements voltages. Connected to the Transformer MV side CVT metering class core. One connection for each phase voltage, plus neutral. |
| CTTB(MV)(BB1) | 4-way test block for the Busbar 1 MV side measurements voltages. Connected to the Busbar 1 MV side CVT metering class core. One connection for each phase voltage, plus neutral. |
| CTTB(MV)(BB2) | 4-way test block for the Busbar 2 MV side measurements voltages. Connected to the Busbar 2 MV side CVT metering class core. One connection for each phase voltage, plus neutral. |

## 3.16 Breaker trip testing

### 3.16.1 Philosophy

The facility to perform trip testing of each tripping system shall be provided. This facility shall be incorporated in the diameter management system. The diameter control device shall include trip testing (on a per phase basis) independently for the bay 1 breaker, bay 2 breaker and the tie bay breaker. Tripping shall be routed via the bay 1 breaker PIUs, bay 2 breaker PIUs and the tie bay breaker PIUs.

Single pole trip testing of any one of the circuit-breakers shall be dependent on the adjacent circuit-breaker to be in the close position and be healthy and the auto-reclosing being permitted. Auto-reclosing shall be initiated for that circuit-breaker being trip tested and any other breaker shall not be permitted to be trip tested until such time that the reclaim time of the circuit-breaker being trip tested has timed out and that the circuit-breaker phase did close successfully.

### 3.16.2 Rationale

Trip testing is conducted on an annual basis to ensure that the circuit-breaker experiences at least one operation in one year. This is to ensure that the mechanical portion of the circuit-breaker does not seize if no operation has occurred on the mechanism during a twelve month period and to ensure the integrity of the trip coil circuit.

The facility shall be integrated in the diameter management system to allow for ease of interlocking and to eliminate errors resulting in no auto-reclosing of the opened poles and for the time based event recording provided by the diameter management system.

### 3.16.3 Design Requirements

The trip testing circuit shall not provide an input to the relevant circuit-breaker failure function. The trip testing circuit shall initiate the relevant reclosing function.

#### 3.16.3.1 Bay 1 breaker trip testing - PTRC 1

Trip testing of the bay 1 breaker shall be provided for, on a per phase basis, to individually trip test each phase of the breaker through the main # bay 1 breaker trip coils. Trip testing shall be initiated from the station HMI. The trip test signals shall be sent via GOOSE to the bay 1 breaker PIU. The single pole reclose cycle of the bay 1 breaker within the diameter control device shall be initiated.

Trip testing of the bay 1 breaker:

- Shall be permitted when the bay 1 breaker is three-pole closed;
- Shall be permitted when all the phases of the tie bay breaker is three-pole closed (for busbar reactor diameter applications, that the bay 2 breaker is three-poles closed);
- Shall not be permitted when the tie bay breaker is in a reclose cycle or the reclaim time is running;
- Single pole reclose initiation shall only be possible whenever the bay 1 breaker auto-reclose is ready for a successful single pole reclose cycle;
- Shall be permitted when the springs are fully charged on all the phases of the bay 1 breaker;
- No bay 1 breaker open pole detected;
- No IEC61850 communications failure with the bay 1 PIU;
- Bay 1 breaker trip circuit healthy;
- Trip testing shall have a fixed time duration seal-in. The seal-in shall be maintained for the set time duration. This time duration shall be user settable; and,
- Trip testing shall not initiate the bay 1 breaker failure protection function.

PTRC 1 shall:

- Phase segregated trip test signals shall be connected to the IED internal disturbance recorder function (RBDR); and,
- Trip test in progress shall be reported to the gateway and station HMI.

#### 3.16.3.2 Bay 2 breaker trip testing - PTRC 2

Trip testing of the bay 2 breaker shall be provided for, on a per phase basis, to individually trip test each phase of the breaker through the main # bay 2 breaker trip coils. Trip testing shall be initiated from the station HMI. The trip test signals shall be sent via GOOSE to the bay 2 breaker PIU. The single pole reclose cycle of the bay 2 breaker within the diameter control device shall be initiated.

Trip testing of the bay 2 breaker:

- Shall be permitted when the bay 2 breaker is three-pole closed;
- Shall be permitted when all the phases of the tie bay breaker is three-pole closed (for busbar reactor diameter applications, that the bay 1 breaker is three-poles closed);
- Shall not be permitted when the tie bay breaker is in a reclose cycle or the reclaim time is running;
- Single pole reclose initiation shall only be possible whenever the bay 2 breaker auto-reclose is ready for a successful single pole reclose cycle;
- Shall be permitted when the springs are fully charged on all the phases of the bay 2 breaker;
- No bay 2 breaker open pole detected;
- No IEC61850 communications failure with the bay 2 PIU;
- Bay 2 breaker trip circuit healthy;
- Trip testing shall have a fixed time duration seal-in. The seal-in shall be maintained for the set time duration. This time duration shall be user settable; and,
- Trip testing shall not initiate the bay 2 breaker failure protection function.

PTRC 2 shall:

- Phase segregated trip test signals shall be connected to the IED internal disturbance recorder function (RBDR); and,
- Trip test in progress shall be reported to the gateway and station HMI.

#### 3.16.3.3 Tie Bay breaker trip testing - PTRC 3

Trip testing of the tie bay breaker shall be provided for, on a per phase basis, to individually trip test each phase of the breaker through the main # tie bay breaker trip coils. Trip testing shall be initiated from the station HMI. The trip test signals shall be sent via GOOSE to the tie bay breaker PIU. The single pole reclose cycle of the tie bay breaker within the diameter control device shall be initiated.

Trip testing of the tie bay breaker:

- Shall be permitted when the tie bay breaker is three-pole closed;
- Shall be permitted when all the phases of the bay 1 breaker and bay 2 breaker is three-pole closed (user selectable to remove a specific bay breaker supervision in the event that that bay is not populated);
- Shall not be permitted when the tie bay breaker is in a reclose cycle or the reclaim time is running;
- Single pole reclose initiation shall only be possible whenever the tie bay breaker auto-reclose is ready for a successful single pole reclose cycle;
- Shall be permitted when the springs are fully charged on all the phases of the tie bay breaker;
- No tie bay breaker open pole detected;
- No IEC61850 communications failure with the tie bay PIU;
- Tie bay breaker trip circuit healthy;
- Trip testing shall have a fixed time duration seal-in. The seal-in shall be maintained for the set time duration. This time duration shall be user settable; and,
- Trip testing shall not initiate the tie bay breaker failure protection function.

PTRC 3 shall:

- Phase segregated trip test signals shall be connected to the IED internal disturbance recorder function (RBDR); and,
- Trip test in progress shall be reported to the gateway and station HMI.

## 3.17 Trip counting

### 3.17.1 Philosophy

Provision shall be made for trip counting to take place. This shall be done on a per phase basis with the information being received from the protection devices and normally open circuit breaker auxiliary contacts. Trip counting shall be inhibited when the TNS switch is not in the NORMAL position. It shall be ensured that only one count (per phase) takes place for a single trip event. The trip counter shall only increment when any of the breakers are tripped due to a fault condition and the trip initiated from the protection scheme. Phase segregated trip counters shall be provided for the bay 1 breaker and the bay 2 breaker. The tie bay breaker and the MV breaker shall have a single trip counter.

### 3.17.2 Rationale

Trip counting is required by the site operator to verify and log that any one of the circuit-breakers were tripped by the protection due to a network fault. Trip counting with the value of the interrupted current are used to aid in the circuit-breaker maintenance intervals.

### 3.17.3 Design requirements

Trip counting shall be user selectable to be only active when the specific bay is populated.

Bay 1 breaker red phase trip counter:

- Blocked by Bay 1 Breaker LOR not selected to remote, GOOSE message from the Bay 1 protection IED.
  - The 1st trigger of the counter is an AND combination of the following:
  - Object 1, Main #, Bay 1 Breaker red phase trip, GOOSE message from object 1 main # protection IED;
  - Object 1, Main #, TNS selected to NORMAL, GOOSE message from object 1 main #protection IED;
  - Object 1 selected for either a Line, Transformer or Busbar Reactor on the Bay 1 side of the Diameter; and,

Bay 1 Breaker not open.

- The 2nd trigger of the counter is as follow:
  - Object 1 trip, for when the Busbar Reactor is on the Bay 1 side of the Diameter (setting).

Bay 1 breaker white phase trip counter:

- Blocked by Bay 1 Breaker LOR not selected to remote, GOOSE message from the Bay 1 protection IED.
- The 1st trigger of the counter is an AND combination of the following:
  - Object 1, Main #, Bay 1 Breaker white phase trip, GOOSE message from object 1 main # protection IED;
  - Object 1, Main #, TNS selected to NORMAL, GOOSE message from object 1 main # protection IED;

  - Object 1 selected for either a Line, Transformer or Busbar Reactor on the Bay 1 side of the Diameter; and,
  - Bay 1 Breaker not open.
- The 2nd trigger of the counter is as follow:
  - Object 1 trip, for when the Busbar Reactor is on the Bay 1 side of the Diameter (setting).

Bay 1 breaker blue phase trip counter:

Blocked by Bay 1 Breaker LOR not selected to remote, GOOSE message from the Bay 1 protection IED.

The 1st trigger of the counter is an AND combination of the following:

Object 1, Main #, Bay 1 Breaker blue phase trip, GOOSE message from object 1 main # protection IED;

Object 1, Main #, TNS selected to NORMAL, GOOSE message from object 1 main # protection IED;

Object 1 selected for either a Line, Transformer or Busbar Reactor on the Bay 1 side of the Diameter; and,

Bay 1 Breaker not open.

The 2nd trigger of the counter is as follow:

Object 1 trip, for when the Busbar Reactor is on the Bay 1 side of the Diameter (setting).

Bay 2 breaker red phase trip counter:

- Blocked by Bay 2 Breaker LOR not selected to remote, GOOSE message from the Bay 2 protection IED.
- The 1st trigger of the counter is an AND combination of the following:
  - Object 2, Main #, Bay 1 Breaker red phase trip, GOOSE message from object 2 main # protection IED;
  - Object 2, Main #, TNS selected to NORMAL, GOOSE message from object 2 main # protection IED;
  - Object 2 selected for either a Line, Transformer or Busbar Reactor on the Bay 2 side of the Diameter; and,
  - Bay 2 Breaker not open.
- The 2nd trigger of the counter is as follow:
  - Object 2 trip, for when the Busbar Reactor is on the Bay 2 side of the Diameter (setting).

Bay 2 breaker white phase trip counter:

- Blocked by Bay 2 Breaker LOR not selected to remote, GOOSE message from the Bay 2 protection IED.
- The 1st trigger of the counter is an AND combination of the following:
  - Object 2, Main #, Bay 1 Breaker white phase trip, GOOSE message from object 2 main # protection IED;
  - Object 2, Main #, TNS selected to NORMAL, GOOSE message from object 2 main # protection IED;
  - Object 2 selected for either a Line, Transformer or Busbar Reactor on the Bay 2 side of the Diameter; and,
  - Bay 2 Breaker not open.

- The 2nd trigger of the counter is as follow:
  - Object 2 trip, for when the Busbar Reactor is on the Bay 2 side of the Diameter (setting).

Bay 2 breaker blue phase trip counter:

- Blocked by Bay 2 Breaker LOR not selected to remote, GOOSE message from the Bay 2 protection IED.
- The 1st trigger of the counter is an AND combination of the following:
  - Object 2, Main #, Bay 1 Breaker blue phase trip, GOOSE message from object 2 main # protection IED;
  - Object 2, Main #, TNS selected to NORMAL, GOOSE message from object 2 main # protection IED;
  - Object 2 selected for either a Line, Transformer or Busbar Reactor on the Bay 2 side of the Diameter; and,
  - Bay 2 Breaker not open.
- The 2nd trigger of the counter is as follow:
  - Object 2 trip, for when the Busbar Reactor is on the Bay 2 side of the Diameter (setting).

Tie Bay breaker three phase trip counter:

- Blocked by:
  - Tie Bay Breaker LOR not selected to remote, GOOSE message from the Object 1 and Object 2 protection IEDs; and,
  - Object 1 or Object 2 selected for a Busbar Reactor diameter application.
- The 1st trigger of the counter is an AND combination of the following:
  - Object 1, Main #, Tie Bay Breaker trip, GOOSE message from object 1 main # protection IED;
  - Object 1, Main #, TNS selected to NORMAL, GOOSE message from object 1 main # protection IED;
  - Object 1 selected for either a Line, Transformer or Busbar Reactor on the Bay 1 side of the Diameter; and,
  - Tie Bay Breaker not open 3-pole open.
- The 2nd trigger of the counter is as follow:
  - Object 2, Main #, Tie Bay Breaker trip, GOOSE message from object 2 main # protection IED;
  - Object 2, Main #, TNS selected to NORMAL, GOOSE message from object 2 main # protection IED;
  - Object 2 selected for either a Line, Transformer or Busbar Reactor on the Bay 2 side of the Diameter; and,
  - Tie Bay Breaker not open 3-pole open.

MV Bay breaker three phase trip counter:

- Blocked by:
  - MV Bay Breaker LOR not selected to remote, GOOSE message from the Object 1 or Object 2 protection IEDs.

- The 1st trigger of the counter is an AND combination of the following:
  - Object 1, Main #, MV Bay Breaker trip, GOOSE message from object 1 main # protection IED;
  - Object 1, Main #, TNS selected to NORMAL, GOOSE message from object 1 main # protection IED; and,
  - MV Bay Breaker not open 3-pole open.
- The 2nd trigger of the counter is as follow:
  - Object 2, Main #, MV Bay Breaker trip, GOOSE message from object 2 main # protection IED;
  - Object 2, Main #, TNS selected to NORMAL, GOOSE message from object 2 main # protection IED; and,
  - MV Bay Breaker not open 3-pole open.

## 3.18 Thermal overload detection

### 3.18.1 Philosophy

Provision shall be made for object 1 and object 2 line and transformer thermal overload functions. The line thermal overload protection function shall match the thermal characteristic of a Transmission line and the transformer thermal overload protection function shall match the thermal characteristic of a power auto-transformer.

### 3.18.2 Rationale

The requirement to operate the power system closer to the thermal limits, during nominal and emergency network conditions necessitate the monitoring and reporting of the thermal overload condition of power lines and transformers. The thermal overload will often not be detected by other protection functions and the introduction of the thermal overload function can allow the protected circuit to operate closer to the thermal limits.

### 3.18.3 Design requirements

The measurement shall be via three phase current detection with an I2t characteristic and settable time constant and shall include thermal memory. An alarm level is required to be reported both local and remote as an early warning to allow operators to take action well before the line will be tripped by overreaching protection zones or unwanted establishment of the power swing function.

#### 3.18.3.1 Object 1 thermal overload detection - PTTR 1

PTTR 1 shall be used for object 1 line and transformer thermal overload functions. Depending on the algorithm, the LN describes either a temperature or a current (thermal model). The line or transformer thermal functions shall continuously measure the temperature and produce an output when a predetermined value is exceeded. The thermal overload function shall have two stages. These stages shall be reported independently. The thermal overload function shall be user selectable between a line and a transformer. PTTR 1:

- Stage 1 shall be reported to:
  - The diameter control IED HMI;
  - The gateway (remote) and station HM; and,
  - IED internal disturbance recorder function (RBDR).

- Stage 2 shall be reported to:
  - The diameter control IED HMI;
  - The gateway (remote) and station HM; and,
  - IED internal disturbance recorder function (RBDR).

#### 3.18.3.2 Object 2 thermal overload detection - PTTR 2

PTTR 2 shall be used for object 2 line and transformer thermal overload functions. Depending on the algorithm, the LN describes either a temperature or a current (thermal model). The line or transformer thermal functions shall continuously measure the temperature and produce an output when a predetermined value is exceeded. The thermal overload function shall have two stages. These stages shall be reported independently. The thermal overload function shall be user selectable between a line and a transformer.

PTTR 2:

- Stage 1 shall be reported to:
  - The diameter control IED HMI;
  - The gateway (remote) and station HM; and,
  - IED internal disturbance recorder function (RBDR).
- Stage 2 shall be reported to:
  - The diameter control IED HMI;
  - The gateway (remote) and station HM; and,
  - IED internal disturbance recorder function (RBDR).

## 3.19 Disturbance recorder function: RDRE

### 3.19.1 Philosophy

The disturbance recorder function, at bay level, described as a requirement in IEC 61850-5 is decomposed into one LN class for analogue channels (RADR) and another LN class for binary channels (RBDR). The output refers to the “IEEE Standard Format for Transient Data Exchange (COMTRADE) for Power Systems” (IEC 60255-24). Disturbance recorders are logical devices built up with one instance of LN RADR or LN RBDR per channel.

The main protection device internal disturbance recorder shall have the capability to record the listed analogue and binary signals. The analogue traces and binary event information shall be displayed within a single window when the data is uploaded to the device’s operating and analysis software for post fault analysis purposes.

### 3.19.2 Rationale

The internal disturbance recorder function is required to record all analogue traces and binaries for the purpose of post fault analysis and to export in the recordings in comtrade format for fault play back purposes.

### 3.19.3 Design Requirements

The main protection device shall perform all the sequence of events and analogue event recording for that main protection system. When the protection device has detected a fault condition (operation of any one of the protection functions or an external trip input), causing the relay to close any one of its trip output contacts, the sequence of events (time on and time off) shall be logged, time stamped (to 1 millisecond resolution) and stored.

Any protection device failure or abnormality shall also be stored and accessible. The presentation of the sequence of events, device failure or device abnormality information shall be such that an inexperienced person can access and evaluate it easily. The analogue traces and sequence of events shall be displayed within a single window when the data is uploaded to the device's operating and analysis software for post fault analysis purposes.

The pre-fault, fault and post-fault durations shall be independently selectable and the set duration shall be sufficient to record an auto-reclose cycle.

#### 3.19.3.1 Disturbance recorder analogue channels: RADR

In addition to the channel number, all attributes needed for the COMTRADE file shall be provided for by data from the measured values. The "circuit component" and "phase identification" is provided by the instance identification of the LN RADR. Channels "1" to "n" are created by "1" to "n" instances.

Triggering by an analogue channel shall be independently selectable per channel. The triggering levels for (High/Low) for analogue quantities shall be independently selectable and also selectable to OFF (not permitted to trigger). All analogue channels shall be recorded independent on the trigger mode. Only the allocated (used) analogue channel shall be recorded. All the input analogue channels (per channel) and the measured analogue channels (e.g. summated current per phase, differential current per phase, bias current per phase, etc.) shall be available to be recorded.

#### 3.19.3.2 Disturbance recorder binary channels: RBDR

In addition to the channel number, all attributes needed for the COMTRADE file are provided by attributes of the binary input (subscribed from another LN). The "circuit component" and "phase identification" is provided by the instance identification of the LN RBDR. Channels "1" to "n" are created by "1" to "n" instances.

The main protection device internal disturbance recorder shall have the capability to record the listed binary signals. The analogue traces and binary event information shall be displayed within a single window when the data is uploaded to the device's operating and analysis software for post fault analysis purposes.

Triggering by a binary channel shall be independently selectable per channel. Triggering shall be selectable between a change from a logical 0 to a logical 1, logical 1 to a logical 0 and OFF (not permitted to trigger). All binary channels shall be recorded independent on the trigger mode. All binary channels shall be recorded independent on the triggering selection. Only the allocated (used) binary channel shall be recorded. All binary information that is required for post fault analysis shall be available to be recorded.

#### 3.19.3.3 External disturbance recorder

The external disturbance recorder is a separate device (not in the scope of this philosophy and housed separately). Alarms shall be routed from the line protection scheme to the external disturbance recorder. The external disturbance recorder will provide the interrogation supply (common positive) for the alarms.

When any one of the functions within the primary protection device asserts, the external disturbance recorder alarm contact outputs shall follow the operation of the protection function.

## 3.20 Time based event recording

### 3.20.1 Philosophy

All intelligent electronic devices shall allow for time based event recording.

### 3.20.2 Rationale

Time based event recording is essential for post fault analysis on a specific bay following a power system disturbance and for testing purposes.

### 3.20.3 Design Requirements

Event records shall be available within the disturbance recording comtrade file. The event shall be available on the IED for the purpose of post fault analysis and for testing purposes.

## 3.21 Automatic reclosing

### 3.21.1 Philosophy

The diameter control system shall include single- and three-pole automatic reclosing for all the circuit-breakers within the diameter. Auto-reclosing modes and cycles shall be user selectable. Auto-reclosing shall be user selectable (enable/disable) dependent on the object type that is connected to the diameter.

### 3.21.2 Rationale

The requirement for single- and three-pole automatic reclosing is in accordance with Eskom's policy of effecting single- and three-pole tripping on the lines in the transmission system.

Historically, as the transmission system was being built up, the emphasis was on returning a line to service as quickly as possible. Now, with a much more developed transmission system, this is no longer as critical. The emphasis has now moved on to the issue of power quality to customers. Therefore, a three-cycle reclosing sequence, i.e. only one reclose shot, is required which preserves single-pole tripping and three-pole automatic reclosing. For those situations which still warrant it, the five-cycle sequence must still be available. However, to accommodate the capability of the circuit-breaker and ratings of other affected items of plant, an additional, separately settable three-pole dead time timer is required for the three-pole shot within the five-cycle sequence.

### 3.21.3 Design Requirements

#### 3.21.3.1 Auto reclosing, bay 1 breaker, line 1 - RREC 1

The bay 1 auto-reclose function for line 1 within the diameter control device shall be capable of accepting both single-pole and three-pole initiations from the main protection devices depending upon the TNS switch selections. Additional single pole initiations shall be derived from the trip testing functions. Single pole reclose initiation from the single pole trip testing function shall only be possible when the diameter device is ready and selected for a single pole reclose cycle and the adjacent breaker(s) is in the three pole close position. The auto-reclose initiate signals shall be received via GOOSE from the line protection device and shall be supervised by the IEC61850 communications to be healthy.

Reclose initiation shall take the form of separate signals for single- and three-pole reclose initiates. A reclose block shall be initiated for all functions (protection device tripping functions) and commands (busstrip command and all external trip commands) which are not selected to initiate reclosing.

The close mode selections shall select the required reclose sequence. The diameter control device shall, depending on the chosen program, control the tripping mode of the line protection device. The line protection device shall be forced to trip three pole, irrespective of the type of fault, when the 'Three Pole Trip Select' GOOSE message are activated by the diameter control device. The activation of this signal shall be dependent on the reclose program selected.

Either, or both, line protection systems may initiate the bay 1 auto-reclose function within the diameter control device, dependent on the TNS switch selection and the master/slave mode selections. All automatic reclosing cycles shall commence immediately on (and not before) detecting that the bay 1 breaker has opened, and shall not wait for the initiate signal to reset first.

An automatic reclosing cycle (single- or three-pole) shall only commence if the initiate signal is received before expiry of a pre-set time window following opening of the bay 1 breaker. If received after expiry of the pre-set time window, no reclosing cycle shall commence.

The bay 1 auto-reclose function within the diameter control device shall revert to the lockout state whenever all three poles of the bay 1 breaker are detected to be open with no reclosing permitted. On detecting that all three poles are open:

- lockout shall occur after the pre-set time window if no reclose initiate signal has been received and/or no reclosing cycle has commenced; and
- immediate lockout shall occur, even if a reclose initiate signal is, or has already been, received, if:
  - the 'block reclosing' signal is high;
  - the 'permit three-pole reclosing' signal is low, i.e. three-pole reclosing is not permitted;
  - the 'permit no closing' signal is high; or,
  - no further reclosing shots are permitted.

Once in the lockout state, receipt of a reclose initiate signal shall not result in commencement of an automatic reclosing cycle. The lockout state shall only occur if all three poles of the bay 1 breaker are open, and not if only one-pole of the bay 1 breaker is open.

Whenever a bay 1 breaker three -pole reclosing cycle commences, an overall timer shall be started. If the closing command cannot be issued for whatever reason before this time has elapsed, the cycle in progress shall be stopped and the closing device shall revert immediately to the lockout state. For single-pole reclosing cycles, the overall timer shall also be started. However, in this case, if the closing command cannot be issued, other action, i.e. tripping of the other two poles by the pole discrepancy protection, is expected to occur well before the overall time elapses. When this occurs, on opening of the other two poles, the single-pole cycle in progress shall be stopped, and now, with all three poles open and no cycle in progress, the closing device shall revert immediately to the lockout state. To cater for the possibility that the other two poles may not be successfully opened, and if conditions remain such that the closing command cannot be issued, the cycle in progress shall be stopped when the overall time elapses. The closing device shall, however, not revert to the lockout state as all three poles of the bay 1 breaker will not be open.

The timing of the overall timer shall reset with the issue of a close output. If another shot is permitted, and occurs, within the reclosing sequence, the timing of the overall timer shall start again with the commencement of the next cycle. If lockout occurs before the overall time elapses, its timing shall reset when the lockout occurs. The lockout state shall be reset by the receipt of a bay 1 breaker manual close initiate signal.

One-pole automatic reclosing shall be permitted only when the 'permit 1-pole reclosing' signal is high; similarly, three-pole automatic reclosing shall be permitted only when the 'permit three-pole reclosing' signal is high. Manual closing shall always be permitted. When the 'permit no closing' signal is high, no automatic reclosing shall be permitted, manual closing shall be permitted. If any of the 'permit reclosing' signals are high at the same time as the 'permit no closing' signal, the 'permit no closing' signal shall take priority, preventing any reclosing and activating the three-pole only trip signal to the bay 1 breaker.

Fast three-pole reclosing shall be selected when the 'select fast three-pole reclosing' signal is high. If low, slow three-pole reclosing shall be selected.

The inhibit reclosing signal shall be established whenever the 'bay 1 breaker charged' signal is low, i.e. the bay 1 breaker is not charged.

For initial three-pole tripping, the bay 1 auto-reclose function shall provide a three-cycle reclosing sequence for permanent (uncleared on reclosing) faults. For initial single-pole tripping, the bay 1 auto-reclose function shall provide a selectable three- or five-cycle reclosing sequence for permanent faults. The three-cycle sequence shall be as follows: trip (single- or three-pole), reclose, trip (three-pole), lockout. The five-cycle sequence shall be as follows: trip (single-pole), reclose, trip (three-pole, even if the uncleared fault remains single-phase-to-ground), reclose, trip (three-pole), lockout. Even if fast three-pole reclosing is selected, the three-pole reclosing cycle in the five-cycle sequence following an unsuccessful single-pole reclose shall be a slow three-pole reclose.

For initial single-pole tripping, the three- or five cycle reclosing sequence shall be selected by way of a selection on the diameter control device.

The bay 1 auto-reclose function, when initiated and in progress, shall inhibit the tie bay auto-reclose function until successful closure of the bay 1 breaker and the bay 1 breaker remain in service. The tie bay breaker auto-reclose inhibit shall then be removed to permit closure by the tie bay auto-reclose function of the tie bay breaker (this can also be a user settable window). The bay 1 auto-reclose function shall not inhibit the tie bay auto-reclose function in the event that the bay 1 breaker was already in the open position when a fault occurred and the auto-reclose functions are initiated.

#### 3.21.3.1.1 Single pole auto-reclosing

Single-pole reclosing shall be permitted if only one pole of the bay 1 breaker has opened. Therefore, the single-pole automatic reclosing cycle shall commence (single-pole dead time started/cycle in progress started) following receipt of a single-pole reclose initiate signal, on detection that only one pole of the bay 1 breaker has opened. The cycle in progress shall reset when the close output is issued. The diameter control device shall issue the close output following expiry of the dead time without further delay provided that no inhibit signal is present to prevent closing.

Following a single-pole trip, it is expected that the single-pole reclose initiate signal will be received, i.e. if single-pole reclosing is not permitted, no single-pole tripping should have occurred. Therefore, it is not expected that the timing window following opening of the bay 1 breaker pole will expire without receipt of the initiate signal. However, if for some unexpected circumstance this input signal is not received, no reclosing cycle shall commence. The bay 1 breaker pole discrepancy protection will then eventually trip the other bay 1 breaker poles. At this time the closing device will detect all three bay 1 breaker poles to be open, and with no cycle in progress, shall revert immediately to the lockout state.

If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed, even if the dead time has elapsed. If the inhibit signal is removed before the dead time elapses, closing shall occur without further delay on expiry of the dead time. However, if by the time the dead time elapses, the inhibit signal has not yet been removed, the close output shall then be issued without further delay on removal of the inhibit signal. If the inhibit signal is not removed by expiry of the bay 1 breaker pole discrepancy time, the other two poles will once again be tripped by the bay 1 pole discrepancy protection. On detecting all three bay 1 breaker poles to be open, the 1-pole cycle in progress shall be stopped. Now, with no cycle in progress, and all three poles open, the closing device shall immediately revert to the lockout state.

If a block reclosing signal is received once the cycle in progress has commenced following single-pole tripping, the reclosing cycle (cycle in progress) shall immediately be stopped. Following the tripping of the other two poles by the bay 1 breaker pole discrepancy protection, the closing device shall once again revert immediately to the lockout state.

If single-pole reclosing is not permitted, but, for some reason, a single-pole reclose initiate signal is received, and only one-pole of the bay 1 breaker is detected to have opened, no single-pole reclosing cycle shall commence. The other poles will be tripped by the bay 1 breaker pole discrepancy protection, whereupon the closing device shall revert to the lockout state.

#### 3.21.3.1.2 Three-pole auto-reclosing

Three-pole reclosing shall only be permitted if all three poles of the bay 1 breaker have opened. Therefore, the thee-pole automatic reclosing cycle, fast or slow, shall commence (relevant three-pole dead time started/cycle in progress started) following receipt of a three-pole reclose initiate signal, on detection that all three poles of the bay 1 breaker have opened, provided that no condition exists which disallows three-pole reclosing, i.e. a condition which causes the closing device to revert immediately to the lockout state. The cycle in progress shall reset when the close output is issued.

If a block reclosing signal is received once the cycle in progress (fast or slow) has commenced, the reclosing cycle (cycle on progress) shall immediately be stopped, and the closing device shall revert immediately to the lockout state.

For slow three-pole reclosing, the close output shall be issued following expiry of the dead time in accordance with the permitted closing conditions set.

If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed, even if the dead time has elapsed. If no inhibit signal is present, or is removed before the dead time elapses, the close output shall be issued once the dead time has elapsed in accordance with the conditions set. However, if closing is prevented upon expiry of the dead time, it shall then be effected as soon as the inhibit signal has been removed, but once again in accordance with the conditions set. If the inhibit signal is not removed by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

If the set condition for reclosing and a synchronism check to be performed, the close output may not be issued until verification that the voltages are in synchronism has been concluded. If this verification is not concluded by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

For fast three-pole reclosing, the diameter control device shall issue the close output following expiry of the dead time without further delay provided that no inhibit signal is present to prevent closing. If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed. If the inhibit signal is removed before the dead time elapses, closing shall occur without further delay on expiry of the dead time. For fast three-pole reclosing, the close output is required immediately following expiry of the dead time. Therefore, if the inhibit signal is not removed, preventing the close output from being issued immediately on expiry of the dead time, the bay closing device shall automatically revert to a slow three-pole reclose, with the amount of dead time elapsed equal to the slow dead time.

If a single-pole cycle is initiated, but all three bay 1 breaker poles are detected to be open, the single-pole cycle shall be blocked, or stopped, and a three-pole reclosing cycle initiated, if three-pole reclosing is permitted. If three-pole reclosing is not permitted, the closing device shall immediately revert to the lockout state. Furthermore, a single-pole reclosing cycle, already in progress, shall automatically convert from the single-pole to a three-pole cycle (single-pole cycle stopped, three-pole cycle initiated), if three-pole reclosing is permitted, for a subsequent three-pole trip due to, e.g. an evolving fault, or a fault occurring during the single-pole open period. Once again, if three-pole reclosing is not permitted, the closing device shall immediately revert to the lockout state. For both circumstances, if a five-cycle sequence has been selected, the sequence shall convert to the three-cycle sequence. Furthermore, for the latter circumstance, even if three-pole fast reclosing is selected, the closing device shall perform a slow three-pole reclose.

On issuing the close output (for manual closing, or automatic reclosing (single- or three-pole)), the closing device shall start the reclaim time. If, following single-pole reclosing, with the five-cycle sequence selected, and three-pole reclosing permitted, a recurring fault, and subsequent reclose initiation, occurs within the reclaim time, this shall constitute the next step in the five-cycle sequence. As before, the reclosing cycle shall commence if all conditions governing commencement of a reclosing cycle are favourable. Commencement of the reclosing cycle shall reset the reclaim time, which shall be started again when, following the expiry of the dead time, and for all closing conditions favourable, the close output is issued.

New faults, with subsequent reclose initiation, occurring after the reclaim time has expired, shall constitute the first step in a new three- or five-cycle sequence.

If the bay 1 closing function detects, within the reclaim time, that all three poles of the bay 1 breaker have re-opened following manual closure, or three-pole automatic reclosure, the bay closing device shall revert immediately to the lockout state, irrespective of the presence of any reclose initiate signal, ensuring no further reclosing attempts are made. However, if the bay 1 closing function detects, within the reclaim time, that all three poles of the bay 1 breaker to have re-opened following a single-pole automatic reclosure, lockout shall only be established, irrespective of the presence of any reclose initiate signal if no further reclosing shot is permitted, i.e. the three-cycle reclosing sequence is selected. If the five-cycle reclosing sequence is selected, lockout must not be established, allowing the three-pole reclosing cycle to commence.

Establishing the lockout state shall reset the timing of the reclaim time.

Following receipt of a manual close initiate signal, the manual close cycle shall commence (manual close cycle in progress) provided that all three poles of the bay 1 breaker are open, and the lockout state has been successfully reset. Receipt of the manual close initiate signal shall reset the lockout state provided that closing is permitted (the 'permit no closing' binary input is not high), and manual closing is not blocked (the 'block manual close' binary input is not high). If either of these binary inputs is high, the lockout state shall not be reset, and no manual close cycle shall commence. Once commenced, a manual close cycle in progress shall reset when the close output is issued.

The overall timer shall also be started whenever a manual close cycle commences. If closing cannot be effected for whatever reason before this time elapses, i.e.:

- the bay 1 breaker is not charged ('bay 1 breaker charged' binary input low);
- the set conditions for closing have not been met;
- synchronism could not be concluded; or,
- the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

If a block manual closing signal is received with a manual closing cycle already in progress, i.e. the manual closing cycle has commenced, but the close output has not yet been issued, the manual closing cycle shall immediately be stopped, and the closing device shall immediately revert to the lockout state.

A manual closing cycle, initiated by the receipt of a manual close input signal, shall be permitted to commence in parallel with a three-pole reclosing cycle already in progress (dead time elapsed), for which the required closing conditions have not yet been met, and for which the overall time has not yet elapsed. If the conditions for manual closing are met, which may be different to those for three-pole reclosing, a close output shall be issued. Issuing of the close output shall reset both cycles in progress. Commencement of the manual closing cycle shall not reset the three-pole cycle in progress, or restart the timing of the overall timer. If the overall time elapses without the close output being issued, both cycles in progress shall be reset, and the closing device shall immediately revert to the lockout state.

The close output, for manual closing, or single- or three-pole automatic reclosing, shall have a fixed (settable, but fixed once set) duration. Once issued, the fixed duration of this output shall not be compromised for any reason, e.g. the subsequent receipt of inhibit/block input signals.

The closing device shall be able to dynamically select the main protection systems for three-pole tripping only by means of a GOOSE signal for each main protection system. The required signal shall be sustained as logic 1 and a logic 0 state whenever single-pole tripping is allowed. Whenever single-pole tripping is disallowed, i.e. only three-pole tripping is allowed, this signal shall be set to the logic 1 state. Three-pole only tripping shall be selected:

- from reset of the single-pole initiate signal until reset of the reclaim time;
- from start of the three-pole reclosing cycle (cycle in progress) until reset of the reclaim time;
- from establishment of the lockout state until reset of the reclaim time following manual closing;
- whenever the 'inhibit reclosing' binary input is high;
- whenever the 'block reclosing' binary input is high (if the block reclosing input is received during a single-pole cycle in progress before reset of the single-pole initiate signal, three-pole tripping may follow if the three-pole only feedback to the protection is timeously received; otherwise, if after the reset of the single-pole initiate signal, the pole disagreement protection will provide the three pole tripping – no reclosing will occur for either of these circumstances);
- whenever single-pole tripping is not permitted, i.e. the 'permit single-pole tripping' GOOSE signal is low (not selected), or the 'permit no closing' signal is high (selected); or,
- whenever the diameter control device is out-of-service.

Bay 1 Breaker Trip Testing (red phase, white phase and blue phase):

- Trip testing is only permitted when the bay 1 breaker is 3-pole closed and healthy;
- Trip testing is only permitted when the tie bay Breaker is 3-pole closed; and,
- Bay 1 auto-reclose is ready for a 1-pole auto-reclose cycle.

#### 3.21.3.2 Auto reclosing, tie bay breaker, line 1 - RREC 3

The tie bay auto-reclose function for line 1 within the diameter control device shall be capable of accepting three-pole initiations from the main protection devices depending upon the TNS switch selections. Additional single pole initiations shall be derived from the trip testing functions. Single pole reclose initiation from the single pole trip testing function shall only be possible when the diameter device is ready and selected for a single pole reclose cycle and the adjacent breaker(s) is in the three pole close position. The auto-reclose initiate signals shall be received via GOOSE from the line protection device and shall be supervised by the IEC61850 communications to be healthy.

Reclose initiation shall take the form of separate signals for single- and three-pole reclose initiates. A reclose block shall be initiated for all functions (protection device tripping functions) and commands (busstrip command and all external trip commands) which are not selected to initiate reclosing.

The close mode selections shall select the required reclose sequence.

Either, or both, line protection systems may initiate the tie bay auto-reclose function within the diameter control device, dependent on the TNS switch selection and the master/slave mode selections. All automatic reclosing cycles shall commence immediately on (and not before) detecting that the tie bay breaker has opened, and shall not wait for the initiate signal to reset first. The three-pole dead time, if permitted and selected, of the tie bay auto-reclose function for line 1 shall be started when the tie bay breaker in in the three pole open position and the tie bay auto-reclose function for line 2 is in progress.

An automatic reclosing cycle (three-pole) shall only commence if the initiate signal is received before expiry of a pre-set time window following opening of the tie bay breaker. If received after expiry of the pre-set time window, no reclosing cycle shall commence.

The tie bay auto-reclose function within the diameter control device shall revert to the lockout state whenever all three poles of the tie bay breaker are detected to be open with no reclosing permitted. On detecting that all three poles are open:

- lockout shall occur after the pre-set time window if no reclose initiate signal has been received and/or no reclosing cycle has commenced; and
- immediate lockout shall occur, even if a reclose initiate signal is, or has already been, received, if:
    - o the ‘block reclosing’ signal is high;
    - o the ‘permit three-pole reclosing’ signal is low, i.e. three-pole reclosing is not permitted;
    - o the ‘permit no closing’ signal is high; or,
    - o no further reclosing shots are permitted.

Once in the lockout state, receipt of a reclose initiate signal shall not result in commencement of an automatic reclosing cycle. The lockout state shall only occur if all three poles of the tie bay breaker are open, and not if only one-pole of the tie bay breaker is open.

Whenever a tie bay breaker three-pole reclosing cycle commences, an overall timer shall be started. If the closing command cannot be issued for whatever reason before this time has elapsed, the cycle in progress shall be stopped and the closing device shall revert immediately to the lockout state. To cater for the possibility that the other one or two poles may not be successfully opened, and if conditions remain such that the closing command cannot be issued, the cycle in progress shall be stopped when the overall time elapses. The closing device shall, however, not revert to the lockout state as all three poles of the tie bay breaker will not be open.

The timing of the overall timer shall reset with the issue of a close output. If another shot is permitted, and occurs, within the reclosing sequence, the timing of the overall timer shall start again with the commencement of the next cycle. If lockout occurs before the overall time elapses, its timing shall reset when the lockout occurs. The lockout state shall be reset by the receipt of a tie bay breaker manual close initiate signal.

Three-pole automatic reclosing shall be permitted only when the ‘permit three-pole reclosing’ signal is high. Manual closing shall always be permitted. When the ‘permit no closing’ signal is high, no automatic reclosing shall be permitted, manual closing shall be permitted. If any of the ‘permit reclosing’ signals are high at the same time as the ‘permit no closing’ signal, the ‘permit no closing’ signal shall take priority, preventing any reclosing and activating the three-pole only trip signal to the tie bay breaker.

Fast three-pole reclosing shall be selected when the ‘select fast three-pole reclosing’ signal is high. If low, slow three-pole reclosing shall be selected.

The inhibit reclosing signal shall be established whenever the ‘tie bay breaker charged’ signal is low, i.e. the tie bay breaker is not charged and the bay 1 auto-reclose function is in progress (bay 1 breaker not successfully closed and remain closed).

For initial three-pole tripping, the tie bay auto-reclose function shall provide a five-cycle reclosing sequence for permanent (uncleared on reclosing) faults. For initial three-pole tripping, the tie bay auto-reclose function shall provide a selectable three- or five-cycle reclosing sequence for permanent faults. The three-cycle sequence shall be as follows: trip (three-pole), reclose, trip (three-pole), lockout. The five-cycle sequence shall be as follows: trip (three-pole), reclose, trip (three-pole), reclose, trip (three-pole) and lockout. Even if fast three-pole reclosing is selected, the three-pole reclosing cycle in the five-cycle sequence following an unsuccessful three-pole fast reclose shall be a slow three-pole reclose.

For three-pole tripping, the three- or five cycle reclosing sequence shall be selected by way of a selection on the diameter control device. The tie bay breaker auto-reclose cycles shall follow the selection for the bay 1 breaker auto-reclose cycle selection.

The tie bay auto-reclose function, when initiated and in progress, shall be inhibit the bay 1 auto-reclose function until successful closure of the bay 1 breaker and the bay 1 breaker remain in service. The tie bay breaker auto-reclose inhibit shall then be removed to permit closure by the tie bay auto-reclose function of the tie bay breaker (this can also be a user settable window). The tie bay auto-reclose function shall not inhibit the tie bay auto-reclose function in the event that the tie bay breaker was already in the open position when a fault occurred and the auto-reclose functions are initiated.

#### 3.21.3.2.1 Three-pole auto-reclosing

Three-pole reclosing shall only be permitted if all three poles of the tie bay breaker have opened. Therefore, the thee-pole automatic reclosing cycle, fast or slow, shall commence (relevant three-pole dead time started/cycle in progress started) following receipt of a three-pole reclose initiate signal, on detection that all three poles of the tie bay breaker have opened, provided that no condition exists which disallows three-pole reclosing, i.e. a condition which causes the closing device to revert immediately to the lockout state. The cycle in progress shall reset when the close output is issued.

If a block reclosing signal is received once the cycle in progress (fast or slow) has commenced, the reclosing cycle (cycle on progress) shall immediately be stopped, and the closing device shall revert immediately to the lockout state.

For slow three-pole reclosing, the close output shall be issued following expiry of the dead time in accordance with the permitted closing conditions set.

If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed, even if the dead time has elapsed. If no inhibit signal is present, or is removed before the dead time elapses, the close output shall be issued once the dead time has elapsed in accordance with the conditions set. However, if closing is prevented upon expiry of the dead time, it shall then be effected as soon as the inhibit signal has been removed, but once again in accordance with the conditions set. If the inhibit signal is not removed by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

If the set condition for reclosing and a synchronism check to be performed, the close output may not be issued until verification that the voltages are in synchronism has been concluded. If this verification is not concluded by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

For fast three-pole reclosing, the diameter control device shall issue the close output following expiry of the dead time without further delay provided that no inhibit signal is present to prevent closing. If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed. If the inhibit signal is removed before the dead time elapses, closing shall occur without further delay on expiry of the dead time. For fast three-pole reclosing, the close output is required immediately following expiry of the dead time. Therefore, if the inhibit signal is not removed, preventing the close output from being issued immediately on expiry of the dead time, the bay closing device shall automatically revert to a slow three-pole reclose, with the amount of dead time elapsed equal to the slow dead time.

On issuing the close output (for manual closing, or automatic reclosing (three-pole)), the closing device shall start the reclaim time. If, with the five-cycle sequence selected, and three-pole reclosing permitted, a recurring fault, and subsequent reclose initiation, occurs within the reclaim time, this shall constitute the next step in the five-cycle sequence. As before, the reclosing cycle shall commence if all conditions governing commencement of a reclosing cycle are favourable. Commencement of the reclosing cycle shall reset the reclaim time, which shall be started again when, following the expiry of the dead time, and for all closing conditions favourable, the close output is issued.

New faults, with subsequent reclose initiation, occurring after the reclaim time has expired, shall constitute the first step in a new three- or five-cycle sequence.

If the tie bay closing function detects, within the reclaim time, that all three poles of the tie bay breaker have re-opened following manual closure, or three-pole automatic reclosure, the bay closing device shall revert immediately to the lockout state, irrespective of the presence of any reclose initiate signal, ensuring no further reclosing attempts are made. If the five-cycle reclosing sequence is selected, lockout must not be established, allowing the three-pole reclosing cycle to commence.

Establishing the lockout state shall reset the timing of the reclaim time.

Following receipt of a manual close initiate signal, the manual close cycle shall commence (manual close cycle in progress) provided that all three poles of the tie bay breaker are open, and the lockout state has been successfully reset. Receipt of the manual close initiate signal shall reset the lockout state provided that closing is permitted (the ‘permit no closing’ binary input is not high), and manual closing is not blocked (the ‘block manual close’ binary input is not high). If either of these binary inputs is high, the lockout state shall not be reset, and no manual close cycle shall commence. Once commenced, a manual close cycle in progress shall reset when the close output is issued.

The overall timer shall also be started whenever a manual close cycle commences. If closing cannot be effected for whatever reason before this time elapses, i.e.:

- the tie bay breaker is not charged (‘tie bay breaker charged’ binary input low);
- the set conditions for closing have not been met;
- synchronism could not be concluded;
- the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state; or,
- the inhibit signal from the bay 1 auto-reclose in progress not removed.

If a block manual closing signal is received with a manual closing cycle already in progress, i.e. the manual closing cycle has commenced, but the close output has not yet been issued, the manual closing cycle shall immediately be stopped, and the closing device shall immediately revert to the lockout state.

A manual closing cycle, initiated by the receipt of a manual close input signal, shall be permitted to commence in parallel with a three-pole reclosing cycle already in progress (dead time elapsed), for which the required closing conditions have not yet been met, and for which the overall time has not yet elapsed. If the conditions for manual closing are met, which may be different to those for three-pole reclosing, a close output shall be issued. Issuing of the close output shall reset both cycles in progress. Commencement of the manual closing cycle shall not reset the three-pole cycle in progress, or restart the timing of the overall timer. If the overall time elapses without the close output being issued, both cycles in progress shall be reset, and the closing device shall immediately revert to the lockout state.

The close output, for manual closing, or three-pole automatic reclosing, shall have a fixed (settable, but fixed once set) duration. Once issued, the fixed duration of this output shall not be compromised for any reason, e.g. the subsequent receipt of inhibit/block input signals.

The tie bay auto-reclose function for line 1, when started or in progress within any one of the cycles, shall divert to a lock-out state in the event that the tie bay auto-reclose function for line 2 receives an initiate signal. For this condition the tie bay auto-reclose reclaim and overall times for line 1 shall be stopped.

Tie Bay Breaker Trip Testing (red phase, white phase and blue phase):

- Trip testing is only permitted when the tie bay breaker is 3-pole closed and healthy;
- Trip testing is only permitted when the bay 1 breaker and/or bay 2 breaker is 3-pole closed; and,
- Tie Bay auto-reclose is ready for a 1-pole auto-reclose cycle.

#### 3.21.3.3 Auto reclosing, bay 2 breaker, line 2 - RREC 2

The bay 2 auto-reclose function for line 2 within the diameter control device shall be capable of accepting both single-pole and three-pole initiations from the main protection devices depending upon the TNS switch selections. Additional single pole initiations shall be derived from the trip testing functions. Single pole reclose initiation from the single pole trip testing function shall only be possible when the diameter device is ready and selected for a single pole reclose cycle and the adjacent breaker(s) is in the three pole close position. The auto-reclose initiate signals shall be received via GOOSE from the line protection device and shall be supervised by the IEC61850 communications to be healthy.

Reclose initiation shall take the form of separate signals for single- and three-pole reclose initiates. A reclose block shall be initiated for all functions (protection device tripping functions) and commands (busstrip command and all external trip commands) which are not selected to initiate reclosing.

The close mode selections shall select the required reclose sequence. The diameter control device shall, depending on the chosen program, control the tripping mode of the line protection device. The line protection device shall be forced to trip three pole, irrespective of the type of fault, when the 'Three Pole Trip Select' GOOSE message are activated by the diameter control device. The activation of this signal shall be dependent on the reclose program selected.

Either, or both, line protection systems may initiate the bay 2 auto-reclose function within the diameter control device, dependent on the TNS switch selection and the master/slave mode selections. All automatic reclosing cycles shall commence immediately on (and not before) detecting that the bay 2 breaker has opened, and shall not wait for the initiate signal to reset first.

An automatic reclosing cycle (single- or three-pole) shall only commence if the initiate signal is received before expiry of a pre-set time window following opening of the bay 2 breaker. If received after expiry of the pre-set time window, no reclosing cycle shall commence.

The bay 2 auto-reclose function within the diameter control device shall revert to the lockout state whenever all three poles of the bay 2 breaker are detected to be open with no reclosing permitted. On detecting that all three poles are open:

- lockout shall occur after the pre-set time window if no reclose initiate signal has been received and/or no reclosing cycle has commenced; and

- immediate lockout shall occur, even if a reclose initiate signal is, or has already been, received, if:
  - the 'block reclosing' signal is high;
  - the 'permit three-pole reclosing' signal is low, i.e. three-pole reclosing is not permitted;
  - the 'permit no closing' signal is high; or,
  - no further reclosing shots are permitted.

Once in the lockout state, receipt of a reclose initiate signal shall not result in commencement of an automatic reclosing cycle. The lockout state shall only occur if all three poles of the bay 2 breaker are open, and not if only one-pole of the bay 2 breaker is open.

Whenever a bay 2 breaker three-pole reclosing cycle commences, an overall timer shall be started. If the closing command cannot be issued for whatever reason before this time has elapsed, the cycle in progress shall be stopped and the closing device shall revert immediately to the lockout state. For single-pole reclosing cycles, the overall timer shall also be started. However, in this case, if the closing command cannot be issued, other action, i.e. tripping of the other two poles by the pole discrepancy protection, is expected to occur well before the overall time elapses. When this occurs, on opening of the other two poles, the 1-pole cycle in progress shall be stopped, and now, with all three poles open and no cycle in progress, the closing device shall revert immediately to the lockout state. To cater for the possibility that the other two poles may not be successfully opened, and if conditions remain such that the closing command cannot be issued, the cycle in progress shall be stopped when the overall time elapses. The closing device shall, however, not revert to the lockout state as all three poles of the bay 2 breaker will not be open.

The timing of the overall timer shall reset with the issue of a close output. If another shot is permitted, and occurs, within the reclosing sequence, the timing of the overall timer shall start again with the commencement of the next cycle. If lockout occurs before the overall time elapses, its timing shall reset when the lockout occurs. The lockout state shall be reset by the receipt of a bay 2 breaker manual close initiate signal.

One-pole automatic reclosing shall be permitted only when the 'permit single-pole reclosing' signal is high; similarly, three-pole automatic reclosing shall be permitted only when the 'permit three-pole reclosing' signal is high. Manual closing shall always be permitted. When the 'permit no closing' signal is high, no automatic reclosing shall be permitted, manual closing shall be permitted. If any of the 'permit reclosing' signals are high at the same time as the 'permit no closing' signal, the 'permit no closing' signal shall take priority, preventing any reclosing and activating the three-pole only trip signal to the bay 2 breaker.

Fast three-pole reclosing shall be selected when the 'select fast three-pole reclosing' signal is high. If low, slow three-pole reclosing shall be selected.

The inhibit reclosing signal shall be established whenever the 'bay 2 breaker charged' signal is low, i.e. the bay 2 breaker is not charged.

For initial three-pole tripping, the bay 2 auto-reclose function shall provide a three-cycle reclosing sequence for permanent (uncleared on reclosing) faults. For initial single-pole tripping, the bay 2 auto-reclose function shall provide a selectable three- or five-cycle reclosing sequence for permanent faults. The three-cycle sequence shall be as follows: trip (single- or three-pole), reclose, trip (three-pole), lockout. The five-cycle sequence shall be as follows: trip (single-pole), reclose, trip (three-pole, even if the uncleared fault remains single-phase-to-ground), reclose, trip (three-pole), lockout. Even if fast three-pole reclosing is selected, the three-pole reclosing cycle in the five-cycle sequence following an unsuccessful single-pole reclose shall be a slow three-pole reclose.

For initial single-pole tripping, the three- or five cycle reclosing sequence shall be selected by way of a selection on the diameter control device.

The bay 2 auto-reclose function, when initiated and in progress, shall inhibit the tie bay auto-reclose function until successful closure of the bay 2 breaker and the bay 2 breaker remain in service. The tie bay breaker auto-reclose inhibit shall then be removed to permit closure by the tie bay auto-reclose function of the tie bay breaker (this can also be a user settable window). The bay 2 auto-reclose function shall not inhibit the tie bay auto-reclose function in the event that the bay 2 breaker was already in the open position when a fault occurred and the auto-reclose functions are initiated.

#### 3.21.3.3.1 Single pole auto-reclosing

Single-pole reclosing shall be permitted if only one pole of the bay 2 breaker has opened. Therefore, the single-pole automatic reclosing cycle shall commence (single-pole dead time started/cycle in progress started) following receipt of a single-pole reclose initiate signal, on detection that only one pole of the bay 2 breaker has opened. The cycle in progress shall reset when the close output is issued. The diameter control device shall issue the close output following expiry of the dead time without further delay provided that no inhibit signal is present to prevent closing.

Following a single-pole trip, it is expected that the single-pole reclose initiate signal will be received, i.e. if single-pole reclosing is not permitted, no single-pole tripping should have occurred. Therefore, it is not expected that the timing window following opening of the bay 2 breaker pole will expire without receipt of the initiate signal. However, if for some unexpected circumstance this input signal is not received, no reclosing cycle shall commence. The bay 2 breaker pole discrepancy protection will then eventually trip the other bay 2 breaker poles. At this time the closing device will detect all three bay 2 breaker poles to be open, and with no cycle in progress, shall revert immediately to the lockout state.

If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed, even if the dead time has elapsed. If the inhibit signal is removed before the dead time elapses, closing shall occur without further delay on expiry of the dead time. However, if by the time the dead time elapses, the inhibit signal has not yet been removed, the close output shall then be issued without further delay on removal of the inhibit signal. If the inhibit signal is not removed by expiry of the bay 2 breaker pole discrepancy time, the other two poles will once again be tripped by the bay 2 pole discrepancy protection. On detecting all three bay 2 breaker poles to be open, the 1-pole cycle in progress shall be stopped. Now, with no cycle in progress, and all three poles open, the closing device shall immediately revert to the lockout state.

If a block reclosing signal is received once the cycle in progress has commenced following single-pole tripping, the reclosing cycle (cycle in progress) shall immediately be stopped. Following the tripping of the other two poles by the bay 2 breaker pole discrepancy protection, the closing device shall once again revert immediately to the lockout state.

If single-pole reclosing is not permitted, but, for some reason, a single-pole reclose initiate signal is received, and only one-pole of the bay 2 breaker is detected to have opened, no single-pole reclosing cycle shall commence. The other poles will be tripped by the bay 2 breaker pole discrepancy protection, whereupon the closing device shall revert to the lockout state.

#### 3.21.3.3.2 Three-pole auto-reclosing

Three-pole reclosing shall only be permitted if all three poles of the bay 2 breaker have opened. Therefore, the thee-pole automatic reclosing cycle, fast or slow, shall commence (relevant three-pole dead time started/cycle in progress started) following receipt of a three-pole reclose initiate signal, on detection that all three poles of the bay 2 breaker have opened, provided that no condition exists which disallows three-pole reclosing, i.e. a condition which causes the closing device to revert immediately to the lockout state. The cycle in progress shall reset when the close output is issued.

If a block reclosing signal is received once the cycle in progress (fast or slow) has commenced, the reclosing cycle (cycle on progress) shall immediately be stopped, and the closing device shall revert immediately to the lockout state.

For slow three-pole reclosing, the close output shall be issued following expiry of the dead time in accordance with the permitted closing conditions set.

If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed, even if the dead time has elapsed. If no inhibit signal is present, or is removed before the dead time elapses, the close output shall be issued once the dead time has elapsed in accordance with the conditions set. However, if closing is prevented upon expiry of the dead time, it shall then be effected as soon as the inhibit signal has been removed, but once again in accordance with the conditions set. If the inhibit signal is not removed by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

If the set condition for reclosing and a synchronism check to be performed, the close output may not be issued until verification that the voltages are in synchronism has been concluded. If this verification is not concluded by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

For fast three-pole reclosing, the diameter control device shall issue the close output following expiry of the dead time without further delay provided that no inhibit signal is present to prevent closing. If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed. If the inhibit signal is removed before the dead time elapses, closing shall occur without further delay on expiry of the dead time. For fast three-pole reclosing, the close output is required immediately following expiry of the dead time. Therefore, if the inhibit signal is not removed, preventing the close output from being issued immediately on expiry of the dead time, the bay closing device shall automatically revert to a slow three-pole reclose, with the amount of dead time elapsed equal to the slow dead time.

If a single-pole cycle is initiated, but all three bay 2 breaker poles are detected to be open, the single-pole cycle shall be blocked, or stopped, and a three-pole reclosing cycle initiated, if three-pole reclosing is permitted. If three-pole reclosing is not permitted, the closing device shall immediately revert to the lockout state. Furthermore, a single-pole reclosing cycle, already in progress, shall automatically convert from the single-pole to a three-pole cycle (single-pole cycle stopped, three-pole cycle initiated), if three-pole reclosing is permitted, for a subsequent three-pole trip due to, e.g. an evolving fault, or a fault occurring during the single-pole open period. Once again, if three-pole reclosing is not permitted, the closing device shall immediately revert to the lockout state. For both circumstances, if a five-cycle sequence has been selected, the sequence shall convert to the three-cycle sequence. Furthermore, for the latter circumstance, even if three-pole fast reclosing is selected, the closing device shall perform a slow three-pole reclose.

On issuing the close output (for manual closing, or automatic reclosing (single- or three-pole)), the closing device shall start the reclaim time. If, following single-pole reclosing, with the five-cycle sequence selected, and three-pole reclosing permitted, a recurring fault, and subsequent reclose initiation, occurs within the reclaim time, this shall constitute the next step in the five-cycle sequence. As before, the reclosing cycle shall commence if all conditions governing commencement of a reclosing cycle are favourable. Commencement of the reclosing cycle shall reset the reclaim time, which shall be started again when, following the expiry of the dead time, and for all closing conditions favourable, the close output is issued.

New faults, with subsequent reclose initiation, occurring after the reclaim time has expired, shall constitute the first step in a new three- or five-cycle sequence.

If the bay 2 closing function detects, within the reclaim time, that all three poles of the bay 2 breaker have re-opened following manual closure, or three-pole automatic reclosure, the bay closing device shall revert immediately to the lockout state, irrespective of the presence of any reclose initiate signal, ensuring no further reclosing attempts are made. However, if the bay 2 closing function detects, within the reclaim time, that all three poles of the bay 2 breaker to have re-opened following a single-pole automatic reclosure, lockout shall only be established, irrespective of the presence of any reclose initiate signal if no further reclosing shot is permitted, i.e. the three-cycle reclosing sequence is selected. If the five-cycle reclosing sequence is selected, lockout must not be established, allowing the three-pole reclosing cycle to commence.

Establishing the lockout state shall reset the timing of the reclaim time.

Following receipt of a manual close initiate signal, the manual close cycle shall commence (manual close cycle in progress) provided that all three poles of the bay 2 breaker are open, and the lockout state has been successfully reset. Receipt of the manual close initiate signal shall reset the lockout state provided that closing is permitted (the 'permit no closing' binary input is not high), and manual closing is not blocked (the 'block manual close' binary input is not high). If either of these binary inputs is high, the lockout state shall not be reset, and no manual close cycle shall commence. Once commenced, a manual close cycle in progress shall reset when the close output is issued.

The overall timer shall also be started whenever a manual close cycle commences. If closing cannot be effected for whatever reason before this time elapses, i.e.:

- the bay 2 breaker is not charged ('bay 2 breaker charged' binary input low);
- the set conditions for closing have not been met;
- synchronism could not be concluded; or,
- the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

If a block manual closing signal is received with a manual closing cycle already in progress, i.e. the manual closing cycle has commenced, but the close output has not yet been issued, the manual closing cycle shall immediately be stopped, and the closing device shall immediately revert to the lockout state.

A manual closing cycle, initiated by the receipt of a manual close input signal, shall be permitted to commence in parallel with a three-pole reclosing cycle already in progress (dead time elapsed), for which the required closing conditions have not yet been met, and for which the overall time has not yet elapsed. If the conditions for manual closing are met, which may be different to those for three-pole reclosing, a close output shall be issued. Issuing of the close output shall reset both cycles in progress. Commencement of the manual closing cycle shall not reset the three-pole cycle in progress, or restart the timing of the overall timer. If the overall time elapses without the close output being issued, both cycles in progress shall be reset, and the closing device shall immediately revert to the lockout state.

The close output, for manual closing, or single- or three-pole automatic reclosing, shall have a fixed (settable, but fixed once set) duration. Once issued, the fixed duration of this output shall not be compromised for any reason, e.g. the subsequent receipt of inhibit/block input signals.

The closing device shall be able to dynamically select the main protection systems for three-pole tripping only by means of a GOOSE signal for each main protection system. The required signal shall be sustained as logic 1 and a logic 0 state whenever single-pole tripping is allowed. Whenever single-pole tripping is disallowed, i.e. only three-pole tripping is allowed, this signal shall be set to the logic 1 state. Three-pole only tripping shall be selected:

- from reset of the single-pole initiate signal until reset of the reclaim time;
- from start of the three-pole reclosing cycle (cycle in progress) until reset of the reclaim time;
- from establishment of the lockout state until reset of the reclaim time following manual closing;
- whenever the 'inhibit reclosing' binary input is high;
- whenever the 'block reclosing' binary input is high (if the block reclosing input is received during a single-pole cycle in progress before reset of the single-pole initiate signal, three-pole tripping may follow if the three-pole only feedback to the protection is timeously received; otherwise, if after the reset of the single-pole initiate signal, the pole disagreement protection will provide the three pole tripping – no reclosing will occur for either of these circumstances);
- whenever single-pole tripping is not permitted, i.e. the 'permit single-pole tripping' GOOSE signal is low (not selected), or the 'permit no closing' signal is high (selected); or,
- whenever the diameter control device is out-of-service.

Bay 2 Breaker Trip Testing (red phase, white phase and blue phase):

- Trip testing is only permitted when the bay 2 breaker is 3-pole closed and healthy;
- Trip testing is only permitted when the tie bay Breaker is 3-pole closed; and,
- Bay 2 auto-reclose is ready for a 1-pole auto-reclose cycle.

#### 3.21.3.4 Auto reclosing, tie bay breaker, line 2 - RREC 4

The tie bay auto-reclose function for line 2 within the diameter control device shall be capable of accepting three-pole initiations from the main protection devices depending upon the TNS switch selections. Additional single pole initiations shall be derived from the trip testing functions. Single pole reclose initiation from the single pole trip testing function shall only be possible when the diameter device is ready and selected for a single pole reclose cycle and the adjacent breaker(s) is in the three pole close position. The auto-reclose initiate signals shall be received via GOOSE from the line protection device and shall be supervised by the IEC61850 communications to be healthy.

Reclose initiation shall take the form of separate signals for single- and three-pole reclose initiates. A reclose block shall be initiated for all functions (protection device tripping functions) and commands (busstrip command and all external trip commands) which are not selected to initiate reclosing.

The close mode selections shall select the required reclose sequence.

Either, or both, line protection systems may initiate the tie bay auto-reclose function within the diameter control device, dependent on the TNS switch selection and the master/slave mode selections. All automatic reclosing cycles shall commence immediately on (and not before) detecting that the tie bay breaker has opened, and shall not wait for the initiate signal to reset first. The three-pole dead time, if permitted and selected, of the tie bay auto-reclose function for line 2 shall be started when the tie bay breaker in in the three pole open position and the tie bay auto-reclose function for line 1 is in progress.

An automatic reclosing cycle (three-pole) shall only commence if the initiate signal is received before expiry of a pre-set time window following opening of the tie bay breaker. If received after expiry of the pre-set time window, no reclosing cycle shall commence.

The tie bay auto-reclose function within the diameter control device shall revert to the lockout state whenever all three poles of the tie bay breaker are detected to be open with no reclosing permitted. On detecting that all three poles are open:

- lockout shall occur after the pre-set time window if no reclose initiate signal has been received and/or no reclosing cycle has commenced; and
- immediate lockout shall occur, even if a reclose initiate signal is, or has already been, received, if:
    - the ‘block reclosing’ signal is high;
    - the ‘permit three-pole reclosing’ signal is low, i.e. three-pole reclosing is not permitted;
    - the ‘permit no closing’ signal is high; or,
    - no further reclosing shots are permitted.

Once in the lockout state, receipt of a reclose initiate signal shall not result in commencement of an automatic reclosing cycle. The lockout state shall only occur if all three poles of the tie bay breaker are open, and not if only one-pole of the tie bay breaker is open.

Whenever a tie bay breaker three-pole reclosing cycle commences, an overall timer shall be started. If the closing command cannot be issued for whatever reason before this time has elapsed, the cycle in progress shall be stopped and the closing device shall revert immediately to the lockout state. To cater for the possibility that the other one or two poles may not be successfully opened, and if conditions remain such that the closing command cannot be issued, the cycle in progress shall be stopped when the overall time elapses. The closing device shall, however, not revert to the lockout state as all three poles of the tie bay breaker will not be open.

The timing of the overall timer shall reset with the issue of a close output. If another shot is permitted, and occurs, within the reclosing sequence, the timing of the overall timer shall start again with the commencement of the next cycle. If lockout occurs before the overall time elapses, its timing shall reset when the lockout occurs.  The lockout state shall be reset by the receipt of a tie bay breaker manual close initiate signal.

Three-pole automatic reclosing shall be permitted only when the ‘permit three-pole reclosing’ signal is high. Manual closing shall always be permitted. When the ‘permit no closing’ signal is high, no automatic reclosing shall be permitted, manual closing shall be permitted. If any of the ‘permit reclosing’ signals are high at the same time as the ‘permit no closing’ signal, the ‘permit no closing’ signal shall take priority, preventing any reclosing and activating the three-pole only trip signal to the tie bay breaker.

Fast three-pole reclosing shall be selected when the ‘select fast three-pole reclosing’ signal is high. If low, slow three-pole reclosing shall be selected.

The inhibit reclosing signal shall be established whenever the ‘tie bay breaker charged’ signal is low, i.e. the tie bay breaker is not charged and the bay 2 auto-reclose function is in progress (bay 2 breaker not successfully closed and remain closed).

For initial three-pole tripping, the tie bay auto-reclose function shall provide a five-cycle reclosing sequence for permanent (uncleared on reclosing) faults. For initial three-pole tripping, the tie bay auto-reclose function shall provide a selectable three- or five-cycle reclosing sequence for permanent faults.  The three-cycle sequence shall be as follows: trip (three-pole), reclose, trip (three-pole), lockout.  The five-cycle sequence shall be as follows: trip (three-pole), reclose, trip (three-pole), reclose, trip (three-pole) and lockout.  Even if fast three-pole reclosing is selected, the three-pole reclosing cycle in the five-cycle sequence following an unsuccessful three-pole fast reclose shall be a slow three-pole reclose.

For three-pole tripping, the three- or five cycle reclosing sequence shall be selected by way of a selection on the diameter control device.  The tie bay breaker auto-reclose cycles shall follow the selection for the bay 2 breaker auto-reclose cycle selections.

The tie bay auto-reclose function, when initiated and in progress, shall be inhibit the bay 2 auto-reclose function until successful closure of the bay 2 breaker and the bay 2 breaker remain in service.  The tie bay breaker auto-reclose inhibit shall then be removed to permit closure by the tie bay auto-reclose function of the tie bay breaker (this can also be a user settable window).  The tie bay auto-reclose function shall not inhibit the tie bay auto-reclose function in the event that the tie bay breaker was already in the open position when a fault occurred and the auto-reclose functions are initiated.

#### 3.21.3.4.1 Three-pole auto-reclosing

Three-pole reclosing shall only be permitted if all three poles of the tie bay breaker have opened. Therefore, the thee-pole automatic reclosing cycle, fast or slow, shall commence (relevant three-pole dead time started/cycle in progress started) following receipt of a three-pole reclose initiate signal, on detection that all three poles of the tie bay breaker have opened, provided that no condition exists which disallows three-pole reclosing, i.e. a condition which causes the closing device to revert immediately to the lockout state. The cycle in progress shall reset when the close output is issued.

If a block reclosing signal is received once the cycle in progress (fast or slow) has commenced, the reclosing cycle (cycle on progress) shall immediately be stopped, and the closing device shall revert immediately to the lockout state.

For slow three-pole reclosing, the close output shall be issued following expiry of the dead time in accordance with the permitted closing conditions set.

If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed, even if the dead time has elapsed. If no inhibit signal is present, or is removed before the dead time elapses, the close output shall be issued once the dead time has elapsed in accordance with the conditions set. However, if closing is prevented upon expiry of the dead time, it shall then be effected as soon as the inhibit signal has been removed, but once again in accordance with the conditions set. If the inhibit signal is not removed by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

If the set condition for reclosing and a synchronism check to be performed, the close output may not be issued until verification that the voltages are in synchronism has been concluded. If this verification is not concluded by the time the overall time expires, the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state.

For fast three-pole reclosing, the diameter control device shall issue the close output following expiry of the dead time without further delay provided that no inhibit signal is present to prevent closing. If an inhibit reclosing signal is already present on receipt of the reclose initiate signal, or occurs with a cycle already in progress, the reclosing cycle may commence or continue, but the close output shall not be issued until the inhibit signal has been removed. If the inhibit signal is removed before the dead time elapses, closing shall occur without further delay on expiry of the dead time. For fast three-pole reclosing, the close output is required immediately following expiry of the dead time. Therefore, if the inhibit signal is not removed, preventing the close output from being issued immediately on expiry of the dead time, the bay closing device shall automatically revert to a slow three-pole reclose, with the amount of dead time elapsed equal to the slow dead time.

On issuing the close output (for manual closing, or automatic reclosing (three-pole)), the closing device shall start the reclaim time. If, with the five-cycle sequence selected, and three-pole reclosing permitted, a recurring fault, and subsequent reclose initiation, occurs within the reclaim time, this shall constitute the next step in the five-cycle sequence. As before, the reclosing cycle shall commence if all conditions governing commencement of a reclosing cycle are favourable. Commencement of the reclosing cycle shall reset the reclaim time, which shall be started again when, following the expiry of the dead time, and for all closing conditions favourable, the close output is issued.

New faults, with subsequent reclose initiation, occurring after the reclaim time has expired, shall constitute the first step in a new three- or five-cycle sequence.

If the tie bay closing function detects, within the reclaim time, that all three poles of the tie bay breaker have re-opened following manual closure, or three-pole automatic reclosure, the bay closing device shall revert immediately to the lockout state, irrespective of the presence of any reclose initiate signal, ensuring no further reclosing attempts are made. If the five-cycle reclosing sequence is selected, lockout must not be established, allowing the three-pole reclosing cycle to commence.

Establishing the lockout state shall reset the timing of the reclaim time.

Following receipt of a manual close initiate signal, the manual close cycle shall commence (manual close cycle in progress) provided that all three poles of the tie bay breaker are open, and the lockout state has been successfully reset. Receipt of the manual close initiate signal shall reset the lockout state provided that closing is permitted (the ‘permit no closing’ binary input is not high), and manual closing is not blocked (the ‘block manual close’ binary input is not high). If either of these binary inputs is high, the lockout state shall not be reset, and no manual close cycle shall commence. Once commenced, a manual close cycle in progress shall reset when the close output is issued.

The overall timer shall also be started whenever a manual close cycle commences. If closing cannot be effected for whatever reason before this time elapses, i.e.:

- the tie bay breaker is not charged (‘tie bay breaker charged’ binary input low);
- the set conditions for closing have not been met;
- synchronism could not be concluded;
- the cycle in progress shall be stopped, and the closing device shall immediately revert to the lockout state; or,
- the inhibit signal from the bay 2 auto-reclose in progress not removed.

If a block manual closing signal is received with a manual closing cycle already in progress, i.e. the manual closing cycle has commenced, but the close output has not yet been issued, the manual closing cycle shall immediately be stopped, and the closing device shall immediately revert to the lockout state.

A manual closing cycle, initiated by the receipt of a manual close input signal, shall be permitted to commence in parallel with a three-pole reclosing cycle already in progress (dead time elapsed), for which the required closing conditions have not yet been met, and for which the overall time has not yet elapsed. If the conditions for manual closing are met, which may be different to those for three-pole reclosing, a close output shall be issued. Issuing of the close output shall reset both cycles in progress. Commencement of the manual closing cycle shall not reset the three-pole cycle in progress, or restart the timing of the overall timer. If the overall time elapses without the close output being issued, both cycles in progress shall be reset, and the closing device shall immediately revert to the lockout state.

The close output, for manual closing, or three-pole automatic reclosing, shall have a fixed (settable, but fixed once set) duration. Once issued, the fixed duration of this output shall not be compromised for any reason, e.g. the subsequent receipt of inhibit/block input signals.

The tie bay auto-reclose function for line 2, when started or in progress within any one of the cycles, shall divert to a lock-out state in the event that the tie bay auto-reclose function for line 1 receives an initiate signal. For this condition the tie bay auto-reclose reclaim and overall times for line 2 shall be stopped.

## 3.22 Auto reclose initiation

### 3.22.1 Philosophy

The diameter control device shall subscribe to the GOOSE auto-reclose initiation signals from the main protection devices for the bay breakers and the tie bay breaker. Reclose initiation shall take the form of separate signals for single- and three-pole reclose initiates for the bay breaker and three-pole reclose initiates for the tie bay breaker. The bay breaker and tie bay breaker auto-reclose block shall be initiated for all functions (protection device tripping functions) and commands (breaker fail command and all external trip commands) which are not permitted to initiate a reclosing cycle.

### 3.22.2 Rationale

The bay breakers and the tie bay breaker reclose initiation and reclose block signals to the auto-reclose functions to ensure the successful start of an auto-reclose cycle or to block auto-reclosing.

### 3.22.3 Design Requirements

The bay breaker and the tie bay breaker reclose initiation and reclose block signals to the auto-reclose functions shall be dependent on the TNS selection (permitted when selected to 'Normal' or 'Test 1'). The bay breaker single- and three-pole auto- reclose initiate signals and the tie bay breaker three-pole auto-reclose initiate signal shall not be slower than the trip signals to the breakers as to ensure the successful start of an auto-reclose cycle. The auto-reclose initiate and block signals shall be send via GOOSE to the diameter control device that is housing the auto-reclose functionality.

## 3.23 Bay breaker three pole trip selected

### 3.23.1 Philosophy

The diameter control systems shall have the capability of providing signals to the protection systems to convert the protection systems to three-pole only tripping for the duration the signal is applied.

### 3.23.2 Rationale

Whenever the diameter control system is unable to perform a single-pole reclosing cycle (both bay breakers and independent signals), it must select the tripping systems for three-pole tripping only.

### 3.23.3 Design requirements

All closing outputs shall initiate the reclaim timer and during the reclaim time shall select the scheme for three-pole tripping only.

If a signal is present which would cause the diameter control system to go to the lockout state on circuit-breaker opening, the diameter control system must select the tripping systems for three-pole tripping only for the specific connected line and related bay breaker.

The protection IED PTRC1 shall provide for a three-pole trip only facility with an input derived from the bay breaker closing functionality when the TNS(M#) switch is in the 'Normal' or 'Test 1' positions. When the three pole trip select input is energised, PTRC1 shall perform only three-pole tripping irrespective of the type of fault or operating protection function. Initiation of the circuit-breaker failure function shall be for three-pole tripping, and initiation of automatic reclosing (if required) shall be three-pole.

The PTRC1 three pole trip selected signal from the bay breaker auto-reclose function shall be supervised by the TNS selected to test 2 (to remove the 3-pole trip selected when on test 2 to permit 1-pole tripping for testing purposes).

IEC61850 communications failure that affects the auto-reclose GOOSE signals, shall also select PTRC1 for three pole tripping only. The IEC61850 communications failure the affects three pole tripping only shall be disabled when the TNS is selected to test 2 (to remove the 3-pole trip selected when on test 2 to permit 1-pole tripping for testing purposes).

#### 3.23.3.1 Bay 1 breaker three pole trip selected

The diameter control device shall send, via GOOSE, to the line 1 protection scheme a three-pole trip select signal. The three-pole trip select signal shall be send when the bay 1 auto-reclose function is not selected for a single-pole reclose cycle or when the bay 1 auto-reclose function is not ready for a single pole reclose cycle.

#### 3.23.3.2 Bay 2 breaker three pole trip selected

The diameter control device shall send, via GOOSE, to the line 2 protection scheme a three-pole trip select signal. The three-pole trip select signal shall be send when the bay 2 auto-reclose function is not selected for a single-pole reclose cycle or when the bay 2 auto-reclose function is not ready for a single pole reclose cycle.

## 3.24 Auto-reclose "wait for master" function

### 3.24.1 Philosophy

The diameter control system shall have a wait from master signal that is send from the bay auto-reclose function to the tie bay auto-reclose function. The bay auto-reclose function, when in progress, will hold back reclosing of the tie bay breaker until successful auto-reclosing of the bay breaker.

### 3.24.2 Philosophy

The hold back of the tie bay breaker auto-reclosing when the bay breaker auto-reclose is in progress is to prevent unwanted closure of also the tie bay breaker onto a permanent fault.

### 3.24.3 Design requirements

The bay 1 breaker auto-reclose function (RREC 1) is the MASTER auto reclose functional block that control the bay 1 circuit-breaker and prove a "wait for master" signal to the tie bay auto-reclose function (RREC 3) that is associated with line 1. This means that no auto-reclose sequence will be started in the SLAVE function block (RREC 3) before the MASTER function block (RREC 1) have had a successful reclosing sequence.

Once the MASTER function block had a successful auto-reclose sequence and the bay 1 circuit-breaker have successfully reclosed, one set time later the "wait for master" signal is removed from the SLAVE and the auto-reclose sequence in the SLAVE function will continue which will reclose the tie bay circuit-breaker.

The bay 2 breaker auto-reclose function (RREC 2) is the MASTER auto reclose functional block that control the bay 2 circuit-breaker and prove a “wait for master” signal to the tie bay auto-reclose function (RREC 4) that is associated with line 2. This means that no auto-reclose sequence will be started in the SLAVE function block (RREC 4) before the MASTER function block (RREC 2) have had a successful reclosing sequence.

Once the MASTER function block had a successful auto-reclose sequence and the bay 2 circuit-breaker have successfully reclosed, one set time later the “wait for master” signal is removed from the SLAVE and the auto-reclose sequence in the SLAVE function will continue which will reclose the tie bay circuit-breaker.

A maximum waiting time, started by the “wait for master” signal, is required for the resetting of the “wait for master”. At time-out it interrupts the reclosing cycle of the slave unit. If reclosing of the bay breaker is unsuccessful the tie bay auto-reclose function will be resetted, hence preventing any closure from the tie bay auto-reclose function. Manual closing will then be required to close both the bay and tie bay breakers once the permanent fault was cleared from the network.

The Tie bay breaker will always trip 3 pole except in the case of a trip testing, it will trip and reclose single pole.

## 3.25 Diameter control devices auto-reclose master and slave modes

### 3.25.1 Philosophy

The diameter control device will be duplicated (main 1 protection system with a diameter interface and a main 2 protection system with a diameter interface). The diameter control devices in both diameter interface schemes shall have the ability to operate in both the master and slave modes. The selection to master on any one of them shall set the other in the slave mode. An IEC61850 communications failure between the two diameter control devices shall set both in the master mode.

### 3.25.2 Philosophy

The diameter control devices operating in a master and slave mode and being initiated bay both main protection systems is to ensure that auto-reclosing is done when any one of the diameter control devices is out of service and also in the event that the one main protection is out of service and the other main diameter control device is in service.

### 3.25.3 Design requirements

The diameter control device, set to the master mode, shall receive auto-reclose initiation signals from all the main 1 and main 2 line protection devices. The slave shall follow the auto-reclose mode selections being made on the master or via the master (On, Off, 1-pole, 3-pole, 1&3pole, 3-pole fast, 3-pole slow, 3-cycle and 5-cycle). Any failure on the diameter interface scheme being select as master that will prevent a successful auto-reclose sequence shall set this diameter control device from master to slave and the other diameter control device from slave to master.

The interfacing between the main 1 and main2 diameter control devices shall be via GOOSE as to prevent inter scheme DC supply connections in the event of this function being done via copper interface.

## 3.26 Auto reclose mode selections

### 3.26.1 Philosophy

The auto-reclose close mode selections are applicable to the lines being connected to the diameter. The auto-reclose functions within the diameter control devices shall have the following mode selections: On, Off, 1-pole, 3-pole, 1&3pole, 3-pole fast, 3-pole slow, 3-cycle and 5-cycle. The two line connected to the diameter shall have independent auto-reclose mode selection.

### 3.26.2 Philosophy

The auto-reclose mode selections are required to determine the tripping and auto-reclosing requirements for a particular line, and the Off selection is required for live line work and during maintenance activities. Auto-reclosing is only required for lines that are connected to the diameter, for transformers and busbar reactors, the auto-reclose functions shall be disabled.

### 3.26.3 Design requirements

The line 1 auto-reclose selections is applicable to the bay 1 breaker and the tie bay breaker, only one set of selections for both breakers. The line 2 auto-reclose selections is applicable to the bay 2 breaker and the tie bay breaker, only one set of selections for both breakers.

| Mode selections | Description |
|---|---|
| ARC(ON)(L1) | Line 1 - Auto Reclose ON Selection with Indication |
| ARC(OFF)(L1) | Line 1 - Auto Reclose OFF Selection with Indication |
| ARC(1P)(L1) | Line 1 - 1 Pole Auto Reclose Selection with Indication |
| ARC(3P)(L1) | Line 1 - 3 Pole Auto Reclose Selection with Indication |
| ARC(1&3P)(L1) | Line 1 - 1&3 Pole Auto Reclose Selection with Indication |
| 3-CYCLE(L1) | Line 1 - 3 Cycle Reclose Selection with Indication |
| 5-CYCLE(L1) | Line 1 - 5 Cycle Reclose Selection with Indication |
| 3-PSLOW(L1) | Line 1 - 3 Pole Slow Auto Reclose Selection with Indication |
| 3-PFAST(L1) | Line 1 - 3 Fast Auto Reclose Selection with Indication |
| ARC(ON)(L2) | Line 2 - Auto Reclose ON Selection with Indication |
| ARC(OFF)(L2) | Line 2 - Auto Reclose OFF Selection with Indication |
| ARC(1P)(L2) | Line 2 - 1 Pole Auto Reclose Selection with Indication |
| ARC(3P)(L2) | Line 2 - 3 Pole Auto Reclose Selection with Indication |
| ARC(1&3P)(L2) | Line 2 - 1&3 Pole Auto Reclose Selection with Indication |
| 3-CYCLE(L2) | Line 2 - 3 Cycle Reclose Selection with Indication |
| 5-CYCLE(L2) | Line 2 - 5 Cycle Reclose Selection with Indication |
| 3-PSLOW(L2) | Line 2 - 3 Pole Slow Auto Reclose Selection with Indication |
| 3-PFAST(L2) | Line 2 - 3 Fast Auto Reclose Selection with Indication |

| |
|---|
| **Auto Reclose ON selection:**<br>Auto-reclose permitted for relevant bay breaker and the tie bay breaker. |
| **Auto Reclose OFF selection:**<br>Auto-reclose not permitted for relevant bay breaker and the tie bay breaker. All tripping shall be three-pole and lock-out. |

**Auto Reclose selection scenario 1:**

ARC(ON), ARC(1P), 3-CYCLE or 5-CYCLE, 3-PFAST or 3-PSLOW

Single-line-to-ground faults:

- Bay breaker single pole trip (faulted phase) – single pole auto-reclose (single-pole dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker – three pole trip and lock-out; and,
- Tie Bay breaker – three pole trip and lock-out.

Auto Reclose selection scenario 2:

ARC(ON), ARC(3P), 3-CYCLE or 5-CYCLE, 3-PFAST

Single-line-to-ground faults:

- Bay breaker three pole trip – three pole auto-reclose (three-pole fast dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker three pole trip – three pole auto-reclose (three-pole fast dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

**Auto Reclose selection scenario 3:**

ARC(ON), ARC(3P), 3-CYCLE or 5-CYCLE, 3-PSLOW

Single-line-to-ground faults:

- Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

**Auto Reclose selection scenario 4:**

ARC(ON), ARC(1&3P), 3-CYCLE, 3-PFAST

Single-line-to-ground faults:

- Bay breaker single pole trip – single pole auto-reclose (single-pole dead time) – three pole trip and lock-out; and,

- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker three pole trip – three pole auto-reclose (three-pole fast dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

**Auto Reclose selection scenario 5:**

ARC(ON), ARC(1&3P), 3-CYCLE, 3-PSLOW

Single-line-to-ground faults:

- Bay breaker single pole trip – single pole auto-reclose (single-pole dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

**Auto Reclose selection scenario 6:**

ARC(ON), ARC(1&3P), 5-CYCLE, 3-PFAST

Single-line-to-ground faults:

- Bay breaker single pole trip – single pole auto-reclose (single-pole dead time) – three pole trip – three pole auto-reclose (three-pole slow dead time, dependent on the spring rewind time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip – three pole auto-reclose (three-pole slow dead time second shot) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker three pole trip – three pole auto-reclose (three-pole fast dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

**Auto Reclose selection scenario 7:**

ARC(ON), ARC(1&3P), 5-CYCLE, 3-PSLOW

Single-line-to-ground faults:

- Bay breaker single pole trip – single pole auto-reclose (single-pole dead time) – three pole trip – three pole auto-reclose (three-pole slow dead time, dependent on the spring rewind time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip – three pole auto-reclose (three-pole slow dead time second shot) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

Multi-phase faults

- Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out; and,
- Tie Bay breaker three pole trip – three pole auto-reclose (three-pole slow dead time) – three pole trip and lock-out (dependent on the successful auto-reclose of the bay breaker).

## 3.27 Synchronism check

### 3.27.1 Philosophy

The diameter control devices shall include a synchronism check function for each breaker. All three-pole auto-reclose and manual close commands (both local and remote) shall be supervised by the relevant breaker's synchronism check function. The synchronism check function shall utilise the CVTs on either side of the circuit-breakers for synchronism check purposes.

The synchronism check function shall measure slip, and only allow closing if the two voltages are within allowed slip limits. The two voltages are also required to be within angular difference limits, within amplitude difference limits and with each voltage being above the set 'live' voltage threshold.

### 3.27.2 Rationale

Synchronism check is required for all circuit-breakers that can connect two systems together.

### 3.27.3 Design Requirements

#### 3.27.3.1 Synchronism-check bay 1 breaker - RSYN 1

The diameter control device shall include a synchronism check function for the bay 1 breaker. All three-pole auto-reclose and manual close commands (both local and remote) shall be supervised by the bay 1 breaker synchronism check function. The bay 1 breaker shall utilise the busbar 1 VT and the connector 1 VT for synchronism check purposes.

The synchronism check function shall measure slip, and only allow closing if the two voltages are within allowed slip limits. The two voltages are also required to be within angular difference limits, within amplitude difference limits and with each voltage being above the set 'live' voltage threshold.

Closing shall only be permitted if the actual system conditions correspond to one of the set conditions for closing (separately settable for manual closing/three-pole (slow) automatic reclosing), i.e. if the actual system conditions do not correspond to one of the set conditions for closing, closing shall not occur. If the synchronism check option is implemented, closing/reclosing, for actual live busbar 1/connector 1 live conditions, shall only occur, with live busbar 1/connector 1 live set for closing/reclosing, following successful confirmation of synchronism. Once initiated, checking for synchronism shall continue until synchronism is confirmed, and closure occurs, or the overall time elapses, at which time the checking for synchronism shall reset. When this occurs, the closing device shall revert to the lockout state.

For manual closing of the bay 1 breaker, with the actual system conditions, other than live busbar 1/connector 1 live, corresponding to one of the set conditions for closing, the close output shall be issued without delay provided that no other constraint exists to prevent closing. For live busbar 1/connector 1 live conditions and with live busbar 1/connector 1 live set conditions for manual closing, checking for synchronism shall commence with commencement of the manual closing cycle. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. bay 1 breaker not charged, closing shall not occur until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For the bay 1 breaker three-pole automatic reclosing, with the actual system conditions, other than live busbar 1/connector 1 live, corresponding to one of the set conditions for three-pole reclosing, the close output shall be issued without further delay following expiry of the dead time provided that no other constraint exists to prevent closing. For live busbar 1/connector 1 live conditions (established on reclosure of the remote-end), and with live busbar 1/connector 1 live a set condition for three-pole reclosing, checking for synchronism shall commence immediately upon expiry of the dead time. If the dead time has already elapsed, with live busbar 1/connector 1 live the only set condition for reclosing, checking for synchronism shall commence immediately upon detecting live busbar 1/connector 1 live conditions. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. inhibit reclosing signal, bay 1 breaker not charged, closing shall not be effected until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For live busbar 1/connector 1 live conditions, three-pole automatic reclosing of the bay 1 breaker shall only occur, with live busbar 1/connector 1 live set for reclosing, following successful confirmation of synchronism. However, for manual closing, for live busbar 1/connector 1 live conditions, with the live busbar 1/connector 1 live condition for closing set, closing of the bay 1 breaker shall occur without delay, provided that no other constraint exists to prevent closing, without performing a synchronism check, if the 'bypass synchronism check' binary input is initiated at the same time as the manual close input is initiated.

The busbar 1 voltage input of the bay 1 breaker synchronism check function shall be fed from the busbar 1 VT core via a 10A MCB (located within the busbar 1 VT JB) and VT test block (VTTB(BB1), as a three phase voltage. The connector 1 voltage input be fed from the connector 1 VT via a 10A MCB (located within the connector 1 VT JB) and VT test block VTTB(CON1).

The following setting options are required, separately for manual closing and automatic reclosing of the bay 1 breaker, to select the permitted closing options:

- dead bus/dead line (bus is busbar 1 and line is connector 1);
- dead bus/live line (bus is busbar 1 and line is connector 1);
- live bus/dead line (bus is busbar 1 and line is connector 1); and,
- live bus/live line (bus is busbar 1 and line is connector 1).

The block synchronism check release input shall be initiated whenever the synchronising voltage is unhealthy. The synchronising voltage unhealthy (SVUNH) GOOSE messages will be send from the bay 1 breaker PIU:

- the busbar 1 voltage is absent due to the tripping of MCB (within busbar 1 VT JB);
- the connector 1 voltage is absent due to the tripping of MCB (within connector 1 VT JB);
- the busbar 1 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device); and,
- the connector 1 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device).

#### 3.27.3.2 Synchronism-check bay 2 breaker - RSYN 2

The diameter control device shall include a synchronism check function for the bay 2 breaker. All three-pole auto-reclose and manual close commands (both local and remote) shall be supervised by the bay 2 breaker synchronism check function. The bay 2 breaker shall utilise the busbar 2 VT and the connector 2 VT for synchronism check purposes.

The synchronism check function shall measure slip, and only allow closing if the two voltages are within allowed slip limits. The two voltages are also required to be within angular difference limits, within amplitude difference limits and with each voltage being above the set 'live' voltage threshold.

Closing shall only be permitted if the actual system conditions correspond to one of the set conditions for closing (separately settable for manual closing/three-pole (slow) automatic reclosing), i.e. if the actual system conditions do not correspond to one of the set conditions for closing, closing shall not occur. If the synchronism check option is implemented, closing/reclosing, for actual live busbar 2/connector 2 live conditions, shall only occur, with live busbar 2/connector 2 live set for closing/reclosing, following successful confirmation of synchronism. Once initiated, checking for synchronism shall continue until synchronism is confirmed, and closure occurs, or the overall time elapses, at which time the checking for synchronism shall reset. When this occurs, the closing device shall revert to the lockout state.

For manual closing of the bay 2 breaker, with the actual system conditions, other than live busbar 2/connector 2 live, corresponding to one of the set conditions for closing, the close output shall be issued without delay provided that no other constraint exists to prevent closing. For live busbar 2/connector 2 live conditions and with live busbar 2/connector 2 live set conditions for manual closing, checking for synchronism shall commence with commencement of the manual closing cycle. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. bay 2 breaker not charged, closing shall not occur until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For the bay 2 breaker three-pole automatic reclosing, with the actual system conditions, other than live busbar 2/connector 2 live, corresponding to one of the set conditions for three-pole reclosing, the close output shall be issued without further delay following expiry of the dead time provided that no other constraint exists to prevent closing. For live busbar 2/connector 2 live conditions (established on reclosure of the remote-end), and with live busbar 2/connector 2 live a set condition for three-pole reclosing, checking for synchronism shall commence immediately upon expiry of the dead time. If the dead time has already elapsed, with live busbar 2/connector 2 live the only set condition for reclosing, checking for synchronism shall commence immediately upon detecting live busbar 2/connector 2 live conditions. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. inhibit reclosing signal, bay 2 breaker not charged, closing shall not be effected until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For live busbar 2/connector 2 live conditions, three-pole automatic reclosing of the bay 2 breaker shall only occur, with live busbar 2/connector 2 live set for reclosing, following successful confirmation of synchronism. However, for manual closing, for live busbar 2/connector 2 live conditions, with the live busbar 2/connector 2 live condition for closing set, closing of the bay 2 breaker shall occur without delay, provided that no other constraint exists to prevent closing, without performing a synchronism check, if the ‘bypass synchronism check’ binary input is initiated at the same time as the manual close input is initiated.

The busbar 2 voltage input of the bay 2 breaker synchronism check function shall be fed from the busbar 1 VT core via a 10A MCB (located within the busbar 2 VT JB) and VT test block (VTTB(BB2), as a three phase voltage. The connector 2 voltage input be fed from the connector 2 VT via a 10A MCB (located within the connector 2 VT JB) and VT test block VTTB(CON2).

The following setting options are required, separately for manual closing and automatic reclosing of the bay 2 breaker, to select the permitted closing options:

- dead bus/dead line (bus is busbar 2 and line is connector 2);
- dead bus/live line (bus is busbar 2 and line is connector 2);
- live bus/dead line (bus is busbar 2 and line is connector 2); and,
- live bus/live line (bus is busbar 2 and line is connector 2).

The block synchronism check release input shall be initiated whenever the synchronising voltage is unhealthy. The synchronising voltage unhealthy (SVUNH) GOOSE messages will be send from the bay 2 breaker PIU:

- the busbar 2 voltage is absent due to the tripping of MCB (within busbar 2 VT JB);
- the connector 2 voltage is absent due to the tripping of MCB (within connector 2 VT JB);

- the busbar 2 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device); and,
- the connector 2 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device).

#### 3.27.3.3 Synchronism-check tie bay breaker - RSYN 3

The diameter control device shall include a synchronism check function for the tie bay breaker. All three-pole auto-reclose and manual close commands (both local and remote) shall be supervised by the tie bay breaker synchronism check function. The tie bay breaker shall utilise the connector 1 VT and the connector 2 VT for synchronism check purposes.

The synchronism check function shall measure slip, and only allow closing if the two voltages are within allowed slip limits. The two voltages are also required to be within angular difference limits, within amplitude difference limits and with each voltage being above the set 'live' voltage threshold.

Closing shall only be permitted if the actual system conditions correspond to one of the set conditions for closing (separately settable for manual closing/three-pole (slow) automatic reclosing), i.e. if the actual system conditions do not correspond to one of the set conditions for closing, closing shall not occur. If the synchronism check option is implemented, closing/reclosing, for actual live connector 1/connector 2 live conditions, shall only occur, with live connector 1/connector 2 live set for closing/reclosing, following successful confirmation of synchronism. Once initiated, checking for synchronism shall continue until synchronism is confirmed, and closure occurs, or the overall time elapses, at which time the checking for synchronism shall reset. When this occurs, the closing device shall revert to the lockout state.

For manual closing of the tie bay breaker, with the actual system conditions, other than live connector 1/connector 2 live, corresponding to one of the set conditions for closing, the close output shall be issued without delay provided that no other constraint exists to prevent closing. For live connector 1/connector 2 live conditions and with live connector 1/connector 2 live set conditions for manual closing, checking for synchronism shall commence with commencement of the manual closing cycle. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. tie bay breaker not charged, closing shall not occur until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For the tie bay breaker three-pole automatic reclosing, with the actual system conditions, other than live connector 1/connector 2 live, corresponding to one of the set conditions for three-pole reclosing, the close output shall be issued without further delay following expiry of the dead time provided that no other constraint exists to prevent closing. For live connector 1/connector 2 live conditions (established on reclosure of the remote-end), and with live connector 1/connector 2 live a set condition for three-pole reclosing, checking for synchronism shall commence immediately upon expiry of the dead time. If the dead time has already elapsed, with live connector 1/connector 2 live the only set condition for reclosing, checking for synchronism shall commence immediately upon detecting live connector 1/connector 2 live conditions. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. inhibit reclosing signal, tie bay breaker not charged, closing shall not be effected until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For live connector 1/connector 2 live conditions, three-pole automatic reclosing of the tie bay breaker shall only occur, with live connector 1/connector 2 live set for reclosing, following successful confirmation of synchronism. However, for manual closing, for live connector 1/connector 2 live conditions, with the live connector 1/connector 2 live condition for closing set, closing of the tie bay breaker shall occur without delay, provided that no other constraint exists to prevent closing, without performing a synchronism check, if the 'bypass synchronism check' binary input is initiated at the same time as the manual close input is initiated.

The connector 1 voltage input of the tie bay breaker synchronism check function shall be fed from the connector 1 VT core via a 10A MCB (located within the connector 1 VT JB) and VT test block (VTTB(CON1), as a three phase voltage. The connector 2 voltage input be fed from the connector 2 VT via a 10A MCB (located within the connector 2 VT JB) and VT test block VTTB(CON2).

The following setting options are required, separately for manual closing and automatic reclosing of the tie bay breaker, to select the permitted closing options:

- dead bus/dead line (bus is connector 1 and line is connector 2);
- dead bus/live line (bus is connector 1 and line is connector 2);
- live bus/dead line (bus is connector 1 and line is connector 2); and,
- live bus/live line (bus is connector 1 and line is connector 2).

The block synchronism check release input shall be initiated whenever the synchronising voltage is unhealthy. The synchronising voltage unhealthy (SVUNH) GOOSE messages will be send from the tie bay breaker PIU:

- the connector 1 voltage is absent due to the tripping of MCB (within connector 1 VT JB);
- the connector 2 voltage is absent due to the tripping of MCB (within connector 2 VT JB);
- the connector 1 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device); and,
- the connector 2 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device).

#### 3.27.3.4 Synchronism-check breaker MV side of transformer - RSYN 4

The diameter control device shall include a synchronism check function for the MV bay breaker. The manual close command (both local and remote) shall be supervised and the MV bay breaker synchronism check function. The MV bay breaker shall utilise the transformer MV side VT and the selected busbar VT(busbar 1 or busbar 2 MV side) for synchronism check purposes.

The synchronism check function shall measure slip, and only allow closing if the two voltages are within allowed slip limits. The two voltages are also required to be within angular difference limits, within amplitude difference limits and with each voltage being above the set ‘live’ voltage threshold.

Closing shall only be permitted if the actual system conditions correspond to one of the set conditions for closing (settable for manual closing), i.e. if the actual system conditions do not correspond to one of the set conditions for closing, closing shall not occur. If the synchronism check option is implemented, closing/reclosing, for actual live transformer/busbar live conditions, shall only occur, with live transformer/busbar live set for closing/reclosing, following successful confirmation of synchronism. Once initiated, checking for synchronism shall continue until synchronism is confirmed, and closure occurs, or the overall time elapses, at which time the checking for synchronism shall reset. When this occurs, the closing device shall revert to the lockout state.

For manual closing of the MV bay breaker, with the actual system conditions, other than live transformer/busbar live, corresponding to one of the set conditions for closing, the close output shall be issued without delay provided that no other constraint exists to prevent closing. For live transformer/busbar live conditions and with live transformer/busbar live set conditions for manual closing, checking for synchronism shall commence with commencement of the manual closing cycle. The close output shall be issued immediately following confirmation of synchronism provided that no other constraint exists to prevent closing. If such a constraint exists, e.g. MV bay breaker not charged, closing shall not occur until the constraint is removed. If, once removed, synchronism is still confirmed, closing shall occur without further delay. If synchronism is no longer confirmed, closing shall only occur once synchronism has been re-confirmed.

For manual closing, for live transformer/busbar live conditions, with the live transformer/busbar live condition for closing set, closing of the MV bay breaker shall occur without delay, provided that no other constraint exists to prevent closing, without performing a synchronism check, if the 'bypass synchronism check' binary input is initiated at the same time as the manual close input is initiated.

The transformer voltage input of the synchronism check function shall be fed from the transformer VT core via a 10A MCB (located within the transformer VT JB) and the VT test block (VTTB(MV)(T)), as a three voltage. The busbar voltage input from busbar 1 and busbar 2 VTs shall be fed via separate 10A MCBs (located within the specific busbar VT JB), VTTB(MV)(BB1) and VTTB(MV)(BB2) test blocks. The correct busbar voltage to be used for synchronism check, dependent upon the busbar to which the transmission line is connected, shall automatically be selected in accordance with the status of busbar 1 isolator and busbar 2 isolator. The busbar voltage selection shall be achieved within the diameter control.

The following setting options are required, for manual closing of the MV bay breaker, to select the permitted closing options:

- dead bus/dead line (bus is busbar 1 or 2 and line is transformer);
- dead bus/live line (bus is busbar 1 or 2 and line is transformer);
- live bus/dead line (bus is busbar 1 or 2 and line is transformer); and,
- live bus/live line (bus is busbar 1 or 2 and line is transformer).

The block synchronism check release input shall be initiated whenever the synchronising voltage is unhealthy. The synchronising voltage unhealthy (SVUNH) GOOSE messages will be send from the MV bay breaker PIU:

- the busbar 1 voltage is absent due to the tripping of MCB (within busbar 1 VT JB), supervised by the busbar 1 isolator closed status;
- the busbar 2 voltage is absent due to the tripping of MCB (within busbar 2 VT JB), supervised by the busbar 2 isolator closed status;
- the transformer voltage is absent due to the tripping of MCB (within transformer VT JB);
- the busbar 1 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device), supervised by the busbar 1 isolator closed status;
- the connector 2 voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device) supervised by the busbar 2 isolator closed status; and,
- the transformer voltage is unhealthy due to the loss of any one of the phases (unhealthy condition shall be measured within the diameter control device).

## 3.28 Manual closing

### 3.28.1 Philosophy

All manual closing operations shall be routed via the diameter control systems, except for local closing of the circuit-breaker from the junction box located near the circuit-breakers.

A manual close operation shall reset the diameter control system from the lockout state.

A manual close block input shall be provided for on the diameter control system to prevent a manual close cycle commencing, or to immediately stop any manual close cycle in progress. The diameter control system shall revert the immediately to the lockout state.

### 3.28.2 Rationale

The local closing facility provided at the junction box is for the only purpose of enabling maintenance to be performed on the relevant circuit-breaker.

Essentially the diameter control systems will be in one of three states:

- ready - system healthy with relevant circuit-breaker(s) closed;
- manual close cycle in progress; and
- lockout state with relevant circuit-breaker(s) open and no cycle in progress.

When in the lockout state, which is the normal state when the relevant circuit-breaker(s) is open and no reclosing cycle is in progress, manual closing must be permitted to enable closing of the relevant circuit-breaker. Therefore, a manual close input must first reset the lockout state and then commence the manual close cycle.

Conditions for which closure must not occur will be wired to the block manual close input. These conditions are expected to be long term (longer than the overall timer). It is therefore not necessary to wait out the overall time before cancelling a cycle in progress and reverting to the lockout state. For this reason triggering this input shall prevent the manual close cycle from commencing, or immediately stop any manual closing cycle in progress.

### 3.28.3 Design Requirements

For a sustained manual close input, the diameter control systems must not immediately commence with a manual close cycle when the relevant circuit-breaker is next opened and the diameter control system(s) detects that circuit-breaker to be open.

## 3.29 Synchronism check VT Fuse failure

### 3.29.1 Philosophy

The synchronism check function shall not incorrectly release a synchronism check to the auto-reclosing and manual closing functions for the loss of any number of VT inputs.

### 3.29.2 Rationale

Monitoring for VT supply failure conditions, plus the associated supply failure logic, is required to ensure that the synchronism check functions remains secure, i.e. that it does not incorrectly release a three pole close command, for the loss of any number of VT inputs.

To prevent maloperations, blocking of all the specific synch functions shall occur immediately on detection of a supply failure condition by the supply failure monitor. Establishment of supply failure (one, two or three phase supplies) shall only occur for genuine supply failure conditions. Once established, supply failure shall be sealed-in, and blocking of the synchronism check functions shall not be released, until the supply is restored. Reset of the supply failure shall occur automatically with restoration of the VT supply. The following VT supply failure detections are required (independent per synchronising voltage input):

- Input from the specific MCB auxiliary monitoring contact (GOOSE signal from PIU); and,
- Unbalance voltage detection done within the diameter control device (delayed to prevent unwanted blocking and alarming during the single pole dead time).

### 3.29.3 Design requirements

The detection of the loss of any VT input and any associated blocking actions shall be automatically reset once the VT supply is restored.

The VT secondary supply failure detection shall only operate for a genuine loss of VT input quantities, and not for open pole conditions or faults on adjacent networks.

The voltage transformer (CVT) secondary supply failure alarm must be delayed as to prevent unnecessary alarming due to unequal three pole opening of the circuit breaker.

The failure of one or more fuses (or single phase MCBs) will affect the behaviour of the synchronism check function. This condition shall be detected to effect blocking of the synchronism check functions for loss of voltage.

Monitoring for VT supply failure conditions, plus the associated supply failure logic, is required to ensure that the synchronism check function remains secure, i.e. that it does not misoperate, either for load conditions or adjacent line fault conditions, for the loss of any number of VT inputs.

To prevent a misoperation, blocking of all the synchronism check functions shall occur immediately on detection of a supply failure condition by the supply failure monitor. Establishment of supply failure (one, two or three phase supplies) shall only occur for genuine supply failure conditions, and not for open pole conditions (one- or three-pole), or for faults on the protected line (weak infeed), or for faults on adjacent networks. A time delay may therefore be necessary before establishment of supply failure. This time delay shall be no longer than that required to ascertain a supply failure condition. Subsequent current detection within the time window following detection of the supply failure condition, but before establishment of supply failure, shall release the blocking of the synchronism check function, allowing their operation. Establishment of supply failure shall occur if the detected supply failure condition persists for the duration of the time delay. Once established, supply failure shall be sealed-in, and blocking of the synchronism check function(s) shall not be released, until the supply is restored. Reset of the supply failure shall occur automatically with restoration of the VT supply.

The VT fuse failure alarm (local and remote) shall be delayed as to prevent unnecessary alarming due to unequal operation of the circuit-breaker poles.

### 3.29.4 Philosophy

A breaker spring charging failed timer (delay-on-pick-up), per breaker, shall be provided to raise an alarm in the event of a failure of any of the breaker charging mechanisms and shall be integrated within the diameter control device.

### 3.29.5 Rationale

Circuit-breaker spring limit switches are wired in series with the circuit-breaker closing circuit (negative side). The alarming is required to correct the situation that will prevent the circuit-breaker to auto-reclose following a network fault. The time delay to alarm is required to be set longer that the nominal spring charging time as to ensure that only the failed condition are reported.

### 3.29.6 Design requirements

#### 3.29.6.1 Bay 1 breaker spring charging fail time

A bay 1 breaker spring charging failed timer (delay-on-pick-up) shall be provided to raise an alarm in the event of a failure of any of the bay 1 breaker charging mechanisms and shall be integrated within the diameter control device.

The bay 1 breaker charging fail:

- Shall be connected to the IED internal disturbance recorder function (RBDR);
- Shall be displayed on the diameter control device HMI; and,
- Shall be reported to the gateway and station HMI.

#### 3.29.6.2 Bay 2 breaker spring charging fail time

A bay 2 breaker spring charging failed timer (delay-on-pick-up) shall be provided to raise an alarm in the event of a failure of any of the bay 2 breaker charging mechanisms and shall be integrated within the diameter control device.

The bay 2 breaker charging fail:

- Shall be connected to the IED internal disturbance recorder function (RBDR);
- Shall be displayed on the diameter control device HMI; and,
- Shall be reported to the gateway and station HMI.

#### 3.29.6.3 Tie Bay breaker spring charging fail time

A tie bay breaker spring charging failed timer (delay-on-pick-up) shall be provided to raise an alarm in the event of a failure of any of the tie bay breaker charging mechanisms and shall be integrated within the diameter control device.

The tie bay breaker charging fail:

- Shall be connected to the IED internal disturbance recorder function (RBDR);
- Shall be displayed on the diameter control device HMI; and,
- Shall be reported to the gateway and station HMI.

#### 3.29.6.4 MV Bay breaker spring charging fail time

A MV bay breaker spring charging failed timer (delay-on-pick-up) shall be provided to raise an alarm in the event of a failure of any of the MV bay breaker charging mechanisms and shall be integrated within the diameter control device.

The MV bay breaker charging fail:

- Shall be connected to the IED internal disturbance recorder function (RBDR);
- Shall be displayed on the diameter control device HMI; and,
- Shall be reported to the gateway and station HMI.

## 3.30 Anti-pumping

### 3.30.1 Philosophy

An anti-pumping function shall be included within the individual circuit-breaker closing circuits and shall be standalone devices, initiated irrespective of whether the close command originates from the auto-reclose function, manual close command (local or remote) or from the control switch within the junction box. A close command shall pick-up the anti-pump relay, which shall have a normally-closed delay-on-pick-up contact in series with the negative of the specific breaker's close coils. This contact shall have the ability to interrupt the circuit-breaker closing circuit (closing coil DC current).

### 3.30.2 Rationale

Anti-pumping is employed to ensure that a permanent close command issued to the breaker, from the diameter control device(s), does not result in repetitive closure of the applicable circuit-breaker(s) in the event of a trip signal being issued. This could result in the circuit-breaker being damaged.

The anti-pumping relay can be considered as a protection device for the circuit-breakers in the event of a failure of the diameter control device, resulting in it issuing a permanent close command.

### 3.30.3 Design Requirements

The anti-pump functions:

- Shall be connected to the IED internal disturbance recorder function (RBDR);
- Shall be displayed on the diameter control device HMI; and,
- Shall be reported to the gateway and station HMI.

## 3.31 Breaker status inputs

### 3.31.1 Philosophy

The diameter control device shall make provision (via GOOSE) to receive breaker statuses from the process interface units within the junction boxes.

### 3.31.2 Rationale

The inputs via GOOSE are to minimise copper interfacing between the diameter interface schemes the primary plant equipment (via JBs). The breaker statuses are required for local and remote indications.

### 3.31.3 Design requirements

The XCBR LN "circuit breaker" covers the circuit breakers, i.e. switches able to interrupt short circuits. An AC circuit breaker is a device that is used to close and interrupt an AC power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions (IEEE C37.2-1996). If there is a single-phase breaker, this LN has an instance per phase. These three instances may be allocated to three physical devices mounted in the switchgear.

The diameter control devices shall subscribe to the XCBR data, the XCBR logical node shall be within the circuit-breaker process interface units.

The bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific circuit-breaker PIU.

For applications with two breaker per phase (six breakers per bay), phase segregated bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific main protection PIU.

The bay 1 & 2 breaker statuses are required within the diameter control device. The bay 1 & 2 breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the bay 1 & 2 main # PIU.

#### 3.31.3.1 Bay 1 breaker status

The bay 1 breaker statuses are required within the diameter control device. The bay 1 breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the bay 1 main # PIU.

The following bay 1 breaker status GOOSE data shall be subscribed to:

- Bay 1 breaker red phase normally open (52a) auxiliary contact;
- Bay 1 breaker red phase normally closed (52b) auxiliary contact;
- Bay 1 breaker white phase normally open (52a) auxiliary contact;
- Bay 1 breaker white phase normally closed (52b) auxiliary contact;
- Bay 1 breaker blue phase normally open (52a) auxiliary contact; and,
- Bay 1 breaker blue phase normally closed (52b) auxiliary contact.

The required bay 1 breaker auxiliary contact information is required to fulfil the following functions, implemented within the line protection device:

- Bay 1 breaker open and close status remote reporting (HMI and GW);
- Bay 1 breaker trip counting (close status per phase); and,
- Bay 1 breaker internal disturbance recording (closed status per phase).

For applications with two breaker per phase (six breakers per bay), phase segregated bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific main protection PIU.

The following bay 1 breaker status GOOSE data shall be subscribed to:

- Bay 1 breaker red phase pole 1 normally open (52a) auxiliary contact;
- Bay 1 breaker red phase pole 1 normally closed (52b) auxiliary contact;
- Bay 1 breaker white phase pole 1 normally open (52a) auxiliary contact;
- Bay 1 breaker white phase pole 1 normally closed (52b) auxiliary contact;
- Bay 1 breaker blue phase pole 1 normally open (52a) auxiliary contact;
- Bay 1 breaker blue phase pole 1 normally closed (52b) auxiliary contact;
- Bay 1 breaker red phase pole 2 normally open (52a) auxiliary contact;
- Bay 1 breaker red phase pole 2 normally closed (52b) auxiliary contact;
- Bay 1 breaker white phase pole 2 normally open (52a) auxiliary contact;
- Bay 1 breaker white phase pole 2 normally closed (52b) auxiliary contact;
- Bay 1 breaker blue phase pole 2 normally open (52a) auxiliary contact; and,
- Bay 1 breaker blue phase pole 2 normally closed (52b) auxiliary contact.

The required bay 1 breaker auxiliary contact information per phase is required to fulfil the following functions:

- Bay 1 breaker open and close status remote reporting (HMI and GW);
- Bay 1 breaker trip counting (close status per phase); and,
- Bay 1 breaker internal disturbance recording (closed status per phase).

#### 3.31.3.2 Bay 2 breaker status

The bay 2 breaker statuses are required within the diameter control device. The bay 2 breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the bay 2 main # PIU.

The following bay 2 breaker status GOOSE data shall be subscribed to:

- Bay 2 breaker red phase normally open (52a) auxiliary contact;
- Bay 2 breaker red phase normally closed (52b) auxiliary contact;
- Bay 2 breaker white phase normally open (52a) auxiliary contact;
- Bay 2 breaker white phase normally closed (52b) auxiliary contact;
- Bay 2 breaker blue phase normally open (52a) auxiliary contact; and,
- Bay 2 breaker blue phase normally closed (52b) auxiliary contact.

The required bay 2 breaker auxiliary contact information is required to fulfil the following functions, implemented within the line protection device:

- Bay 2 breaker open and close status remote reporting (HMI and GW);
- Bay 2 breaker trip counting (close status per phase); and,
- Bay 2 breaker internal disturbance recording (closed status per phase).

For applications with two breaker per phase (six breakers per bay), phase segregated bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific main protection PIU.

The following bay 2 breaker status GOOSE data shall be subscribed to:

- Bay 2 breaker red phase pole 1 normally open (52a) auxiliary contact;
- Bay 2 breaker red phase pole 1 normally closed (52b) auxiliary contact;

- Bay 2 breaker white phase pole 1 normally open (52a) auxiliary contact;
- Bay 2 breaker white phase pole 1 normally closed (52b) auxiliary contact;
- Bay 2 breaker blue phase pole 1 normally open (52a) auxiliary contact;
- Bay 2 breaker blue phase pole 1 normally closed (52b) auxiliary contact;
- Bay 2 breaker red phase pole 2 normally open (52a) auxiliary contact;
- Bay 2 breaker red phase pole 2 normally closed (52b) auxiliary contact;
- Bay 2 breaker white phase pole 2 normally open (52a) auxiliary contact;
- Bay 2 breaker white phase pole 2 normally closed (52b) auxiliary contact;
- Bay 2 breaker blue phase pole 2 normally open (52a) auxiliary contact; and,
- Bay 2 breaker blue phase pole 2 normally closed (52b) auxiliary contact.

The required bay 2 breaker auxiliary contact information per phase is required to fulfil the following functions:

- Bay 2 breaker open and close status remote reporting (HMI and GW);
- Bay 2 breaker trip counting (close status per phase); and,
- Bay 2 breaker internal disturbance recording (closed status per phase).

#### 3.31.3.3 Tie bay breaker status: XCBR

The LN “circuit breaker” covers the circuit breakers, i.e. switches able to interrupt short circuits. An AC circuit breaker is a device that is used to close and interrupt an AC power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions (IEEE C37.2-1996). If there is a single-phase breaker, this LN has an instance per phase. These three instances may be allocated to three physical devices mounted in the switchgear.

The diameter control devices shall subscribe to the XCBR data, the XCBR logical node shall be within the circuit-breaker process interface units.

The tie bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific circuit-breaker PIU.

For applications with two breaker per phase (six breakers per bay), phase segregated tie bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific main protection PIU.

The Tie Bay breaker statuses are required within the diameter control device. The Tie Bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the Tie Bay main # PIU.

The following tie bay breaker status GOOSE data shall be subscribed to:

- Tie Bay breaker red phase normally open (52a) auxiliary contact;
- Tie Bay breaker red phase normally closed (52b) auxiliary contact;
- Tie Bay breaker white phase normally open (52a) auxiliary contact;
- Tie Bay breaker white phase normally closed (52b) auxiliary contact;
- Tie Bay breaker blue phase normally open (52a) auxiliary contact; and,
- Tie Bay breaker blue phase normally closed (52b) auxiliary contact.

The required Tie Bay breaker auxiliary contact information is required to fulfil the following functions, implemented within the line protection device:

- Tie Bay breaker open and close status remote reporting (HMI and GW);
- Tie Bay breaker trip counting (close status per phase); and,
- Tie Bay breaker internal disturbance recording (closed status per phase).

For applications with two breaker per phase (six breakers per bay), phase segregated bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific main protection PIU.

The following Tie Bay breaker status GOOSE data shall be subscribed to:

- Tie Bay breaker red phase pole 1 normally open (52a) auxiliary contact;
- Tie Bay breaker red phase pole 1 normally closed (52b) auxiliary contact;
- Tie Bay breaker white phase pole 1 normally open (52a) auxiliary contact;
- Tie Bay breaker white phase pole 1 normally closed (52b) auxiliary contact;
- Tie Bay breaker blue phase pole 1 normally open (52a) auxiliary contact;
- Tie Bay breaker blue phase pole 1 normally closed (52b) auxiliary contact;
- Tie Bay breaker red phase pole 2 normally open (52a) auxiliary contact;
- Tie Bay breaker red phase pole 2 normally closed (52b) auxiliary contact;
- Tie Bay breaker white phase pole 2 normally open (52a) auxiliary contact;
- Tie Bay breaker white phase pole 2 normally closed (52b) auxiliary contact;
- Tie Bay breaker blue phase pole 2 normally open (52a) auxiliary contact; and,
- Tie Bay breaker blue phase pole 2 normally closed (52b) auxiliary contact.

The required Tie Bay breaker auxiliary contact information per phase is required to fulfil the following functions:

- Tie Bay breaker open and close status remote reporting (HMI and GW);
- Tie Bay breaker trip counting (close status per phase); and,
- Tie Bay breaker internal disturbance recording (closed status per phase).

#### 3.31.3.4 MV bay breaker status: XCBR

The LN “circuit breaker” covers the circuit breakers, i.e. switches able to interrupt short circuits. An AC circuit breaker is a device that is used to close and interrupt an AC power circuit under normal conditions or to interrupt this circuit under fault or emergency conditions (IEEE C37.2-1996). If there is a single-phase breaker, this LN has an instance per phase. These three instances may be allocated to three physical devices mounted in the switchgear.

The diameter control devices shall subscribe to the XCBR data, the XCBR logical node shall be within the circuit-breaker process interface units.

The MV bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific circuit-breaker PIU.

For applications with two breaker per phase (six breakers per bay), phase segregated tie bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the specific main protection PIU.

The MV Bay breaker statuses are required within the diameter control device. The MV Bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the MV Bay main # PIU.

The MV Bay breaker statuses are required within the diameter control device. The MV Bay breaker statuses (52a and 52b contacts) information shall be received via GOOSE data from the MV Bay main # PIU.

The following MV bay breaker status GOOSE data shall be subscribed to:

- MV Bay breaker red phase normally open (52a) auxiliary contact;
- MV Bay breaker red phase normally closed (52b) auxiliary contact;
- MV Bay breaker white phase normally open (52a) auxiliary contact;

- MV Bay breaker white phase normally closed (52b) auxiliary contact;
- MV Bay breaker blue phase normally open (52a) auxiliary contact; and,
- MV Bay breaker blue phase normally closed (52b) auxiliary contact.

The required MV Bay breaker auxiliary contact information is required to fulfil the following functions, implemented within the line protection device:

- MV Bay breaker open and close status remote reporting (HMI and GW);
- MV Bay breaker trip counting (close status per phase); and,
- MV Bay breaker internal disturbance recording (closed status per phase).

## 3.32 Isolator status inputs

### 3.32.1 Philosophy

The diameter control device shall make provision (via GOOSE) to receive isolator plant statuses from the process interface units within the junction boxes.

### 3.32.2 Rationale

The inputs via GOOSE are to minimise copper interfacing between the diameter interface schemes the primary plant equipment (via JBs). The isolator plant statuses are required for local and remote indications.

### 3.32.3 Design requirements

The XSWI LN “switch” covers the switching devices not able to switch short circuits. Line switch is a switch used as a disconnecting, load-interrupter, or isolating switch on an AC or DC power circuit (IEEE C37.2-1996). If there is a single-phase switch, this LN has an instance per phase. These three instances may be allocated to three physical devices mounted in the switchgear. Each isolator shall have a dedicated assigned logical node.

The diameter control devices shall subscribe to the XSWI data, the XSWI logical node shall be within the circuit-breaker process interface units.

The isolator statuses (M and N contacts) information shall be received via GOOSE data from the specific circuit-breaker PIU.

#### 3.32.3.1 Object 1 isolator status

The Object 1 isolator status is required within the diameter control device. The Object 1 isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 1 main # PIU. The following Object 1 isolator status GOOSE data shall be subscribed to:

- Object 1 isolator red phase normally open (M) auxiliary contact;
- Object 1 isolator red phase normally closed (N) auxiliary contact;
- Object 1 isolator white phase normally open (M) auxiliary contact;
- Object 1 isolator white phase normally closed (N) auxiliary contact;
- Object 1 isolator blue phase normally open (M) auxiliary contact; and,
- Object 1 isolator blue phase normally closed (N) auxiliary contact.

The Object 1 isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Object 1 isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Object 1 isolator discrepancy;

- Object 1 open and close status remote reporting (HMI and GW); and,
- Object 1 open and close status local reporting (IED HMI).

#### 3.32.3.2 Object 2 isolator status

The Object 2 isolator status is required within the diameter control device. The Object 2 isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 2 main # PIU. The following Object 2 isolator status GOOSE data shall be subscribed to:

- Object 2 isolator red phase normally open (M) auxiliary contact;
- Object 2 isolator red phase normally closed (N) auxiliary contact;
- Object 2 isolator white phase normally open (M) auxiliary contact;
- Object 2 isolator white phase normally closed (N) auxiliary contact;
- Object 2 isolator blue phase normally open (M) auxiliary contact; and,
- Object 2 isolator blue phase normally closed (N) auxiliary contact.

The Object 2 isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Object 2 isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Object 2 isolator discrepancy;
- Object 2 open and close status remote reporting (HMI and GW); and,
- Object 2 open and close status local reporting (IED HMI).

#### 3.32.3.3 Line 1 reactor transfer isolator status

The Line 1 reactor transfer isolator status is required within the diameter control device. The Line 1 reactor transfer isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 1 main # PIU. The following Line 1 reactor transfer isolator status GOOSE data shall be subscribed to:

- Line 1 reactor transfer isolator red phase normally open (M) auxiliary contact;
- Line 1 reactor transfer isolator red phase normally closed (N) auxiliary contact;
- Line 1 reactor transfer isolator white phase normally open (M) auxiliary contact;
- Line 1 reactor transfer isolator white phase normally closed (N) auxiliary contact;
- Line 1 reactor transfer isolator blue phase normally open (M) auxiliary contact; and,
- Line 1 reactor transfer isolator blue phase normally closed (N) auxiliary contact.

The Line 1 reactor transfer isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Line 1 reactor transfer isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Line 1 reactor transfer isolator discrepancy;
- Line 1 reactor transfer open and close status remote reporting (HMI and GW); and,
- Line 1 reactor transfer open and close status local reporting (IED HMI).

#### 3.32.3.4 Line 2 reactor transfer isolator status

The Line 2 reactor transfer isolator status is required within the diameter control device. The Line 2 reactor transfer isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 2 main # PIU. The following Line 2 reactor transfer isolator status GOOSE data shall be subscribed to:

- Line 2 reactor transfer isolator red phase normally open (M) auxiliary contact;
- Line 2 reactor transfer isolator red phase normally closed (N) auxiliary contact;
- Line 2 reactor transfer isolator white phase normally open (M) auxiliary contact;
- Line 2 reactor transfer isolator white phase normally closed (N) auxiliary contact;
- Line 2 reactor transfer isolator blue phase normally open (M) auxiliary contact; and,
- Line 2 reactor transfer isolator blue phase normally closed (N) auxiliary contact.

The Line 2 reactor transfer isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Line 2 reactor transfer isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Line 2 reactor transfer isolator discrepancy;
- Line 2 reactor transfer open and close status remote reporting (HMI and GW); and,
- Line 2 reactor transfer open and close status local reporting (IED HMI).

#### 3.32.3.5 Bay 1 Busbar 1 isolator status

The Bay 1 Busbar 1 isolator status is required within the diameter control device. The Bay 1 Busbar 1 isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 1 main # PIU. The following Bay 1 Busbar 1 isolator status GOOSE data shall be subscribed to:

- Bay 1 Busbar 1 isolator red phase normally open (M) auxiliary contact;
- Bay 1 Busbar 1 isolator red phase normally closed (N) auxiliary contact;
- Bay 1 Busbar 1 isolator white phase normally open (M) auxiliary contact;
- Bay 1 Busbar 1 isolator white phase normally closed (N) auxiliary contact;
- Bay 1 Busbar 1 isolator blue phase normally open (M) auxiliary contact; and,
- Bay 1 Busbar 1 isolator blue phase normally closed (N) auxiliary contact.

The Bay 1 Busbar 1 isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Bay 1 Busbar 1 isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Bay 1 Busbar 1 isolator discrepancy;
- Bay 1 Busbar 1 open and close status remote reporting (HMI and GW); and,
- Bay 1 Busbar 1 open and close status local reporting (IED HMI).

#### 3.32.3.6 Bay 1 isolator busbar 2 side status

The Bay 1 isolator busbar 2 side isolator status is required within the diameter control device. The Bay 1 isolator busbar 2 side isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 1 main # PIU. The following Bay 1 isolator busbar 2 side isolator status GOOSE data shall be subscribed to:

- Bay 1 isolator busbar 2 side isolator red phase normally open (M) auxiliary contact;
- Bay 1 isolator busbar 2 side isolator red phase normally closed (N) auxiliary contact;
- Bay 1 isolator busbar 2 side isolator white phase normally open (M) auxiliary contact;
- Bay 1 isolator busbar 2 side isolator white phase normally closed (N) auxiliary contact;
- Bay 1 isolator busbar 2 side isolator blue phase normally open (M) auxiliary contact; and,
- Bay 1 isolator busbar 2 side isolator blue phase normally closed (N) auxiliary contact.

The Bay 1 isolator busbar 2 side isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Bay 1 isolator busbar 2 side isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Bay 1 isolator busbar 2 side isolator discrepancy;
- Bay 1 isolator busbar 2 side open and close status remote reporting (HMI and GW); and,
- Bay 1 isolator busbar 2 side open and close status local reporting (IED HMI).

#### 3.32.3.7 Bay 2 busbar 2 isolator status

The Bay 2 busbar 2 isolator status is required within the diameter control device. The Bay 2 busbar 2 isolator statuses (M and N contacts) information shall be received via GOOSE data from the bay 2 main # PIU. The following Bay 2 busbar 2 isolator status GOOSE data shall be subscribed to:

- Bay 2 busbar 2 isolator red phase normally open (M) auxiliary contact;
- Bay 2 busbar 2 isolator red phase normally closed (N) auxiliary contact;
- Bay 2 busbar 2 isolator white phase normally open (M) auxiliary contact;
- Bay 2 busbar 2 isolator white phase normally closed (N) auxiliary contact;
- Bay 2 busbar 2 isolator blue phase normally open (M) auxiliary contact; and,
- Bay 2 busbar 2 isolator blue phase normally closed (N) auxiliary contact.

The Bay 2 busbar 2 isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Bay 2 busbar 2 isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Bay 2 busbar 2 isolator discrepancy;
- Bay 2 busbar 2 open and close status remote reporting (HMI and GW); and,
- Bay 2 busbar 2 open and close status local reporting (IED HMI).

#### 3.32.3.8 Bay 2 isolator busbar 1 side status

The Bay 2 isolator busbar 1 side status is required within the diameter control device. The Bay 2 isolator busbar 1 side statuses (M and N contacts) information shall be received via GOOSE data from the bay 2 main # PIU. The following Bay 2 isolator busbar 1 side status GOOSE data shall be subscribed to:

- Bay 2 isolator busbar 1 side red phase normally open (M) auxiliary contact;
- Bay 2 isolator busbar 1 side red phase normally closed (N) auxiliary contact;
- Bay 2 isolator busbar 1 side white phase normally open (M) auxiliary contact;
- Bay 2 isolator busbar 1 side white phase normally closed (N) auxiliary contact;
- Bay 2 isolator busbar 1 side blue phase normally open (M) auxiliary contact; and,
- Bay 2 isolator busbar 1 side blue phase normally closed (N) auxiliary contact.

The Bay 2 isolator busbar 1 side M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Bay 2 isolator busbar 1 side auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Bay 2 isolator busbar 1 side discrepancy;
- Bay 2 isolator busbar 1 side open and close status remote reporting (HMI and GW); and,
- Bay 2 isolator busbar 1 side open and close status local reporting (IED HMI).

#### 3.32.3.9 Tie Bay isolator busbar 1 side status

The Tie Bay isolator busbar 1 side status is required within the diameter control device. The Tie Bay isolator busbar 1 side statuses (M and N contacts) information shall be received via GOOSE data from the tie bay main # PIU. The following Tie Bay isolator busbar 1 side status GOOSE data shall be subscribed to:

- Tie Bay isolator busbar 1 side red phase normally open (M) auxiliary contact;
- Tie Bay isolator busbar 1 side red phase normally closed (N) auxiliary contact;
- Tie Bay isolator busbar 1 side white phase normally open (M) auxiliary contact;
- Tie Bay isolator busbar 1 side white phase normally closed (N) auxiliary contact;
- Tie Bay isolator busbar 1 side blue phase normally open (M) auxiliary contact; and,
- Tie Bay isolator busbar 1 side blue phase normally closed (N) auxiliary contact.

The Tie Bay isolator busbar 1 side M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Tie Bay isolator busbar 1 side auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Tie Bay isolator busbar 1 side discrepancy;
- Tie Bay isolator busbar 1 open and close status remote reporting (HMI and GW); and,
- Tie Bay isolator busbar 1 open and close status local reporting (IED HMI).

#### 3.32.3.10 Tie Bay isolator busbar 2 side status

The Tie Bay isolator busbar 2 side status is required within the diameter control device. The Tie Bay isolator busbar 2 side statuses (M and N contacts) information shall be received via GOOSE data from the tie bay main # PIU. The following Tie Bay isolator busbar 2 side status GOOSE data shall be subscribed to:

- Tie Bay isolator busbar 2 side red phase normally open (M) auxiliary contact;
- Tie Bay isolator busbar 2 side red phase normally closed (N) auxiliary contact;
- Tie Bay isolator busbar 2 side white phase normally open (M) auxiliary contact;
- Tie Bay isolator busbar 2 side white phase normally closed (N) auxiliary contact;
- Tie Bay isolator busbar 2 side blue phase normally open (M) auxiliary contact; and,
- Tie Bay isolator busbar 2 side blue phase normally closed (N) auxiliary contact.

The Tie Bay isolator busbar 2 side M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required Tie Bay isolator busbar 2 side auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- Tie Bay isolator busbar 2 side discrepancy;
- Tie Bay isolator busbar 2 side open and close status remote reporting (HMI and GW); and,
- Tie Bay isolator busbar 2 side open and close status local reporting (IED HMI).

#### 3.32.3.11 MV Bay busbar 1 isolator status

The MV Bay busbar 1 isolator status is required within the diameter control device. The MV Bay busbar 1 isolator statuses (M and N contacts) information shall be received via GOOSE data from the MV bay main # PIU. The following MV Bay busbar 1 isolator status GOOSE data shall be subscribed to:

- MV Bay busbar 1 isolator red phase normally open (M) auxiliary contact;
- MV Bay busbar 1 isolator red phase normally closed (N) auxiliary contact;

- MV Bay busbar 1 isolator white phase normally open (M) auxiliary contact;
- MV Bay busbar 1 isolator white phase normally closed (N) auxiliary contact;
- MV Bay busbar 1 isolator blue phase normally open (M) auxiliary contact; and,
- MV Bay busbar 1 isolator blue phase normally closed (N) auxiliary contact.

The MV Bay busbar 1 isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required MV Bay busbar 1 isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- MV Bay busbar 1 isolator discrepancy;
- MV Bay busbar 1 open and close status remote reporting (HMI and GW); and,
- MV Bay busbar 1 open and close status local reporting (IED HMI).

#### 3.32.3.12 MV Bay busbar 2 isolator status

The MV Bay busbar 2 isolator status is required within the diameter control device. The MV Bay busbar 2 isolator statuses (M and N contacts) information shall be received via GOOSE data from the MV bay main # PIU. The following MV Bay busbar 2 isolator status GOOSE data shall be subscribed to:

- MV Bay busbar 2 isolator red phase normally open (M) auxiliary contact;
- MV Bay busbar 2 isolator red phase normally closed (N) auxiliary contact;
- MV Bay busbar 2 isolator white phase normally open (M) auxiliary contact;
- MV Bay busbar 2 isolator white phase normally closed (N) auxiliary contact;
- MV Bay busbar 2 isolator blue phase normally open (M) auxiliary contact; and,
- MV Bay busbar 2 isolator blue phase normally closed (N) auxiliary contact.

The MV Bay busbar 2 isolator M auxiliary contacts shall be available in a serial combination (M contacts of the three phases in series) and the N auxiliary contacts shall be available in a serial combination (N contacts of the three phases in series). The required MV Bay busbar 2 isolator auxiliary contact information is required to fulfil the following functions, implemented within the diameter control device:

- MV Bay busbar 2 isolator discrepancy;
- MV Bay busbar 2 open and close status remote reporting (HMI and GW); and,
- MV Bay busbar 2 open and close status local reporting (IED HMI).

## 3.33 Isolator discrepancy

### 3.33.1 Philosophy

The isolator discrepancy functions shall be included within the diameter control devices to detect a discrepancy between the phases of the relevant isolator. Detection of an isolator discrepancy condition shall be by way of the relevant isolator auxiliary contacts, and shall be independent of the action from which it resulted.

### 3.33.2 Rationale

The isolator pole discrepancy is required to detect in the event of any one of the isolators being in discrepancy, beyond a set timing window.

Alarming of the isolator pole discrepancies is required to prevent unwanted controller operation of the diameter primary plant equipment.

### 3.33.3 Design requirements

The isolator discrepancy shall be derived from the isolator statuses information received via GOOSE from the specific main protection PIU. The isolators shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The isolator discrepancies shall be drop-off time delays and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a discrepancy alarm, for the specific isolator discrepancy condition which persists beyond the normal limits (timer setting). The isolator discrepancy function shall be user selectable IN/OUT.

#### 3.33.3.1 Object 1 isolator discrepancy

The Object 1 isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Object 1 isolator. Detection of an Object 1 isolator discrepancy condition shall be by way of the Object 1 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Object 1 isolator discrepancy shall be derived from the Object 1 isolator statuses information received via GOOSE from the bay 1 main # PIU. The Object 1 isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Object 1 isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue an Object 1 isolator discrepancy alarm, for an Object 1 isolator discrepancy condition which persists beyond the normal limits (timer setting). The Object 1 isolator discrepancy function shall be user selectable IN/OUT.

The Object 1 isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.2 Object 2 isolator discrepancy

The Object 2 isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Object 2 isolator. Detection of an Object 2 isolator discrepancy condition shall be by way of the Object 2 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Object 2 isolator discrepancy shall be derived from the Object 2 isolator statuses information received via GOOSE from the bay 2 main # PIU. The Object 2 isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Object 2 isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue an Object 2 isolator discrepancy alarm, for an Object 2 isolator discrepancy condition which persists beyond the normal limits (timer setting). The Object 2 isolator discrepancy function shall be user selectable IN/OUT.

The Object 2 isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.3 Line 1 reactor transfer isolator discrepancy

The Line 1 reactor transfer isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Line 1 reactor transfer isolator. Detection of a Line 1 reactor transfer isolator discrepancy condition shall be by way of the Object 1 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Line 1 reactor transfer isolator discrepancy shall be derived from the Line 1 reactor transfer isolator statuses information received via GOOSE from the bay 1 main # PIU. The Line 1 reactor transfer isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Line 1 reactor transfer isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a Line 1 reactor transfer isolator discrepancy alarm, for a Line 1 reactor transfer isolator discrepancy condition which persists beyond the normal limits (timer setting). The Line 1 reactor transfer isolator discrepancy function shall be user selectable IN/OUT.

The Line 1 reactor transfer isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.4 Line 2 reactor transfer isolator discrepancy

The Line 2 reactor transfer isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Line 2 reactor transfer isolator. Detection of a Line 2 reactor transfer isolator discrepancy condition shall be by way of the Object 1 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Line 2 reactor transfer isolator discrepancy shall be derived from the Line 2 reactor transfer isolator statuses information received via GOOSE from the bay 2 main # PIU. The Line 2 reactor transfer isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Line 2 reactor transfer isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations.

This timer shall be normally picked-up, and shall only drop-off, and issue a Line 2 reactor transfer isolator discrepancy alarm, for a Line 2 reactor transfer isolator discrepancy condition which persists beyond the normal limits (timer setting). The Line 2 reactor transfer isolator discrepancy function shall be user selectable IN/OUT.

The Line 2 reactor transfer isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.5 Bay 1 Busbar 1 isolator discrepancy

The Bay 1 Busbar 1 isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Bay 1 Busbar 1 isolator. Detection of a Bay 1 Busbar 1 isolator discrepancy condition shall be by way of the Bay 1 Busbar 1 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Bay 1 Busbar 1 isolator discrepancy shall be derived from the Bay 1 Busbar 1 isolator statuses information received via GOOSE from the bay 1 main # PIU. The Bay 1 Busbar 1 isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Bay 1 Busbar 1 isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations.

This timer shall be normally picked-up, and shall only drop-off, and issue a Bay 1 Busbar 1 isolator discrepancy alarm, for a Bay 1 Busbar 1 isolator discrepancy condition which persists beyond the normal limits (timer setting). The Bay 1 Busbar 1 isolator discrepancy function shall be user selectable IN/OUT.

The Bay 1 Busbar 1 isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.6 Bay 1 isolator busbar 2 side isolator discrepancy

The Bay 1 isolator busbar 2 side isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Bay 1 isolator busbar 2 side isolator. Detection of a Bay 1 isolator busbar 2 side isolator discrepancy condition shall be by way of the Bay 1 isolator busbar 2 side isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Bay 1 isolator busbar 2 side isolator discrepancy shall be derived from the Bay 1 isolator busbar 2 side isolator statuses information received via GOOSE from the bay 1 main # PIU. The Bay 1 isolator busbar 2 side isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Bay 1 isolator busbar 2 side isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue an Bay 1 isolator busbar 2 side isolator discrepancy alarm, for an Bay 1 isolator busbar 2 side isolator discrepancy condition which persists beyond the normal limits (timer setting). The Bay 1 isolator busbar 2 side isolator discrepancy function shall be user selectable IN/OUT.

The Bay 1 isolator busbar 2 side isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.7 Bay 2 busbar 2 isolator discrepancy

The Bay 2 busbar 2 isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Bay 2 busbar 2 isolator. Detection of a Bay 2 busbar 2 isolator discrepancy condition shall be by way of the Bay 2 busbar 2 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The Bay 2 busbar 2 isolator discrepancy shall be derived from the Bay 2 busbar 2 isolator statuses information received via GOOSE from the bay 2 main # PIU. The Bay 2 busbar 2 isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Bay 2 busbar 2 isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a Bay 2 busbar 2 isolator discrepancy alarm, for an Bay 2 busbar 2 isolator discrepancy condition which persists beyond the normal limits (timer setting). The Bay 2 busbar 2 isolator discrepancy function shall be user selectable IN/OUT.

The Bay 2 busbar 2 isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.8 Bay 2 isolator busbar 1 side discrepancy

The Bay 2 isolator busbar 1 side discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Bay 2 isolator busbar 1 side. Detection of a Bay 2 isolator busbar 1 side discrepancy condition shall be by way of the Bay 2 isolator busbar 1 side auxiliary contacts, and shall be independent of the action from which it resulted.

The Bay 2 isolator busbar 1 side discrepancy shall be derived from the Bay 2 isolator busbar 1 side statuses information received via GOOSE from the bay 2 main # PIU. The Bay 2 isolator busbar 1 side shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The Bay 2 isolator busbar 1 side discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a Bay 2 isolator busbar 1 side discrepancy alarm, for a Bay 2 isolator busbar 1 side discrepancy condition which persists beyond the normal limits (timer setting). The Bay 2 isolator busbar 1 side discrepancy function shall be user selectable IN/OUT.

The Bay 2 isolator busbar 1 side discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.9 Tie Bay isolator busbar 1 side discrepancy

The Tie Bay isolator busbar 1 side discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Tie Bay isolator busbar 1 side. Detection of a Tie Bay isolator busbar 1 side discrepancy condition shall be by way of the Tie Bay isolator busbar 1 side auxiliary contacts, and shall be independent of the action from which it resulted. The Tie Bay isolator busbar 1 side discrepancy shall be derived from the Tie Bay isolator busbar 1 side statuses information received via GOOSE from the tie bay main # PIU. The Tie Bay isolator busbar 1 side shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts.

The Tie Bay isolator busbar 1 side discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a Tie Bay isolator busbar 1 side discrepancy alarm, for an Tie Bay isolator busbar 1 side discrepancy condition which persists beyond the normal limits (timer setting). The Tie Bay isolator busbar 1 side discrepancy function shall be user selectable IN/OUT.

The Tie Bay isolator busbar 1 side discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.10 Tie Bay isolator busbar 2 side discrepancy

The Tie Bay isolator busbar 2 side discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the Tie Bay isolator busbar 2 side. Detection of a Tie Bay isolator busbar 2 side discrepancy condition shall be by way of the Tie Bay isolator busbar 2 side auxiliary contacts, and shall be independent of the action from which it resulted. The Tie Bay isolator busbar 2 side discrepancy shall be derived from the Tie Bay isolator busbar 2 side statuses information received via GOOSE from the tie bay main # PIU. The Tie Bay isolator busbar 2 side shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts.

The Tie Bay isolator busbar 2 side discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a Tie Bay isolator busbar 2 side discrepancy alarm, for an Tie Bay isolator busbar 2 side discrepancy condition which persists beyond the normal limits (timer setting). The Tie Bay isolator busbar 2 side discrepancy function shall be user selectable IN/OUT.

The Tie Bay isolator busbar 2 side discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.11 MV Bay busbar 1 isolator discrepancy

The MV Bay busbar 1 isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the MV Bay busbar 1 isolator. Detection of a MV Bay busbar 1 isolator discrepancy condition shall be by way of the MV Bay busbar 1 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The MV Bay busbar 1 isolator discrepancy shall be derived from the MV Bay busbar 1 isolator statuses information received via GOOSE from the MV bay main # PIU. The MV Bay busbar 1 isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The MV Bay busbar 1 isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a MV Bay busbar 1 isolator discrepancy alarm, for an MV Bay busbar 1 isolator discrepancy condition which persists beyond the normal limits (timer setting). The MV Bay busbar 1 isolator discrepancy function shall be user selectable IN/OUT.

The MV Bay busbar 1 isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

#### 3.33.3.12 MV Bay busbar 2 isolator discrepancy

The MV Bay busbar 2 isolator discrepancy function shall be included within the diameter control device to detect a discrepancy between the phases of the MV Bay busbar 2 isolator. Detection of a MV Bay busbar 1 isolator discrepancy condition shall be by way of the MV Bay busbar 2 isolator auxiliary contacts, and shall be independent of the action from which it resulted. The MV Bay busbar 2 isolator discrepancy shall be derived from the MV Bay busbar 2 isolator statuses information received via GOOSE from the MV bay main # PIU. The MV Bay busbar 2 isolator shall consist of three (one per phase) normally open isolator auxiliary contacts in parallel with three (one per phase) normally closed auxiliary contacts, with this parallel arrangement of contacts. The MV Bay busbar 2 isolator discrepancy shall be a drop-off time delay and shall be settable to accommodate the maximum normal discrepancy between the phases during open and close operations. This timer shall be normally picked-up, and shall only drop-off, and issue a MV Bay busbar 2 isolator discrepancy alarm, for an MV Bay busbar 2 isolator discrepancy condition which persists beyond the normal limits (timer setting). The MV Bay busbar 2 isolator discrepancy function shall be user selectable IN/OUT.

The MV Bay busbar 2 isolator discrepancy condition (settable time delay), shall:

- Reported to the gateway and station HMI; and
- Displayed on the line protection IED.

## 3.34 Supervision and Monitoring functions

### 3.34.1 Philosophy

The diameter control device shall have the capability to supervise and monitor conditions and health that will adversely affect the operation and/or availability of the diameter interface control systems.

### 3.34.2 Rationale

The capability to supervise and monitor conditions and health is required to be reported locally and remotely for actions to restore the diameter interface control systems and primary plant back to normal.

### 3.34.3 Design requirements

The supervision and monitoring information shall be received via GOOSE data from the specific circuit-breaker PIU.

#### 3.34.3.1 Tie Bay breaker trip circuit supervision

Trip circuit supervision shall continuously monitor each phase of the trip circuit of the tie bay breaker. The trip circuit shall be supervised with the tie bay breaker in the close and open positions. The trip circuit supervision shall be integrated within the diameter control IED. The trip circuit supervision shall not adversely affect the dependability and security of the tie bay breaker trip circuit. Trip circuit supervision shall:

- Monitor each phase of the tie bay breaker trip circuit independently;
- Reported locally at the line protection IED HMI;
- Reported locally to the main # protection system unhealthy indication; and,
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.2 Bay 1 breaker SF6 gas supervision - SIMG

The bay 1 breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) SIMG logical nodes shall be located within the bay 1 breaker PIUs and be send via GOOSE to the diameter control IED. The bay 1 breaker $SF_6$ gas critical signals shall block manual closing (local or remote) of the bay 1 breaker. When the bay 1 breaker bay are populated with six breakers (two per phase), each breaker's $SF_6$ gas insulation medium shall be monitored and reported independently (six for $SF_6$ gas low and six for $SF_6$ gas critical).

The bay 1 breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.3 Bay 2 breaker SF6 gas supervision - SIMG

The bay 2 breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) SIMG logical nodes shall be located within the bay 2 breaker PIUs and be send via GOOSE to the diameter control IED. The bay 2 breaker $SF_6$ gas critical signals shall block manual closing (local or remote) of the bay 2 breaker. When the bay 2 breaker bay are populated with six breakers (two per phase), each breaker's $SF_6$ gas insulation medium shall be monitored and reported independently (six for $SF_6$ gas low and six for $SF_6$ gas critical).

The bay 2 breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.4 Tie Bay breaker SF6 gas supervision - SIMG

The tie bay breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) SIMG logical nodes shall be located within the tie bay breaker PIUs and be send via GOOSE to the diameter control IED. The tie bay breaker $SF_6$ gas critical signals shall block manual closing (local or remote) of the tie bay breaker. When the tie bay breaker bay are populated with six breakers (two per phase), each breaker's $SF_6$ gas insulation medium shall be monitored and reported independently (six for $SF_6$ gas low and six for $SF_6$ gas critical).

The tie bay breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.5 MV Bay breaker SF6 gas supervision - SIMG

The MV bay breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) SIMG logical nodes shall be located within the MV bay breaker PIUs and be send via GOOSE to the diameter control IED. The MV bay breaker $SF_6$ gas critical signals shall block manual closing (local or remote) of the tie bay breaker.

The MV bay breaker $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per breaker) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.6 Bay 1 breaker busbar 1 side CT SF6 gas supervision - SIMG

The bay 1 breaker busbar 1 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the bay 1 breaker PIUs and be send via GOOSE to the diameter control IED.

The bay 1 breaker busbar 1 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.7 Bay 1 breaker connector 1 side CT SF6 gas supervision - SIMG

The bay 1 breaker connector 1 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the bay 1 breaker PIUs and be send via GOOSE to the diameter control IED.

The bay 1 breaker connector 1 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.8 Bay 2 breaker busbar 2 side CT SF6 gas supervision - SIMG

The bay 2 breaker busbar 2 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the bay 2 breaker PIUs and be send via GOOSE to the diameter control IED.

The bay 2 breaker busbar 2 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.9 Bay 2 breaker connector 2 side CT SF6 gas supervision - SIMG

The bay 2 breaker connector 2 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the bay 2 breaker PIUs and be send via GOOSE to the diameter control IED.

The bay 2 breaker connector 2 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.10 Tie Bay breaker busbar 1 side CT SF6 gas supervision - SIMG

The tie bay breaker busbar 1 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the tie bay breaker PIUs and be send via GOOSE to the diameter control IED.

The tie bay breaker busbar 1 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.11 Tie Bay breaker busbar 2 side CT SF6 gas supervision - SIMG

The tie bay breaker busbar 2 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the tie bay breaker PIUs and be send via GOOSE to the diameter control IED.

The tie bay breaker busbar 2 side CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.12 MV Bay breaker CT SF6 gas supervision - SIMG

The MV breaker CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) SIMG logical nodes shall be located within the MV bay breaker PIUs and be send via GOOSE to the diameter control IED.

The MV bay breaker CT $SF_6$ gas insulation medium monitoring device(s) low and critical signals (per CT) shall:

- Reported locally at the diameter control IED HMI;
- Reported locally to the main # protection system unhealthy indication;
- Reported remotely via the gateway; and,
- Reported to the station HMI.

#### 3.34.3.13 Heater: KHTR

This logical node represents a heater, cubicle heater or any other heater that can be controlled.

The heater information is not used within the diameter control device and shall be send from the relevant breaker PIU via the diameter control device to the gateway for remote and station HMI reporting.

All the primary plant heater data shall be reported.

#### 3.34.3.14 Diameter Interface Panel Not Healthy indication

The diameter interface panel not healthy lamp is an alarm condition that indicates that the diameter interface is in an abnormal state. The following conditions shall activate the DIPNH alarm:

DCF(M#) - Main # Protection DC supply failed (MCB switched Off or tripped, and open circuit in DC supply rail wiring loops);

- Bay 1 SIS - OFF and MAINTENANCE selections;
- Bay 2 SIS - OFF and MAINTENANCE selections;
- Tie Bay SIS - OFF and MAINTENANCE selections;
- MV Bay SIS - OFF and MAINTENANCE selections;
- Diameter control device failed;
- Ethernet switch failed;
- Diameter interface unhealthy; and,
- Lamp Check - Lamp check push button to test the lamp health.

The diameter interface panel not healthy lamp (DIPNH) indication shall be provided external to the diameter control IED. The DIPNH lamp shall be positioned on the top left hand side of the panel. The DIPNH lamp shall be red and supplied by 230 VAC.

#### 3.34.3.15 Bay 1 JB Not Healthy indications

The alarm "Bay 1 Junction Box Not Healthy" (B1JBNH) shall be used to indicate "PNH" type alarm conditions that occur within the bay 1 JB. The B1JBNH is an alarm condition that indicates that the Bay 1 JB is in an abnormal state. The B1JBNH alarm shall be a hardwire interface between the Bay 1 JB and the diameter interface panel:

- Bay 1 Main # PIU failed;
- Bay 1 JB Any switch or MCB in an abnormal state; and
- Bay 1 JB Loss of DC supplies.

The bay 1 JB not healthy lamp (B1JBNH) indication shall be provided external to the diameter control IED. The B1JB Not Healthy (B1JBNH) lamp shall be positioned on the top right hand side of the bay 1 mimic. The B1JBNH lamp shall be red and supplied by 230 VAC.

#### 3.34.3.16 Bay 2 JB Not Healthy indications

The alarm "Bay 2 Junction Box Not Healthy" (B2JBNH) shall be used to indicate "PNH" type alarm conditions that occur within the bay 2 JB. The B2JBNH is an alarm condition that indicates that the Bay 2 JB is in an abnormal state. The B2JBNH alarm shall be a hardwire interface between the Bay 2 JB and the diameter interface panel:

- Bay 2 Main # PIU failed;
- Bay 2 JB Any switch or MCB in an abnormal state; and
- Bay 2 JB Loss of DC supplies.

The bay 2 JB not healthy lamp (B2JBNH) indication shall be provided external to the diameter control IED. The B2JB Not Healthy (B2JBNH) lamp shall be positioned on the top right hand side of the bay 2 mimic. The B2JBNH lamp shall be red and supplied by 230 VAC.

#### 3.34.3.17 Tie Bay JB Not Healthy indications

The alarm "Tie Bay Junction Box Not Healthy" (TBJBNH) shall be used to indicate "PNH" type alarm conditions that occur within the tie bay JB. The TBJBNH is an alarm condition that indicates that the Tie Bay JB is in an abnormal state. The TBJBNH alarm shall be a hardwire interface between the Tie Bay JB and the diameter interface panel:

- Tie Bay Main # PIU failed;
- Tie Bay JB Any switch or MCB in an abnormal state; and
- Tie Bay JB Loss of DC supplies.

The tie bay JB not healthy lamp (TBJBNH) indication shall be provided external to the diameter control IED. The TBJB Not Healthy (TBJBNH) lamp shall be positioned on the top right hand side of the tie bay mimic. The TBJBNH lamp shall be red and supplied by 230 VAC.

#### 3.34.3.18 MV Bay JB Not Healthy indications

The alarm "MV Bay Junction Box Not Healthy" (MVBJBNH) shall be used to indicate "PNH" type alarm conditions that occur within the MV bay JB. The MVBJBNH is an alarm condition that indicates that the MV Bay JB is in an abnormal state. The MVBJBNH alarm shall be a hardwire interface between the MV Bay JB and the diameter interface panel:

- MV Bay Main # PIU failed;
- MV Bay JB Any switch or MCB in an abnormal state; and
- MV Bay JB Loss of DC supplies.

The MV bay JB not healthy lamp (MVBJBNH) indication shall be provided external to the diameter control IED. The MVBJB Not Healthy (MVBJBNH) lamp shall be positioned on the bottom right hand side of the tie bay mimic. The MVBJBNH lamp shall be red and supplied by 230 VAC.

#### 3.34.3.19 DC supply monitoring

Each DC supply rail shall be monitored and reported (local and remote). Each monitoring device shall be energised upon application of the DC supply it is monitoring, with its associated DC fail normally closed alarm contacts being maintained in an open circuit condition. In the event of a DC supply failure, or the switching to the 'Off' position of the relevant DC MCB, the DC fail monitoring device shall be de-energised, resulting in the closing of the alarm contacts. The DC supply fail monitoring device shall be connected to the last loop of the supply being monitored. Each supply rail controlled by an MCB shall be monitored. The DC supply monitoring device shall reset and alarm at 0.8 Vn.

The following DC rail monitoring is required:

- Main # tie bay breaker tripping supply rail;
- Main # bay 1 closing supply rail;
- Main # bay 2 closing supply rail;
- Main # tie bay closing supply rail;
- Main # MV bay closing supply rail;
- Main # bay 1 indication supply rail;
- Main # bay 2 indication supply rail;
- Main # tie bay indication supply rail; and,
- Main # MV bay indication supply rail.
- The following equipment failure alarms are required:
- Main # Diameter control device failed; and,
- Main # Ethernet switch failed.

#### 3.34.3.20 AC supply monitoring

The 230 VAC supply shall be supplied from the station AC board. The 230 VAC supply monitoring shall be done and reported via the diameter control device.

An AC fail relay, ACF(Scheme), shall monitor the status of the 230V AC 'panel not healthy' 'Bay 1 JB not healthy', 'Tie Bay JB not healthy', 'Bay 2 JB not healthy' and 'MV Bay JB not healthy' indication supply. This relay will be energised upon application of the AC supply it is monitoring, with its associated AC fail normally closed alarm contacts being maintained in an open circuit condition. In the event of an AC supply failure, the AC fail relay shall be de-energised, resulting in the closing of the alarm contacts. The AC supply fail monitoring relay shall be connected to the last loop of the supply being monitored. The AC supply fail monitoring alarm contact shall be remotely reported via the diameter control device (DCD).

#### 3.34.3.21 IEC61850 communications failure

IEC61850 communications failure that affects the GOOSE signals shall be monitored by the diameter control device and:

- Reported locally at the diameter control IED HMI;
- Reported locally to the diameter control system unhealthy indication;
- Select to the master mode (if selected to slave);
- Shall not cause an unwanted or over performance; and,
- Reported to the station HMI.

IEC61850 communications failure shall independently monitor the communications with all other devices. The communications failure to a specific IED shall not affect the performance of the information exchange between the other IEDs with healthy communications. The following IEDs communications shall be independently monitored:

- Other main diameter control IED;
- Object 1 Main 1 protection IED;
- Object 1 Main 2 protection IED;
- Object 2 Main 1 protection IED;
- Object 2 Main 2 protection IED;
- Bay 1 Main # PIU;
- Bay 2 Main # PIU;
- Tie Bay Main # PIU; and,
- MV Bay Main # PIU.

## 3.35 Measurements

### 3.35.1 Philosophy

The diameter control device shall display locally (IED HMI) and report remotely measurements quantities, on a real time basis, without human intervention to view the values. The measurement for each quantity shall be measured separately and continuously.

### 3.35.2 Rationale

Primary quantities are required both locally and remotely to enable the optimum operating of the power system, load forecasting, system expansion planning and for statistical purposes.

Local measurements quantities are required for visual verification during testing, primary plant injection testing and for operational purposes.

### 3.35.3 Design requirements

The requisite remote analogue indications shall be to provide for via Ethernet communications (IEC61850) from the diameter control IED. Digital indications shall be provided via the Ethernet SCADA communication link. The measurements quantities shall be derived from metering class CTs and VTs. The diameter control IED analogue input class for connection to the metering class CTs and VTs shall be 0.5 or better.

The diameter control IED HMI shall display the analogue quantities continuously. Integral dead-band reporting shall be used for remote reporting (Station HMI and control centres). The measured value is reported if the time integral of all changes exceeds a pre-set limit. A minimum settable value shall be possible for all the measured quantities, typical 5% for currents, active power, reactive power and apparent power, and 3% for voltage and frequency.

All measurements quantities shall be visible by default, that is, no external influence shall be required to view any quantity.

The diameter control IED HMI shall have the capability to display and remote reporting of the following measurements quantities:

- Object 1 Phase-phase voltages (R-W, W-B and B-R);
- Object 1 Phase currents (R-N, W-N and B-N);
- Object 1 Active Power (P);
- Object 1 Reactive Power (Q);

- Object 1 Power factor (PF);
- Object 1 Frequency (F);
- Object 2 Phase-phase voltages (R-W, W-B and B-R);
- Object 2 Phase currents (R-N, W-N and B-N);
- Object 2 Active Power (P);
- Object 2 Reactive Power (Q);
- Object 2 Power factor (PF);
- Object 2 Frequency (F);
- Busbar 1 Phase-phase voltages (R-W, W-B and B-R);
- Busbar 2 Phase-phase voltages (R-W, W-B and B-R);
- Connector 1 Phase-phase voltages (R-W, W-B and B-R);
- Connector 1 Phase-phase voltages (R-W, W-B and B-R);
- Bay 1 Breaker Phase currents (R-N, W-N and B-N);
- Bay 1 Breaker Active Power (P);
- Bay 1 Breaker Reactive Power (Q);
- Bay 1 Breaker Power factor (PF);
- Bay 1 Breaker Frequency (F);
- Bay 2 Breaker Phase currents (R-N, W-N and B-N);
- Bay 2 Breaker Active Power (P);
- Bay 2 Breaker Reactive Power (Q);
- Bay 2 Breaker Power factor (PF);
- Bay 2 Breaker Frequency (F);
- Tie Bay Breaker Phase currents (R-N, W-N and B-N);
- Tie Bay Breaker Active Power (P);
- Tie Bay Breaker Reactive Power (Q);
- Tie Bay Breaker Power factor (PF);
- Tie Bay Breaker Frequency (F);
- Transformer MV Side Phase-phase voltages (R-W, W-B and B-R);
- MV Bay Breaker Phase currents (R-N, W-N and B-N);
- MV Bay Breaker Active Power (P);
- MV Bay Breaker Reactive Power (Q);
- MV Bay Breaker Power factor (PF);
- MV Bay Breaker Frequency (F);
- Bay 1 breaker synchronising voltage difference (ΔV);
- Bay 1 breaker synchronising frequency difference (ΔF);
- Bay 1 breaker synchronising angular difference (ΔΦ);

- Bay 2 breaker synchronising voltage difference (ΔV);
- Bay 2 breaker synchronising frequency difference (ΔF);
- Bay 2 breaker synchronising angular difference (ΔΦ);
- Tie Bay breaker synchronising voltage difference (ΔV);
- Tie Bay breaker synchronising frequency difference (ΔF);
- Tie Bay breaker synchronising angular difference (ΔΦ);
- MV Bay breaker synchronising voltage difference (ΔV);
- MV Bay breaker synchronising frequency difference (ΔF); and,
- MV Bay breaker synchronising angular difference (ΔΦ).

## 3.36 Interlocking: CILO

### 3.36.1 Philosophy

The diameter control device shall provide for interlocking at bay level for all primary plant local and remote control commands. Provision shall be made to override interlocking from remote.

### 3.36.2 Rationale

Interlocking is required to reducing operating errors. Interlocking shall be applied on all operating diagrams to safeguard against inadvertent operation of isolators and breakers. The operating diagram in turn is defined as the centralised active diagram, mimic panel or Human Machine Interface (HMI) at a power station or substation control room.

### 3.36.3 Design requirements

All interlocking rules referring to a bay are included in the CILO Logical Node. Releases or blockings of requested commands are issued. In the case of status changes affecting interlocking, blocking commands are issued. The bay interlocking is required to safeguard all affected equipment as well as maintenance personnel against the incorrect operation of primary plant.

The following general rules are applied:

- No earth may be applied when the plant on either side has not been isolated;
- No isolator may be closed when an earth is applied on either side and the breaker is open;
- No isolator may be opened when the breaker is closed;
- All position indicators for the primary plant shall be handled by a double point indication;
- All interlocking circuits shall be fail safe. In case of interlocking supply loss or broken conductor(s), no interlocking release shall be issued; and,
- Interlocking shall be applied at the lowest level to ensure that bypassing of the required interlocking cannot be performed from the clients.

The interlocking rules per primary plant item shall be finalised and implemented during the product development phase.

#### 3.36.3.1 Switch Controller: CSWI

The switch control CSWI logical node handles all switchgear operations from the operators and from related automatics. It checks the authorization of the commands. It supervises the command execution and gives an alarm in case of an improper ending of the command. It asks for releases from interlocking, synchrocheck and auto-reclosure.

The switch control CSWI logical nodes shall be located within the diameter control device and shall be controlled by the relevant supervisory isolating switch. The following CSWI are required to control (open and close) the primary plant and auto-reclose mode selections within the diameter:

| | | |
|---|---|---|
| 1 | Bay 1 Breaker | Open and close commands |
| 2 | Bay 1 Busbar 1 isolator | Open and close commands |
| 3 | Bay 1 Isolator Busbar 2 side | Open and close commands |
| 4 | Object 1 Isolator | Open and close commands |
| 5 | Line 1 Reactor Transfer Isolator | Open and close commands |
| 6 | Tie Bay Breaker | Open and close commands |
| 7 | Tie Bay Isolator Busbar 1 side | Open and close commands |
| 8 | Tie Bay Isolator Busbar 2 side | Open and close commands |
| 9 | Bay 2 Breaker | Open and close commands |
| 10 | Bay 2 Busbar 2 isolator | Open and close commands |
| 11 | Bay 2 Isolator Busbar 1 side | Open and close commands |
| 12 | Object 2 Isolator | Open and close commands |
| 13 | Line 2 Reactor Transfer Isolator | Open and close commands |
| 14 | MV Bay Breaker | Open and close commands |
| 15 | MV Bay Busbar 1 isolator | Open and close commands |
| 16 | MV Bay Busbar 2 isolator | Open and close commands |
| 17 | Line 1 - Auto-reclose | ON and OFF selections |
| 18 | Line 1 – 1-Pole and 3-Pole | Auto-reclose selections |
| 19 | Line 1 – 1 & 3 Pole | Auto-reclose selections |
| 20 | Line 1 – 3-Cycle and 5-Cycle | Reclose selections |
| 21 | Line 1 – 3-Pole slow and 3-Pole fast | Auto-reclose selections |
| 22 | Line 1 - TPK | Normal and Transfer selections |
| 23 | Line 1 – Auto-reclose | Master and Slave selections |
| 24 | Line 2 - Auto-reclose | ON and OFF selections |
| 25 | Line 2 – 1-Pole and 3-Pole | Auto-reclose selections |
| 26 | Line 2 - 1&3 Pole | Auto-reclose selections |
| 27 | Line 2 – 3-Cycle and 5-Cycle | Reclose selections |
| 28 | Line 2 – 3-Pole slow and 3-Pole fast | Auto-reclose selections |
| 29 | Line 2 - TPK | Normal and Transfer selections |
| 30 | Line 2 – Auto-reclose | Master and Slave selections |

## 3.37 Ethernet switches and communications architecture

### 3.37.1 Philosophy

The breaker-and-a half diameter control device shall connect to the other diameter control device and line protection IEDs via a 100 Megabit Multi-mode optical interface and the panel ethernet switch. The IEDs within the diameter shall connect to the ethernet switch within that diameter interface panel in a star topology. The connections between the ethernet switch and the IEDs shall be multi-mode fibre.

### 3.37.2 Rationale

The optical ethernet interface is required for the GOOSE data between IEDs and the MMS data to the required clients and subscribers.

### 3.37.3 Design requirements

The IEDs and PIUs fibre connection requirements shall comply with the Generic Specification for Intelligent Electronic Devices (IEDs) Standard, Unique Identifier 240-64685228. The ethernet switch, per bay, shall interface with the substation automation network topology as per the Substation Automation Network Architecture Standard, Unique Identifier TST 41-1077.

The breaker-and-a half diameter interface panel shall include fibre patch panels to interface between the fibre cables entering the panel between the IEDs and the PIUs. The fibre patch panels shall be fitted FC fibre connections and shall include pigtails and midcouplers. The fibre patch panel shall make provision for the required number of fibre connections including 2 spares.

## 3.38 Buswiring between diameter interface and object protection schemes

### 3.38.1 Philosophy

The breaker-and-a-half diameter interface scheme shall have the capability to interface with the object 1 and object 2 protection schemes.

### 3.38.2 Rationale

Buswiring is required to interface between the breaker-and-a-half diameter interface scheme and the object 1 and object 2 protection schemes for the purpose of AC indication supply, DC tripping supply and external disturbance recorder interface.

### 3.38.3 Design requirements

The breaker-and-a-half diameter interface scheme shall be designed that the object protection panel can be mounted on either the left hand or right hand or both sides of the diameter interface panel (6DIP-#100). The breaker-and-a-half diameter interface scheme shall be an independent design with an own set of scheme diagrams. The functions that need to be interfaced between the diameter interface panel and the two object protection panels shall be wired to dedicated terminal rails (terminal rail per object protection interface). These buswires shall be added in the factory. These buswires will only be added on site, with the addition of an object protection scheme to an in-service diameter. The buswiring ferule numbering shall include an identifier per object protection scheme.

The following buswires to interface with object 1 shall be provided for:

| | **Buswire description** |
|---|---|
| 1 | 230 VAC supply (Live) |
| 2 | 230 VAC supply (Neutral) |
| 3 | Main # Tie Bay Breaker Tripping DC Positive |

| | |
|---|---|
| 4 | Main # Tie Bay Breaker Tripping DC Negative |
| 5 | Tie Bay Breaker Red Phase Trip Test and Open Command |
| 6 | Tie Bay Breaker White Phase Trip Test and Open Command |
| 7 | Tie Bay Breaker Blue Phase Trip Test and Open Command |
| 8 | Main # Bay Breaker Tripping DC Positive |
| 9 | Bay Breaker Red Phase Trip Test and Open Command |
| 10 | Bay Breaker White Phase Trip Test and Open Command |
| 11 | Bay Breaker Blue Phase Trip Test and Open Command |
| 12 | Main # DC Positive |
| 13 | Main # Bay Isolating Switch Breaker Fail Isolated |
| 14 | Main # Tie Bay Isolating Switch Breaker Fail Isolated |
| 15 | External Disturbance Recorder Common Positive |
| 16 | Bay 1 Breaker Closing Unhealthy |
| 17 | Tie Bay Breaker Closing Unhealthy |

The following buswires to interface with object 2 shall be provided for:

| | Buswire description |
|---|---|
| 1 | 230 VAC supply (Live) |
| 2 | 230 VAC supply (Neutral) |
| 3 | Main # Tie Bay Breaker Tripping DC Positive |
| 4 | Main # Tie Bay Breaker Tripping DC Negative |
| 5 | Tie Bay Breaker Red Phase Trip Test and Open Command |
| 6 | Tie Bay Breaker White Phase Trip Test and Open Command |
| 7 | Tie Bay Breaker Blue Phase Trip Test and Open Command |
| 8 | Main # Bay Breaker Tripping DC Positive |
| 9 | Bay Breaker Red Phase Trip Test and Open Command |
| 10 | Bay Breaker White Phase Trip Test and Open Command |
| 11 | Bay Breaker Blue Phase Trip Test and Open Command |
| 12 | Main # DC Positive |
| 13 | Main # Bay Isolating Switch Breaker Fail Isolated |
| 14 | Main # Tie Bay Isolating Switch Breaker Fail Isolated |
| 15 | External Disturbance Recorder Common Positive |
| 16 | Bay 2 Breaker Closing Unhealthy |
| 17 | Tie Bay Breaker Closing Unhealthy |

## 3.39 Model power system simulator testing

### 3.39.1 Philosophy

In order to prove the operation of the protection scheme it is required that extensive model power system simulator testing of the protection and closing control devices be done.

### 3.39.2 Rationale

Eskom's main reason for including simulator testing as a certification requirement is to acquire sufficient confidence in the relay's performance that it may be applied on Eskom's transmission system. At the end of the simulator testing, Eskom will be in possession of a set of results against which a full evaluation of the relay can be made with respect to:

- the performance of the measurement algorithms, which encompasses the operating times, dependability/security, selectivity, and phase selection; and
- the logic functionality.

A relay's speed of operation is a fundamental performance issue, and to a large degree it is what differentiates the different classes of relays. Evaluation of operating speed therefore constitutes one of the primary aims of the simulator testing. There are definite system requirements on the speed of operation for issues of system stability, power quality to customers, limitation of damage, and safety to personnel.

A relay's dependability and security are, respectively, measures of its ability to operate when required to, and to restrain when required to. Its dependability/security performance therefore impacts directly on the sustained good performance of the system. Evaluation of the relay's dependability and security is achieved, respectively, by subjecting it to internal (line) faults (for which operation is required) and external faults (for which no operation is required).

A relay's selectivity is a measure of its ability to detect faults to be within a specified zone of network, and it therefore influences both the dependability and security. To ensure optimum system performance, only the faulted item must be removed. Selectivity as applicable to impedance protection includes the relay's directional determination capability (correct determination of forward faults as forward, and reverse faults as reverse), and reach accuracy capability (correct determination of fault location, i.e. no over- or under-reaching). Evaluation of the relay's selectivity is achieved by incorporating close-in forward and reverse faults to determine directional capability (no inadvertent tripping of the line for reverse faults or failure to trip for forward line faults), and remote-end forward faults to verify satisfactory reach discrimination (no inadvertent tripping of the line due to pick-up of the underreaching zone, and no failure to pick-up of the first (permissive) overreaching zone).

### 3.39.3 Design requirements

The tests shall be carried out by the tenderers in conjunction with the Purchaser's engineers at the tenderer's principal works on their model power system simulator. The purchaser will supply source and line data for the simulations as well as a list of the required tests and test scenarios during the product development phase. The protection equipment must not only be subjected to the list of required tests provided by the purchaser. The successful tenderers shall be responsible for the provision of all the equipment and protection/closing devices required, to conduct the MPS tests. All preparation shall be finalised before arrival of the purchaser's project engineers. The device settings shall be the responsibility of the tenderers, and shall be submitted to the identified purchaser's settings engineer for sanctioning prior commencement of the model power system simulator testing.

It is expected that any failures/shortcomings in the devices, identified during the above tests, shall immediately be noted and resolved by the tenderer's design engineers. The tenderers shall provide solution(s) to the identified failure(s)/shortcoming(s). The solution(s) shall be implemented to the device(s) in question and the tests that have highlighted the failure(s)/shortcoming(s) shall be repeated to confirm the solution(s). In the event that fundamental solution(s) are implemented, all the specified tests shall be repeated. The nature of the failure(s)/shortcoming(s) shall dictate whether or not the remainder of the tests shall be concluded before implementation of the solution(s). Should a further round of simulator testing be necessary this shall be at the supplier's cost. Additional and/or different tests/test scenarios may be prescribed for any subsequent rounds of testing.

The tenderers are required to provide full details of his "power system simulator", including its ranges of simulation and capabilities, with the offer.

Eskom requires that:

- the test set-up incorporates two relays, one at each end of the line (left and right), interconnected via a teleprotection link exhibiting characteristics (e.g. end-to-end delay time) that are representative of the systems that exist in reality. The relays are set to operate in a protection mode that is typical of that intended for operation on Eskom's transmission system.
- an independent disturbance recorder(s) is used to capture analogue and digital information from each line-end. The captured records are saved, and printed for immediate analysis purposes. In parallel, each relay event record is also saved and printed for analysis purposes.
- the performance of the relays is recorded on a standard summary sheet, one for each relay, alongside details of the fault and system parameters, plus any comments pertinent to the performance of the relay for that fault. The information gathered from the internally generated event records is also recorded on a summary sheet, again with any pertinent comments. In this way, the performance of the relays is thoroughly analysed for each fault, with a summary for quick reference and for later sample analysis.

When devising the scope of tests to be performed, it is not sufficient to adopt just a single set of system parameters (line, left and right source impedances, etc.) on which to apply a range of faults as this does not adequately represent the diverse system conditions, or cover the performance spectrum of the relay, which is not consistent over a broad spectrum of system conditions. The challenge is therefore to devise the best sample of tests, taking into account the constraints of time, simulator capability, etc., but at the same time achieving a sample which is representative of the diversity of the system, and brings out the full spectrum of the relay's performance.

When analysing the tests, the issues of dependability, security, selectivity, and phase selection are readily determined from the actual tests. The results can be viewed altogether, or within the different categories. The relay's performance either meets the set criteria, or it does not. The broad spectrum of test cases, spread over the different categories, allows the relay's performance and/or any weaknesses within the defined boundaries to be clearly determined.

To obtain the actual operating time profiles, the measured operating times can be plotted. These can be plotted by category, or even broken down further into the different types of faults.

## 3.40 In-service experience requirements

### 3.40.1 Philosophy

Eskom will use primary protection relays which satisfy the following six conditions:

- Are available 'off-the-shelf';
- Have a proven track record in terms of an acceptable in-service record on networks of greater than 200 kV in utilities world wide;
- Have a minimum in-service experience of 50 relay-years with at least 25 relays having an in-service record of more than 6 months. This must apply to the same or similar production unit version of relay that Eskom would employ;

- Successfully pass required simulator testing; and,
- Successfully pass all specified environmental tests.

The product(s) offered by the tenders shall comply with these requirements at the tender submission (closing) date.

### 3.40.2 Rationale

The successful implementation of a new protection relay product on a system is critical for the sustained good performance of protection of the network. Manufacturers are continually developing new relay products. The new numerical relays have two fundamental components, namely hardware and software, the integrity of both being vitally important to the performance of the product. It is therefore of paramount importance that all aspects of a new relay product are proven to the satisfaction of the utility purchasing the product, in order that the relay can be successfully applied with confidence and without 'teething' problems. It is on this basis that the above philosophy statement has been developed, whereby each important aspect of the new relay is carefully evaluated and/or tested.

The following rationale points cover the individual elements of the philosophy statement:

- Development of products in conjunction with manufacturers is time consuming and expensive. A preferred approach is to enter into 'partnerships' with manufacturers thereby influencing their product designs on an ongoing basis. Relays can then be purchased as standard products rather than as 'specials';
- It is preferred that relay products purchased have been in service elsewhere on similar network voltage levels. This would provide some confidence as to the soundness of design and reduction of possible 'teething' problems;
- The reasoning behind the requirement for the 'piggy-back' mode is to allow Eskom personnel the opportunity to become familiar with the relay product and also to 'soak' test such components as power supplies that have, in the past, been areas of concern;
- Simulator testing tests the design and capabilities of the product with the tender specification serving as the basis for evaluation. This is a type test which provides the opportunity for extensively evaluating the relay's performance in terms of its designed functions (also security, speed, dependability and selectivity); and,
- Electrical environmental tests are required to verify the capability of the relay to survive the harsh substation environment.

### 3.40.3 Design requirements

The tenderers shall provide details of their device's operating record and installation details with their offers. The tenderers shall also provide details on all offered IEDs, the firmware upgrades made in the past 3 years. The Purchaser will use protection devices that satisfy the following conditions:

Available 'off-the-shelf';

- Have a proven track record in terms of an acceptable in-service record on networks of greater than 200kV in utilities world-wide and representative to the Eskom network. The tenderers shall provide proof of track record by documentation and reference to buyers and/or utilities world-wide;
- Have a minimum in-service experience of 50 equipment-years, at time of tender closure, with at least 25 devices/relays having an in-service record of more than 12 months. This shall apply to the same or similar production unit version of device/relay that the Purchaser would employ;
- The offered IEDs shall not be scheduled for discontinuation or major changes within the first 4 years of the production phase;
- The vendor shall notify Eskom well in advance regarding any discontinuation, major hardware and firmware changes of the offered IEDs;

- Successfully pass required model power system simulator testing;
- Successfully pass all functional testing; and,
- Successfully pass all specified environmental type tests.

Cumulative years of service are only based on an in-service period of identical hardware and firmware versions.

## 3.41 Warrantees, spares and support

### 3.41.1 Warrantees

The supplier shall provide a minimum of a 10 year warrantee on the protective IEDs provided in the scheme. The warranty shall include the repair of all failures due to latent defects (i.e. excluding failure due to mishandling or misuse of the equipment by Eskom or Eskom appointed representatives). Any charges associated with the repair/replacements and shipping of the defective equipment from the local supplier's office to and from the works of the overseas principal shall be for the supplier's expense.

The supplier of IEDs for protection schemes shall undertake, in writing, to support each product for a minimum period of 15 years from the date of contract signature. Product support shall include services to repair or replace any damaged or failed IED that falls outside the terms of the abovementioned warrantee. Eskom shall be liable for all costs associated with these services. Replacement IEDs shall preferably be of the same type, model number and firmware as the failed IED, but alternative products of substantially similar physical dimensions and terminal layouts offering the same or increased functionality shall be accepted in fulfilment of this requirement.

The supplier shall notify Eskom of the planned discontinuation of any IED used in a current or previous national contract.

### 3.41.2 Spares

The Supplier shall supply a comprehensive list of spares that shall, at minimum, include one of the devices/relays used, as well as MCB's, switches, lamps, empty sub-racks and any consumable items. The Supplier shall also include on the list of spares any other recommended spares necessary for the proper maintenance of the protection scheme. The spares items shall be priced individually and the list shall include a description of the item, a reference number, the pricing details and the guaranteed delivery time. All spares shall be delivered in approved cases suitable for storing such parts over a period of 10 years without damage or deterioration.

Spare devices shall be available from the tenderers for a period of at least 10 years subsequent to the expiry of the contract. Spares shall be carried at the tenderers's local works according to the following amount of schemes in service:

**Table 1: Spares requirements**

| Number of schemes in service | Available immediately (within 24 hours of order) | Additionally available on demand within 72 hours |
|---|---|---|
| 1 to 20 schemes | 2 spare of each device | A maximum of 3 spares of each device |
| 21 schemes and more | 3 spares of each device | A maximum of 4 spares of each device |

The successful *tenderers* shall maintain an up-to-date register of at least three contact persons who may be contacted regarding spares. This information shall be communicated to the *purchaser* when any of the details contained therein are altered.

The *purchaser* shall annually audit the spares holding as per the requirements of this specification.

### 3.41.3 Repairs

The tenderers shall provide a schedule detailing the guaranteed turnaround time for the repair of faulty equipment. The turnaround time shall include any international transport and customs clearance times as applicable. If the turnaround times differ for different equipment, the schedule shall include these details. The tenderers shall also state the extent to which repairs can be effected at the tenderers's local works, including the capability and equipment that the tenderers possesses in order to effect such repairs. The tenderers shall, for all repair work, inform the purchaser of the exact nature of the failure, how such failure was remedied and how these failures, and other similar failures, can be prevented. The solutions to the identified failures/deficiencies shall also be implemented to all the in-service and spare devices and shall be for the cost of the tenderers. The implementation will be governed by the availability of the devices due to power network constraints.

### 3.41.4 Support

The purchaser requires a maximum transfer of technology from the supplier's principals to enhance the local support capabilities. The tenderers shall indicate in his offer how he intends committing to this requirement.

- The transfer of technology shall include, but not be limited to:
- Operating and analysis software;
- IED functions (detailed description and explanations); and,
- Compilation of standard IED (Eskom) templates that also include the IEC61850 engineering.

The vendor shall have at least more than one local skill with specialist knowledge. The specialist knowledge shall include but not be limited to the overall life cycle of the solutions, including:

- Ordering options;
- Configurations and settings; and,
- Commissioning and maintenance.

## 3.42 Documentation

### 3.42.1 Scheme manual requirements

The required documentation shall include a full description of the scheme including the detailed information/manuals on all scheme components and devices. Also required are the complete drawings for each of the scheme permutations. The scheme manual shall include the product configuration and a hard copy of the scheme drawings. All documentation called for shall be finalised and approved before the engineering/development phase ends and awarding of production contract phase.

The documentation shall be clear, concise and to the point. The supplier shall compile all documentation and a complete documentation set (printed and bounded and in electronic format *.doc(x)) shall be submitted to the purchaser on conclusion of the engineering/development phase.

The scheme manual shall have as a minimum the following chapters:

| **Chapter 1** | **General Description** | |
|---|---|---|
| | 1.1 | Basic description of the scheme and devices |
| | 1.2 | Intended area of application |
| | 1.3 | Brief description of the protection and closing functions |
| | 1.4 | Contract/agreement data |
| | 1.5 | Device configuration (logic diagrams) |
| | 1.6 | Drawing set (scheme) |

| **Chapter 2** | **Mechanical Construction** | |
|---|---|---|
| | 2.1 | Mechanical drawings |
| | 2.2 | Construction details |

| **Chapter 3** | **Controls, Indications and Test Facilities** | |
|---|---|---|
| | 3.1 | List of controls and indications |
| | 3.2 | Detailed description of functions |
| | 3.3 | General operational data |
| | 3.4 | Test facilities |

| **Chapter 4** | **Protection Functionality** | |
|---|---|---|
| | 4.1 | Detailed description of the diameter control functions |
| | 4.2 | Scheme control philosophy |
| | 4.3 | Scheme logic |
| | 4.4 | Application guidance |
| | 4.5 | Burdens |

| **Chapter 5** | **Substation automation integration** | |
|---|---|---|
| | 5.1 | MMS data sets with data attributes (also the subscribers to the data) |
| | 5.2 | GOOSE data sets with data attributes (also the subscribers to the data) |

| **Chapter 6** | **Installation, Commissioning and Testing** | |
|---|---|---|
| | 6.1 | Installation procedure/requirements |
| | 6.2 | Commissioning guidelines |
| | 6.3 | Routing testing guidelines |

| **Chapter 7** | **Maintenance** | |
|---|---|---|
| | 7.1 | Maintenance requirements |
| | 7.2 | Recommended "In-service" checks |
| | 7.3 | Cross-referencing to relay manual |
| | 7.4 | Audit intervals and scope |
| | 7.5 | Physical replacement / refurbishment procedure |

| **Chapter 8** | **Parts List** | |
|---|---|---|
| | 8.1 | Parts list (Bill of material) |

| **Chapter 9** | **Associated Publications** | |
|---|---|---|
| | 9.1 | Information about all equipment used in scheme |

| **Chapter 10** | **Document Control** | |
|---|---|---|
| | 10.1 | Revision control |

| **Chapter 11** | **Software and firmware** | |
|---|---|---|
| | 11.1 | Hardware, firmware and software version control procedure |
| | 11.2 | History of updates (Include ordering codes) |
| | 11.3 | Upgrade procedure |
| | 11.4 | Communication software |
| | 11.5 | IED to Data Communications Equipment protocol |

| **Chapter 12** | **Peripheral Equipment** | |
|---|---|---|
| | 12.1 | IED to PC requirements (port, cable, etc.) |
| | 12.2 | IED to Data Communications Equipment requirements (port, cable, etc.) |
| | 12.3 | Printer requirements |
| | 12.4 | PC requirements |

### 3.42.2 Settings guide

The settings guide shall include a comprehensive set of blank and example setting details to cover all user settable functions in the scheme and devices shall be provided. A list of the settings, as set by the supplier prior to shipment of the scheme, shall also be provided to the *purchaser*. The supplier shall provide the recommended setting limits to ensure that the required protection performance is obtained. A list of settings (including the Eskom default settings) and settings guidelines shall be provided for all functional elements and shall indicate any setting limitation and any possible conflict with any other setting.

The settings guide (printed and bounded and in electronic format *.doc(x)) shall be finalised, approved and submitted to the *purchaser* before the engineering/development phase ends and awarding of production contract phase.

### 3.42.3 Scheme selection and application guide

The scheme selection and application guide shall include a complete description of the different scheme permutations and selection thereof for specific applications. The application section of the guide shall include a full description and the physical interfacing of the scheme with components external to the scheme (e.g. DC board, CTs, VTs, JB, substation automation, etc.).

The scheme selection and guide (printed and bounded and in electronic format *.doc(x)) shall be finalised, approved and submitted to the *purchaser* before the engineering/development phase ends and awarding of production contract phase.

### 3.42.4 Scheme drawings

The scheme drawings shall be as per the drawing standard 6DIP - #100. The supplier shall be accountable for the compilation of drawing for all scheme/module permutations.

### 3.42.5 Documentation handover requirements

The supplier shall be accountable, on completion of engineering/development phase to handover the following documentation to the Eskom's responsible engineer. The documentation format shall be printed and bounded and in electronic format *.doc(x), vendor specific documentation shall be in Acrobat format.

- Scheme manual (section 7.1);
- Settings guide (section 7.2);
- Scheme selection and application guide (section 7.3);
- Scheme drawings in Microstation format (section 7.4);
- Factory acceptance testing report;
- Type test report;
- MPS test report (where applicable);
- Scheme and spares lists for codification;
- Final PS5 price schedules; and,
- Equipment/IED manuals.

## 3.43 Training

The tenderer shall include proposals for the training of Eskom personnel. The following item shall be quoted:

The local specialised training of selected Purchaser protection engineers (not more than 20) by an expert(s) from the tenderer's principal works. The price shall be quoted on a per week basis. Details of the specialised training will be negotiated during the development phase of the contract. The required training shall include, but not be limited to, an in-depth working knowledge of all devices and products (hardware, firmware and software functionality), the relay operating and analysis software, setting and application, commissioning, maintenance and first-line fault finding.

The Grid staff training at the tenderer's local works (not more than 8). The price shall be quoted on a per week basis. Details of the training will be negotiated during the development phase of the contract. The required training shall include, but not be limited to, a working knowledge of all devices and products (hardware, firmware and software functionality), the relay operating and analysis software, setting and application, commissioning, maintenance and first-line fault finding.

## 3.44 IEC 61850 Engineering tools

The need for the engineering tools has developed as the technology has been and is being installed and commissioned in Eskom substations. At present, the required tools can be broadly categorised into:

- Configuration tools;
- Simulation tools; and,
- Communication Analysis tools.

### 3.44.1 Configuration tools

The configuration tool shall have the capability to assemble individual device configuration files (known as CID files) into the substation-wide configuration files (known as SCD files) and inter substation configuration files (known as SED files). This tool shall therefore be used to configure and have the ability to validate the configured files, hence ensuring the integrity of the configuration files as per the IEC 61850 standard.

### 3.44.2 Simulation tools

The simulation tools are essential to perform system-wide testing in a simulation environment using actual SCD file configurations.

#### 3.44.2.1 Vertical communications

This tool shall have the ability to test the "vertical" communication of the IEDs to the substation gateway. The tool is required to simulate every IED described in the SCD file. Each IED should respond using its configured IP address and OSI addressing parameters. Each virtualized IED is further required to allow the data simulation of any data attribute of any attribute described within the file. The tool should optionally allow the setting of "invalid" data values for a data attribute in order to verify the correct operation of the gateway. The simulator shall respond to read requests and shall also generate information reports where the data attributes are allocated to datasets referred to by Report Control Blocks (RCBs). The tool is also required to simulate multiple data attributes concurrently and as such some form of scripting would be required. In such a "bulk data simulation" mode, the tool is expected to stress test the gateway for extreme conditions.

#### 3.44.2.2 Horizontal communications

This tool shall have the ability to test the "horizontal" communication of the IEDs using GOOSE messaging. The purpose behind this simulation mode is to test one or more physical IEDs within the context of the full substation automation system. The tool should therefore allow the enabling of individual IEDs within the simulation environment. It shall be possible to simulate the values of data attributes corresponding to dataset "elements" associated with GOOSE Control Blocks (GCBs). The tool is also required to simulate multiple data attributes concurrently and as such some form of scripting would be required.

The final simulation purpose of the tool is to test the "horizontal" communication of the IEDs using Sampled Values. The purpose behind this simulation mode is to test one or more physical IEDs within the context of the full substation automation system. The tool should therefore allow the simulation of individual IEDs and/or merging units within the simulation environment. It shall be possible to simulate the values of data attributes corresponding to dataset "elements" associated with Sampled Value Control Blocks (SVCBs). The tool is also required to simulate multiple data attributes concurrently and as such some form of scripting would be required.

#### 3.44.2.3 Communication analysis tools

The fundamental infrastructure required for IEC 61850 substation automation systems is a high-speed industrial Ethernet network. The inter-device communication often needs to be verified and in some cases detailed analysis is required to isolate problems and to troubleshoot commissioning issues. A tool that can analyse traffic patterns, performance and detailed message analysis is required to facilitate this requirement.

## 4. Authorization

This document has been seen and accepted by:

| Name and surname | Designation |
|---|---|
| Ian Worthington | Chief Engineer – Secondary Plant (Transmission) |
| Paul Grobler | Chief Engineer |
| Jan Cronje | Chief Technologist |

| Name and surname | Designation |
|---|---|
| Anita Oommen | Middle Manager |
| Paul Keller | Chief Technologist |
| Anura Perera | Chief Engineer |
| Vincent Jansen van Rensburg | Chief Technologist |
| Bongani Qwabe | Chief Technologist |

## 5. Revisions

| Date | Rev | Compiler | Remarks |
|---|---|---|---|
| Nov 2015 | 1 | T Bower | First issue. |

## 6. Development team

This document was developed by Thys Bower.

## 7. Acknowledgements

Not applicable

# Annex A – Impact Assessment

Impact assessment form to be completed for all documents.

## 1 Guidelines

- All comments must be completed.
- Motivate why items are N/A (not applicable)
- Indicate actions to be taken, persons or organisations responsible for actions and deadline for action.
- Change control committees to discuss the impact assessment, and if necessary give feedback to the compiler of any omissions or errors.

## 2 Critical points

### 2.1 Importance of this document. E.g. is implementation required due to safety deficiencies, statutory requirements, technology changes, document revisions, improved service quality, improved service performance, optimised costs.

Comment: This standard is required to document the breaker-and-a-half diameter interface requirements for Transmission and Distribution protection & control schemes.

### 2.2 If the document to be released impacts on statutory or legal compliance - this need to be very clearly stated and so highlighted.

Comment: No statutory or legal compliance required.

### 2.3 Impact on stock holding and depletion of existing stock prior to switch over.

Comment: No impact.

### 2.4 When will new stock be available?

Comment: Not applicable.

### 2.5 Has the interchangeability of the product or item been verified - i.e. when it fails is a straight swop possible with a competitor's product?

Comment: Not interchangeable.

### 2.6 Identify and provide details of other critical (items required for the successful implementation of this document) points to be considered in the implementation of this document.

Comment: This document must be used as reference when compiling the bay specific protection & control scheme standards for application to Transmission and Distribution stations.

### 2.7 Provide details of any comments made by the Regions regarding the implementation of this document.

Comment: (N/A during commenting phase)

## 3 Implementation timeframe

### 3.1 Time period for implementation of requirements.

Comment: The breaker-and-a-half diameter interface requirements will be implemented during the product development phase.

### 3.2 Deadline for changeover to new item and personnel to be informed of DX wide change-over.

Comment: No changeover required, new standard.

## 4 Buyers Guide and Power Office

### 4.1 Does the Buyers Guide or Buyers List need updating?

Comment: No.

### 4.2 What Buyer's Guides or items have been created?

Comment: N/A

### 4.3 List all assembly drawing changes that have been revised in conjunction with this document.

Comment: N/A

### 4.4 If the implementation of this document requires assessment by CAP, provide details under 5

### 4.5 Which Power Office packages have been created, modified or removed?

Comment: N/A

## 5 CAP / LAP Pre-Qualification Process related impacts

### 5.1 Is an ad-hoc re-evaluation of all currently accepted suppliers required as a result of implementation of this document?

Comment: N/A

### 5.2 If NO, provide motivation for issuing this specification before Acceptance Cycle Expiry date.

Comment: N/A

### 5.3 Are ALL suppliers (currently accepted per LAP), aware of the nature of changes contained in this document?

Comment: N/A

### 5.4 Is implementation of the provisions of this document required during the current supplier qualification period?

Comment: N/A

### 5.5 If Yes to 5.4, what date has been set for all currently accepted suppliers to comply fully?

Comment: N/A

### 5.6 If Yes to 5.4, have all currently accepted suppliers been sent a prior formal notification informing them of Eskom's expectations, including the implementation date deadline?

Comment: N/A

### 5.7 Can the changes made, potentially impact upon the purchase price of the material/equipment?

Comment: N/A

### 5.8 Material group(s) affected by specification: (Refer to Pre-Qualification invitation schedule for list of material groups)

Comment: N/A

## 6 Training or communication

### 6.1 Is training required?

Comment: No

**6.2 State the level of training required to implement this document. (E.g. awareness training, practical / on job, module, etc.)**

Comment: N/A

**6.3 State designations of personnel that will require training.**

Comment: N/A

**6.4 Is the training material available? Identify person responsible for the development of training material.**

Comment: N/A

**6.5 If applicable, provide details of training that will take place. (E.G. sponsor, costs, trainer, schedule of training, course material availability, training in erection / use of new equipment, maintenance training, etc).**

Comment: N/A

**6.6 Was Technical Training Section consulted w.r.t module development process?**

Comment: N/A

**6.7 State communications channels to be used to inform target audience.**

Comment: N/A

## 7 Special tools, equipment, software

**7.1 What special tools, equipment, software, etc will need to be purchased by the Region to effectively implement?**

Comment: N/A

**7.2 Are there stock numbers available for the new equipment?**

Comment: N/A

**7.3 What will be the costs of these special tools, equipment, software?**

## 8 Finances

**8.1 What total costs would the Regions be required to incur in implementing this document? Identify all cost activities associated with implementation, e.g. labour, training, tooling, stock, obsolescence**

Comment: N/A

Impact assessment completed by:

Name: Thys Bower

Designation: Senior Consultant