Eskom	Standard	Technology

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Compiled by	**Approved by**	**Authorized by**
Patrick T Mashigo	**Bongani Qwabe**	**Nelson Luthuli**
Chief Technologist Protection PTM&C	**Chief Technologist Protection PTM&C**	**Senior Manager PTM&C (Acting)**
Date: 04 July 2022	Date: 04/07/2022	Date: 05 July 2022

Supported by SCOT/SC

Anita Oommen

SCOT/SC Chairperson

Date: 05 July 2022

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SCOT Study Committee Number/Name: **Protection and Automation Study Committee**

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Executive Summary

The overall engineering and the management of busbar protection is of great importance to power utilities as busbar faults, and associated protection operations, have a significant impact on the safety and the stability of the transmission network. Busbar protection may simultaneously trip a number of bus segments or even an entire busbar of a substation and the fast isolation of busbar faults is critical to minimise the impact to the transmission network. The failure of protection operating, or any unwanted tripping may also lead to severe consequences on a transmission system. Although busbar protection is quite expensive and complicated, its features limit impact to the power network, may save equipment and people's lives.

A busbar protection system should dynamically replicate the bus topology and contain design flexibility to protect all existing bus arrangements. In general, the main requirements for busbar protection include security, dependability, speed, sensitivity and selectivity. All these requirements are interrelated and it is not possible to satisfy one without affecting the other.

The dominating protection principle of busbar protection is the differential principle. The main types of differential current protection relays are low-impedance and high-impedance differential protection. Low-impedance differential principle is mostly used in Transmission, although, the high-impedance differential principle may be used to reduce costs and in the Distribution environment. Both types of differential current protection relays have advantages and disadvantages. The low-impedance differential protection relays are frequently numeric and more flexible which allows protecting substations with complex schemes. Low-impedance differential protection relays can stay in operation even during the reconstruction of substations when usually some temporary operating is needed.

1. Introduction

Busbar/s are very critical elements in a power system, since they are the points of coupling of many circuits, transmission, generation, or loads. A single bus fault can cause damage equivalent to many simultaneous faults and such faults usually draw large currents. Therefore, a high-speed buszone protection is often required to limit the damage to equipment, safety of personnel and system stability or to maintain service to as much load as possible.

2. Supporting clauses

2.1 Scope

This document describes Eskom Transmission breaker–and-half and double busbar buszone protection schemes philosophy for Phase VI buszone protection.

2.1.1 Purpose

The purpose of this standard is to provide a summary of the recommended protection philosophy as applied to Eskom Transmission low impedance buszone protection.

2.1.2 Applicability

This standard is applicable to all Eskom Transmission Phase VI low impedance buszone protection schemes to provide a general description of the protection relay functions as required.

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] SANS 61869-1 (IEC 61869-1) Instrument transformers – Part 1: General requirements.

[2] ST_240-56364481 - Protection Settings Philosophy for EHV and HV Networks Rev 2

[3] Reliable Busbar and Breaker Failure Protection With Advanced Zone Selection - Armando Guzman, Casper Labuschagne, and Bai-Lin Qin, *Schweitzer Engineering Laboratories, Inc.* Presented at the 31st Annual Western Protective Relay Conference Spokane, Washington October 19–21, 2004

[4] Busbar Protection – Busbar Differential: Best Practice and Recommendations – European Network of Transmission System Operators for Electricity

[5] ST_240-170000297 - Phase VI Breaker-and- Half Transformer and Shunt Reactors Protection Philosophy

2.2.2 Informative

[6] ST 240-56364481: Protection settings philosophy for EHV and HV networks (Superseded SPL 46-101)

[7] [19] 240-68277442 Specification for Transmission protection schemes Low impedance busbar protection

[8] [10] 240-64685228 Generic Specification for protective Intelligent Electronic Devices (IEDs)

2.3 Definitions

2.3.1 General

Definition	Description
Breaker-and-a-half	The breaker and a half bus arrangement is relatively simple and consists of two main busbars, each normally energised. Between each of the main busbars are similar arranged “bays” of three circuit breakers configured such that the two lines or a combination transmission line and transformer position share the centre circuit breaker.
Circuit Breaker Failure	Circuit breaker failure protection is a backup protection in case the designated circuit breaker failed to open and clear.
Discrimination	The ability to select zones in order to trip the minimum number of breakers to clear the fault.
Double busbar	A substation layout consisting of the conventional double busbar configuration with or without bus section / bus couplers etc. A set of isolator links per busbar are used to connect the transformer bay to either busbar.
Intelligent electronic device (IED)	A microprocessor-based device that encompasses all or some of the following functionalities: protection, control and automation, metering, telecontrol, substation DC and auxiliary supply systems, quality of supply monitoring, and disturbance and event recording.
Protection system	The protection system is that part of the tripping system, which provides the requisite primary, back-up system, and auxiliary protection functions.
Reliability	The ability of the protection to operate consistently for all faults to which it should respond and remain inoperative to all faults to which it should not.
Scheme	A set of components that work together in order to execute a specific behaviour under predefined power system conditions sensed through the scheme interface (Cigré Working Group B5.27). ‘Scheme’ is most commonly applied in the context of power system protection equipment where it historically applied to the secondary plant components associated with the protection and control of a specific primary bay. In the latest design philosophy each main or back-up protection module associated with a specific primary bay are designated as separate, independent schemes.
Security	The probability of not having unwanted operation under given conditions for a given time interval (IEC 50-448).
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.
Stability	The ability to differentiate between internal faults (in-zone) and external faults.
Zone	An area between two Current Transformers regarded as unit protection. It is a selective part of a multi-zone busbar protection, generally supervising current flow into and out of a single section (zone) of busbar

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
AC	Alternating Current
AIS	Air Insulated Switchgear
BAH	Breaker and Half
B/B	Busbar
BC	Bus Coupler
BS	Bus Section
BFI	Breaker Fail Initiate
BFTI	Breaker Fail Trip Isolate
BFT	Breaker Fail Trip
BFP	Breaker Fail Protection
BU	Bay Unit
BZI	Buszone Isolate
BZP	Buszone Protection Panel
BZTI	Buszone Trip Isolate
CB	Circuit Breaker
CBF	Circuit Breaker Failure
CP	Control Panel
CT	Current Transformer
CTR	Current Transformer Ratio
CU	Central Unit
DC	Direct Current
EHV	Extra High Voltage
FDR	Feeder
GIS	Gas Insulated Switchgear
HV	High Voltage
IED	Intelligent Electronic Device
KV	kiloVolt
LED	Light Emitting Diode
LCS	Lamp Check Switch
PTM&C	Protection Telecommunication Measurements & Control
TNS	Test Normal Switch
Z1/Z2	Zone 1/Zone 2

2.5 Roles and responsibilities

PTM&C is responsible to generate and document the breaker-and-a-half and double busbar protection buszone schemes philosophy document

2.6 Process for monitoring

The document shall be updated with any changes in philosophy should these be required for future generations of Buszone protection.

2.7 Related/supporting documents

Not applicable.

3. Busbar Protection Requirements

3.1 General

The key criteria for busbar protection are security, speed and stability.

3.1.1 Security

Fast operating times for all busbar faults on transmission network is an ultimate requirement.

3.1.2 Speed

The primary objective of busbar protection is to limit the damage and to remove busbar faults before back-up remote line protection, to maintain system stability.

3.1.3 Stability

The stability of buszone protection is more significant. It should be noted that rate of fault in busbar are quite low (about one fault per busbar in 2-3 years). Therefore, a weakness in the stability of a protection system may have detrimental effects on the stability of the protection system.

Transmission BAH, EHV and HV busbar are mostly protected by current differential protection (low impedance buszone) set to be as sensitive as possible for “in-zone faults” and to maintain stability for any faults outside the protected zone, even with a fully saturated CT.

Most of faults occurred on busbar are one phase to ground, but faults may be caused from different sources and a significant number are inter-phase clear of earth. In fact, a large proportion of busbar faults result from human error rather than the failure of circuit breaker or primary components. Nowadays, with the advent of fully phase-segregated circuit breaker, only earth faults are possible, therefore, we only concern about earth fault sensitivity. Otherwise, the ability to detect phase faults clear of earth is an advantage, although the phase fault sensitivity need not be very high.

3.2 Buszone Applications

Low impedance buszone protection and control schemes cater for busbar/s voltage ranging from 88kV to 765 kV. The different scheme permutations shall provide protection and control for busbars on breaker-and-a-half arrangements, as well as multi busbar arrangements. The permutations also accommodate double busbar arrangements with a minimum of 8 bays and up to a maximum of 48 bays and the breaker-and-a-half arrangements with 8 or 14 bays.

3.3 Busbar Configurations

3.3.1 Breaker -and-a- Half

A breaker -and-a- half configuration consists of two busbars unlike the double busbar configuration and transfer scheme, both busbars are energized during normal operation. For every two circuits there are three circuit breakers with each circuit sharing a common centre breaker (tie breaker). Any breaker can be removed for maintenance without affecting the service on the corresponding existing feeder, and a fault on either busbar can be isolated without interrupting service to the outgoing lines. If the tie breaker fails, this will cause the loss of two circuits while the loss of an outside breaker would disrupt only one breaker as shown in figure 1 below.

When busbar protection is required, then each busbar shall be considered individually and a single busbar scheme configuration is applied. Each busbar forms its own zone independent from each other. The breaker-and-a-half configuration is flexible in operation and high reliable.

In that case, it is necessary to install CT with bay unit on each zone of busbar protection in every branch where applicable.

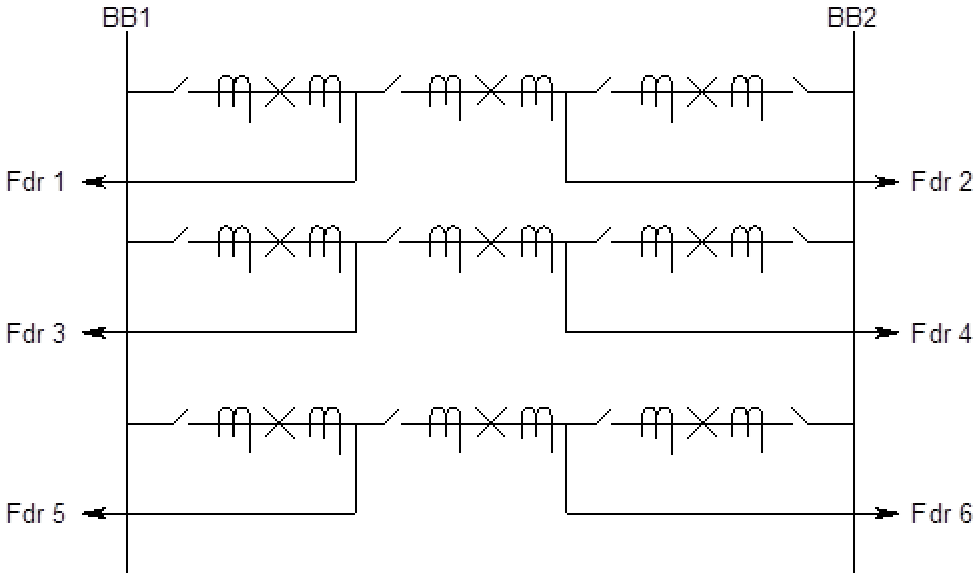

Figure 1: Breaker -and-a- Half Configuration

Note: The failure of any Tiebreaker in a diameter do not result in Bus zone operation in cases where, both bays are populated. It shall trip both bay breakers in that diameter. However, failure of any bay breaker in any diameter shall trip all bay breakers connected to that busbar i.e., bay breakers of all diameters of that busbar.

3.3.2 Double Busbar with eleven zones

The double busbar configuration consists of two main busbars that are both normally energized. A substation layout consisting of the conventional double busbar configuration with or without bus section / bus couplers etc. A set of isolator links per busbar are used to connect the transformer or feeder bay to either busbar as shown in figure 2 below.

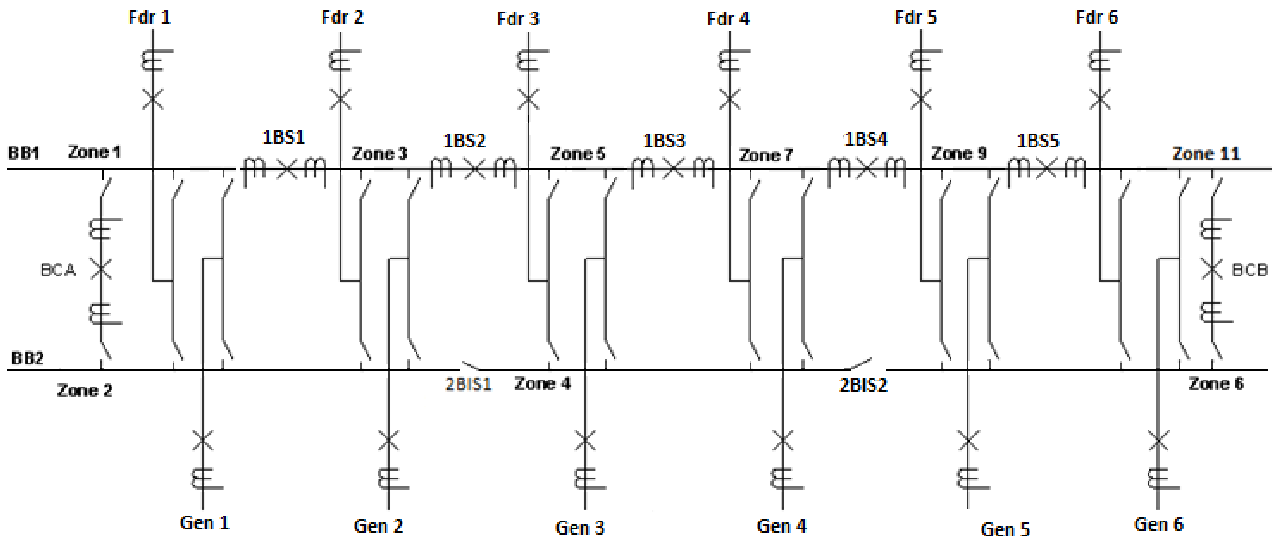

Figure 2: Double Busbar with eleven zones Configuration

3.3.3 Double Busbar with transfer bar

The double busbar configuration consists of two main busbars that are both normally energized, it has the flexibility to allow the grouping of circuits onto separate busbars with facilities for transfer from one busbar to another for maintenance or operational reasons. In case where the transfer bay is connected it becomes part of zone that it transferred from i.e. zone 4 as shown in figure 3 below.

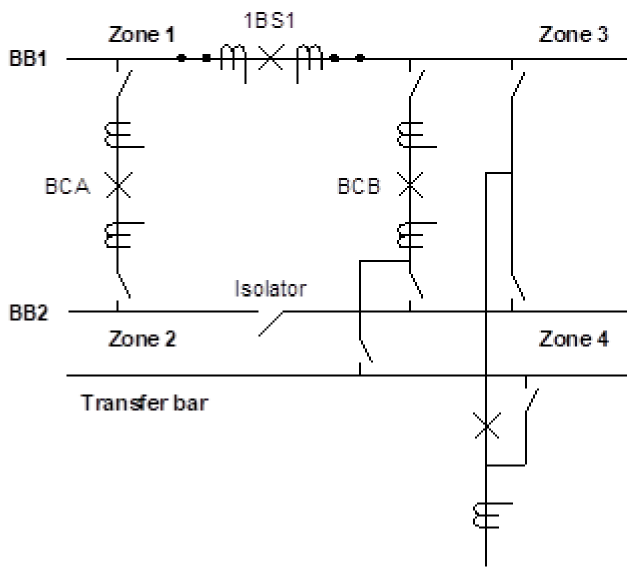

Figure 3: Double Busbar with four zones and Transfer bar Configuration

3.4 CT Requirements

3.4.1 Philosophy

The relay performance depends on the CT that drives it.

The ratings of the CTs shall be selected to avoid steady-state saturation.

Protection CTs are required to maintain their performance up to several times the rated primary current.

Ratio mismatch between CTs of different bays, to a maximum mismatch ratio of 10:1

Secondary CT current input to the buszone must be 1A

Must cater for CT class mismatch, e.g.: TPY and TPZ or TPS - match e.g. 500/1 TPY to 1600/1 TPS

Additional:

- The burden presented to each bay's CTs should be low enough to permit the sharing of the CT with other protection applications
- The CT secondaries may not be switched by isolator auxiliary contacts, CT circuits should preferably not be switched at all, i.e. by isolator mimic relays
- The scheme shall cater for a combination of inboard and outboard CTs
- The scheme shall detect current transformer anomalies (typically open-circuited CTs) and report same

3.4.2 Basic Principles

During an internal fault, or a fault external to the transformer but in the protected zone one or more CTs may saturate and result in the failure of a transformer differential relay to operate or cause delay in its operation.

The performance of a CT is a function of the burden connected to the secondary winding of the CT.

3.4.3 Buszone CT Ratio Selection Method

To ensure adequate performance of primary and secondary plant in normal and fault conditions the CT ratio has to be selected to meet the following requirements:

- Must be higher than maximum expected load. Normally the emergency thermal limit of the circuit should be used. In some circumstances, however, where e.g. small load is supplied over long distances the CT ratio can be reduced to ensure reliable operation of protection equipment.
- Must not be too high, to ensure sufficient current for protection starters to pick-up.
  - $If_{min}/CTR > 0.1$
  - Where: If_{min} - fault current at the end of line in minimum condition.
  - CTR- CT ratio.
- Must not be too low, such that the CT will not saturate during faults.

As far as possible the following guideline should be used:

- $If_{max}/CTR < 20$ for electronic and digital relays,
- $If_{max}/CTR < 10$ for electromechanical relays.

Where: If_{max} - maximum fault current.

3.4.4 Checking for Saturation of Class P CTs

The secondary voltage developed across the CT is defined by:

$$EMF = ALF\,(R_{CT} + R_b)\,I_{sn}$$

Where: EMF = Voltage developed

ALF = Accuracy limit factor = If/CTR

$R_{CT} =$ CT resistance

$R_b =$ Rrel + Rlead, Where: Rlead = loop resistance

For phase –ground fault

Isn = nominal secondary current of CT

These CTs do not have transient performance capability, and if because of this the voltage developed is above the knee-point voltage of the CT, given by 1V/turn, the following measures shall be taken:

- Increase the CTR
- Decrease the burden (if possible)
- Speed up the relay time

3.4.5 Checking for Saturation of Class X (TPS) CTs

Because most system fault currents contain a transient DC component, the total flux in the core is several times the alternating flux (which would be the only flux required if there was no DC component of current). The ratio of maximum flux to the peak value of the AC component of the flux is defined as the Transient factor (K_{td}). This is approximately equal to the X/R ratio of the primary circuit.

Rated transient dimensioning factor of the CT K_{td} = $\left[w.T_P.T_s / \ (T_P - T_S)\right]e^{-t/T_P} - e^{-t/T_s})$

Where: t = duration of fault current

The required CT knee-point voltage (rated equivalent limiting secondary e.m.f) E_{al} is then given by:

$$E_{al} = K_{ssc}.K_{td}\,(R_{CT} + R_b)x\,I_{sn}$$ Where: $K_{ssc} = \frac{I_f}{CTR}$

$K_{td} =$ Rated transient dimensioning factor of the CT

$R_{CT} =$ CT resistance

$R_b =$ Rrel + Rlead, where Rlead = loop resistance

Phase-ground fault

I_{sn} = nominal secondary current of CT

The secondary fault e.m.f can be practically calculated as follows:

$$V = [\frac{I_f}{CTR\,(R_{CT} + R_b)}]\left(1 + \frac{X}{R}\right)$$

This may be checked against the specified V_k of the CT (can be approximated to be based on 1V/turn for Class X and TPS CTs) [2].

Note: Any special CT requirements shall be provided in the supplier's transformer protection scheme application guidelines.

3.5 Current Transformer Location

Accurate CT positioning ensures that busbar faults that shall be seen by the busbar protection relay and that all possible areas that a fault can occur on a busbar shall be covered by the protection. These CT location variations shall be used on Transmission system networks, where single and dual CTs are located on the bus couplers and bus sections. Different possible scenario is discussed below and furthermore under the end fault protection function section, in reference to figure 10.

3.5.1 Single CT, two-core application

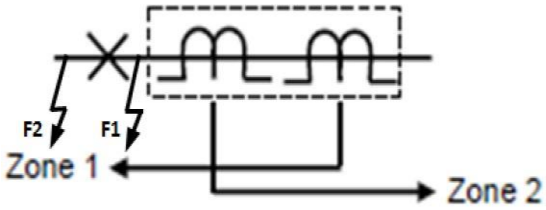

Figure 4: Single CT, two-core application

In figure 4 above shows a scenario of a single CT, two-core application where there shall be an area between the bus coupler/section circuit breaker and the CT that area is called dead zone in which faults can occur (i.e. fault F1). Below is a description of possible fault scenarios.

3.5.1.1 Single CT, two-core application fault analysis

Fault F1 will cause Zone 1 protection to trip immediately however, Zone 2 would still feed the fault. Therefore, Zone 2 protection would have to detect and clear the fault that is outside its natural protective zone. This shall be achieved within the algorithm and usually introduces a time delay.

If a fault F2 were to occur, Zone 1 shall trip immediately. The circuit breaker will open and remove the CT measurement from Zone 1 and Zone 2 algorithm. Zone 2 will remain stable, as the circuit breaker is open.

3.5.2 Single CT, single core application with overlapping zones

In figure 5 below displays a scenario of a single CT, single core application and the description of possible fault scenarios for this application.

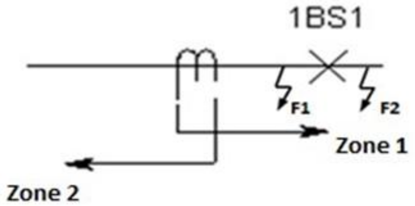

Figure 5: Single CT, single core configuration with overlapping zones

3.5.2.1 Single CT, single core application with overlapping zones fault analysis

1) The same CT core is normally wired to either as Zone 1 or Zone 2, which ever zone that is not physically wired will be an inverted quantity within the algorithm.

Fault F1 will cause Zone 1 protection to trip immediately however, Zone 2 would still feed the fault. Therefore, Zone 2 protection would have to detect and clear the fault that is outside its natural protective zone. This generally shall be achieved within the algorithm and usually introduces a time delay.

2) If a fault F2 were to occur, Zone 1 shall trip immediately. The circuit breaker 1BS1 will open and remove the CT measurement from Zone 1 and Zone 2. Zone 2 will remain stable, as the circuit breaker is open.

3.5.3 Dual CT application with overlapping zones

In figure 6 below displays the possible fault scenarios for dual CT applications with overlapping zones a scenario where CTs shall be positioned on both sides of the circuit breaker to ensure that the protection zones overlap. This prevents tripping delays for any busbar faults and allows for selective clearance for non-overlapping areas. Low impedance protection schemes may designate either single or dual CT cores on bus couplers and bus section as per the protection requirements for that substation.

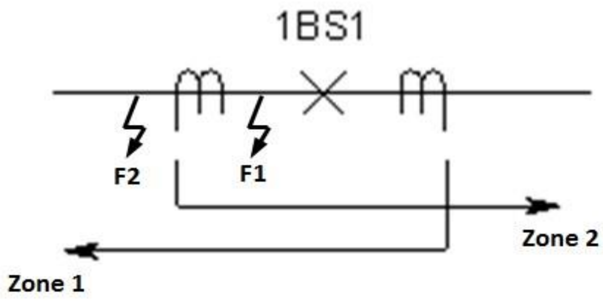

Figure 6: Dual CT configuration with overlapping zone

3.5.3.1 Dual CT configuration with overlapping zone fault analysis

1) If fault F1 occurs, both Zone 1 and Zone 2 protection will trip immediately, as results circuit breaker 1BS1 will open.

2) If fault F2 develops, Zone 1 protection shall trip as a results circuit breaker 1BS1 will open.

3.5.4 Basis of Dual CT application with overlapping zones

Eskom transmission has adopted standardised philosophy that all GIS and Power Station substations will use dual CTs on both sides of the bus coupler/bus section circuit breaker. These bus coupler and bus section circuit breakers require immediate tripping when busbar faults occur due to the importance of maintaining stability at these power and substations.

3.5.5 Basis of Single CT application with overlapping zones

Eskom transmission has adopted standardised philosophy that all AIS substations will use single CT on both bus coupler/bus section circuit breakers.

4. Low Impedance Buszone Protection

4.1 Differential Protection Fundamental Principles

There are number of protection systems that are designated for busbar protection, however Eskom Transmission shall utilize differential protection schemes, it could be low impedance or high impedance scheme.

Differential protection is the most sensitive and reliable method for protecting a substation busbar/s. The phasor summation of all the measured current entering and leaving the busbar must be zero unless there is a fault within the protective zone.

For a fault not in the protective zone, the instantaneous direction of at least one current is opposite to the others, and the sum of the currents in is identical to the sum out. A fault on the busbar provides a path for current flow that is not included in these summations. This is called the differential current. Detection of a difference exceeding the predictable errors in the comparison is one important basis for busbar relay.

In dealing with high-voltage power systems, the relay is dependent on the current transformers secondary currents in the individual circuits to provide information to it regarding the high-voltage currents. The following figures below show typical examples of the location of current transformers that shall be used for this purpose.

The differential current can be defined as I operate = |Iz1 + Iz2, as shown in figure 7 below. That illustrates the basic schematic of a circulating current differential system with current distribution for a through-fault condition.

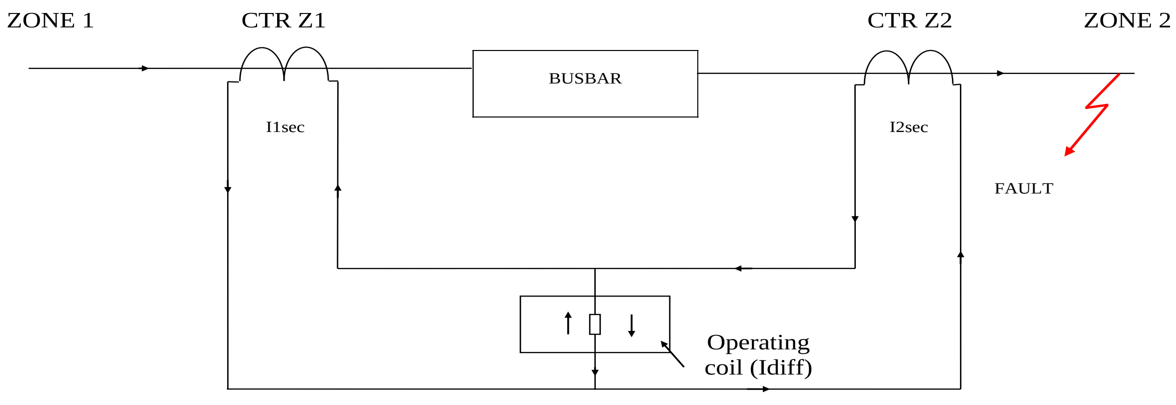

Figure 7: Circulating current differential protection (through fault)

For an in-zone fault, the differential current is non-zero and the relay must operate as fast as possible. If there was no infeed into the fault from Zone 2, then the relay current would only be I_{1sec} and this must also positively operate the relay down to the lowest value of fault current likely to exist on the primary system.

Figure 8 below illustrate the current distribution for an in-zone fault fed from both line ends.

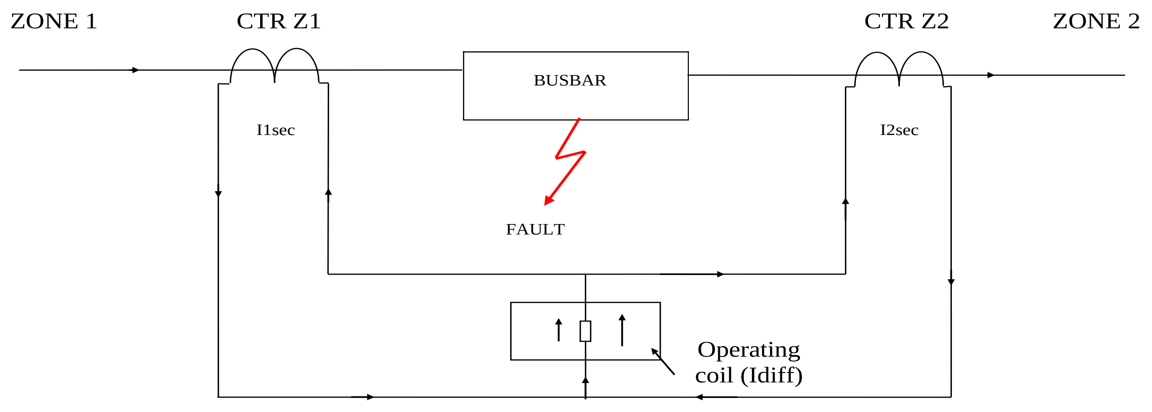

Figure 8: Circulating current differential protection (in-zone fault)

4.2 Busbar Protection Tripping Criteria

Busbar protection philosophy traditionally requirements for two-out-of-two tripping criteria, where two separate measuring elements must agree before protection issues a trip signal. Realization of the two-out-of-two tripping criteria can occur through one of two combinations:

- Dual differential element combination (main zone and check zone)
- Breaker fail initiate and release

4.2.1 Defining the Standard Characteristics

Traditionally the standard differential characteristic is determined by the two settable parameters" Stabilisation factor k" and "Differential current limit Id>".

The vectorial sum Id as the tripping quantity

$Id = |I1 + I2 ... + In|$

is counterbalanced by the restraining quantity

$Is = | I1 | + | I2 | ... + | In |$

which is the arithmetic sum of the magnitudes of each current.

The criterion for a short circuit on the busbar is thus:

$Id > k. Is, mod$

The modified stabilizing quantity Is, mod is derived from Is

Figure 9 illustrates the characteristic of a stabilized (restrained) differential protection system. In the diagram, the system of coordinates represents the sum Is, mod of the magnitudes of all quantities flowing through the busbar while the vectorial sum Id shall be plotted as the ordinate. Both axes use rated current as the unit, and both have the same scale.
If a short-circuit occurs on the busbars whereby the same phase relation applies to all in feeding currents, Id is equal to Is. The fault characteristic is a straight line inclined at 45°.

Any difference in phase relation of the fault currents leads to a (practically insignificant) lowering of the fault characteristic. Since in fault-free operation Id is approximately zero, the x-axis may be referred to as the normal load line.
The stabilizing factors can be selected in a range of k = 0.10 to 0.80 for the bus zone-specific busbar protection or k = 0.00 to 0.80 for the check zone.
The factors are represented as three straight lines with corresponding gradient and form the operating characteristic.
The differential protection system determines whether the total of all currents supplied by the current transformers represents a point in the diagram above or below the set characteristic line. If the point lies above that line, tripping is initiated.

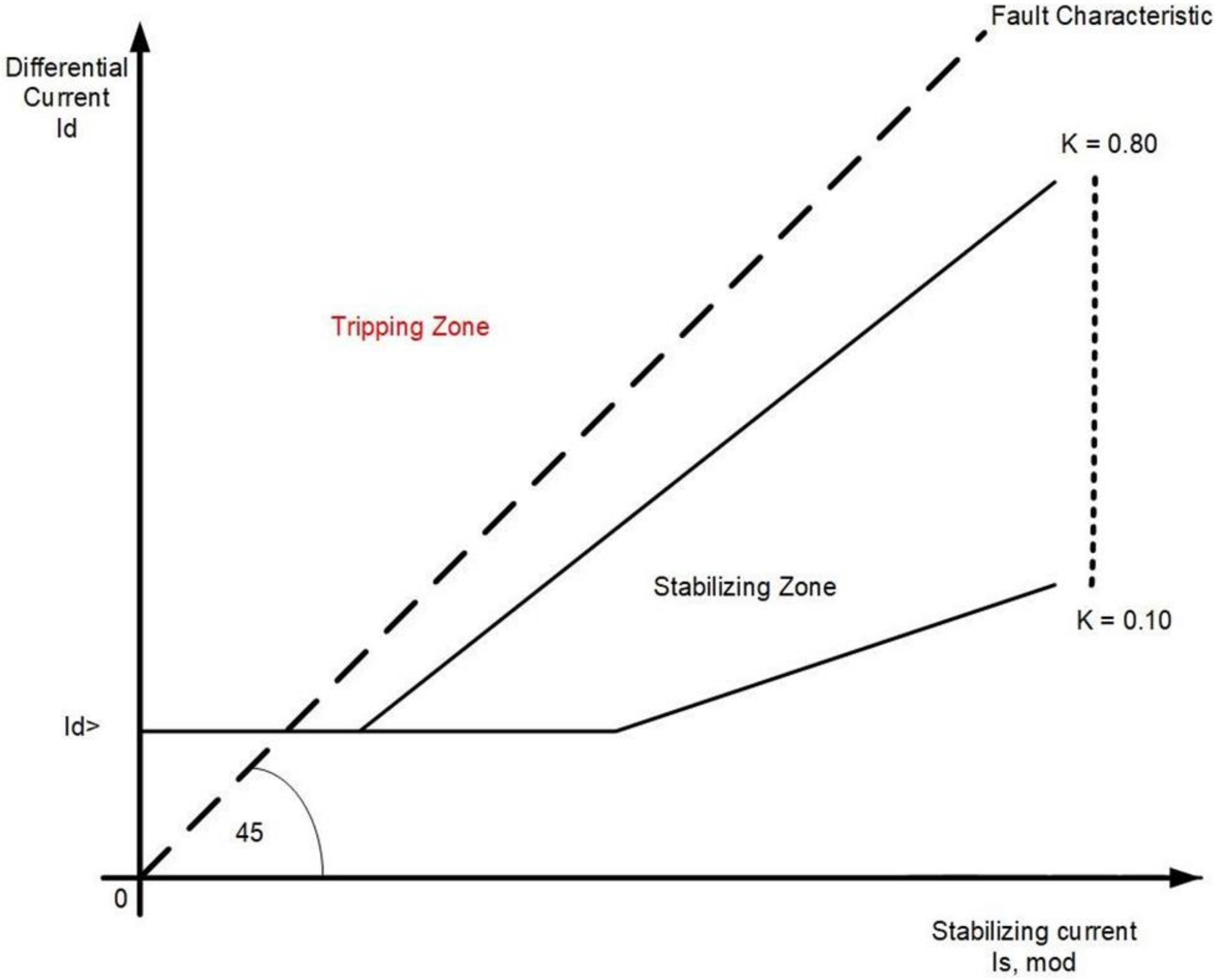

Figure 9: The characteristic of a stabilized differential protection system

4.2.2 Standard Measuring Method

The measuring method of the busbar protection can be summarized as follows:

Tripping occurs when

- Id > set limit and
- Id > k × Is, mod and
- release from ”1-out-of-1”, ”2-out-of-2” or filter algorithm

Each combination has an advantage over the other; the weakness of one is the strength of the other. General differential elements are more vulnerable to CT saturation than are directional elements, but directional elements are more vulnerable to high-impedance faults.

In a substation, CT saturation can occur because of large fault currents, poor CT selection, or possible remanent flux from switching operations. A high-impedance fault can occur in cases of arc resistance, impedance grounding, or deterioration of system grounding.

CT saturation is a concern in networks with high fault currents and low CT ratios. In networks with impedance grounding, all ground faults are high-impedance faults. Although relays may have been correctly selected in the initial network design, changes in the network can adversely influence the network parameters.

For example, network extensions or reduced source impedance result in higher fault current, and deterioration of the substation grounding mat can result in higher fault impedance for ground faults.

Modern busbar protection relays should not only include protection elements to allow for diverse network parameters, but the implementation of these elements in the relays must ensure continual, uncompromising relay performance, despite changes in network parameters. In general, busbar protection must always comply with the following performance requirements:

- Fast operating times for all busbar faults
- Security for external faults with heavy CT saturation
- Minimum delay for evolving faults (external to internal fault)

Furthermore, the continuing drive for substation automation includes electrically operated disconnects to connect terminals to busbars. Depending on the particular busbar protection, disconnect operation may require disabling of the busbar protection during the switching operation to avoid relay mis-operation resulting from incorrect terminal current-to-differential element assignment.

Zone selection provides a way to replicate the station disconnect status by using the disconnector auxiliary contacts, there is no need to disable busbar protection.

4.3 Breaker Fail Protection

The primary function of the circuit breaker failure protection (CBF) in the phase VI busbar protection scheme detects a failure of the circuit breaker in the event of a feeder short-circuit. Traditionally, two separate devices provide busbar and breaker failure protection. This device separation results in additional wiring and duplication of common functionality. For example, busbar protection uses disconnect status from each terminal to assign the proper currents to the differential element and to determine which terminals to trip for busbar faults.

And breaker failure protection uses the same information to determine which breakers to trip for breaker failure conditions. Therefore, the phase VI buszone protection scheme employ an integrated busbar and breaker failure protection that eliminates duplication of common functionality, minimizes wiring, and simplifies protection scheme design.

In addition to that it shall also cater for those sites at which bay-based breaker failure has not been fitted. Subsequently, the buszone scheme shall cater for cases of certain feeder bays having their own breaker failure relays fitted, together with certain feeder bays requiring the use of the bus zone scheme breaker failure features.

The scheme shall use an image of the busbar sections corresponding to the actual operating conditions. When breaker failure occurs, the relay trips all breakers supplying the fault current connected to the same busbars as the faulty breaker.

The integrated circuit breaker failure protection (CBF) shall comprise the following functions:

- In case of a busbar short-circuit, a breaker failure is detected by comparison of current thresholds.
- In all operating modes of the circuit breaker failure protection, a bay-selective command is output by the bay units to trip the circuit breaker at the remote end (transfer trip command).
- The external breaker failure protection shall be started for one phase or for three phases.
- The breaker failure protection can be started on a single channel or, for extra reliability, on 2 channels. Both settings may be combined with a monitoring feature.
- Reduced response times in case of a circuit breaker malfunction
- Query of the circuit breaker position in case of low-current faults
- The circuit breaker failure protection function can be deactivated for test purposes.

The scheme may have different modes for the circuit breaker failure protection as each mode will be described below, however the phase VI busbar protection scheme shall ensure that the trip by external CBF mode is selected as defined below.

- **TRIP by external CBF**:

The external circuit breaker fail has been extensively used in Eskom Transmission, where a separate circuit breaker failure protection is provided, the central unit shall generate zone-selective feeder trip commands utilizing the integrated disconnector model.

Breaker failure philosophy on low impedance buszone schemes is, the protection scheme breaker fail relay issue a breaker fail initiation and a busstrip command to the buszone protection scheme and the buszone scheme trip all bays to specific selected zones.

In addition, shall be the combination of current level (with or without circuit breaker status monitoring) and time elapsed, following a main protection device operation.

If the breaker fail mode shall be set to initiate and release with supervision, breaker fail release supervision - parameter setting shall be used to set the time for supervising the duration of the CBF release signal.

Breaker fail start/release supervision shall be used to set the supervision delay during which, counting from the initiation moment, the release signals for the breaker failure protection must be issued.

- **Query**:

After initiation by a TRIP command from the feeder protection, the relay checks the feeder current. If the measured current stays above the set threshold after a set time has elapsed, the central unit shall issue zone-selective TRIP commands in the bays considering the disconnector replica.

- **TRIP repetition with subsequent I> query**:

When initiated by a TRIP command from the feeder protection, the central unit shall issue a second TRIP command to the circuit breaker of the initiating feeder after a set time delay. In case this second TRIP command is also unsuccessful, tripping as per mode I>query is affected.

- **Unbalancing**:

After initiation by a TRIP command from the feeder protection, the central unit system checks the feeder current. If the measured current stays above the set threshold after a set time has elapsed, the polarity of the current in this feeder will be inverted by the central unit shall (unbalancing).

- **TRIP repetition with subsequent unbalancing**:

When initiated by a TRIP command from the feeder protection, the central unit shall issue a second TRIP command to the circuit breaker of the initiating feeder after a set time delay. In case this second TRIP command is also unsuccessful, tripping as per mode Unbalancing is effected.

- **TRIP repetition with subsequent unbalancing with pulse trigger or I>query**:

This mode shall be used when the CBF is triggered by the remote station. The function is triggered by a trip command from the feeder protection at the remote feeder terminal. The further proceeding is described in the modes TRIP repetition with subsequent unbalancing and I>query.

- **Low-current CBF**:

This mode outputs a TRIP command even in the case of low-current faults (e.g. tripping by Buchholz protection). After a settable timer the circuit breaker position is queried. A TRIP repetition also takes place with a low-current operating mode.

5. Busbar Protection Functions

General

This section summarizes general protection functions and features that are required to protect double busbar and breaker-and-a-half transmission networks.

5.1 End Fault Protection

The function of the end fault protection is to protect the zone between the current transformer and the circuit breaker on bus coupler and bus section schemes when the circuit breaker is in an open state as shown in figure 10 below.

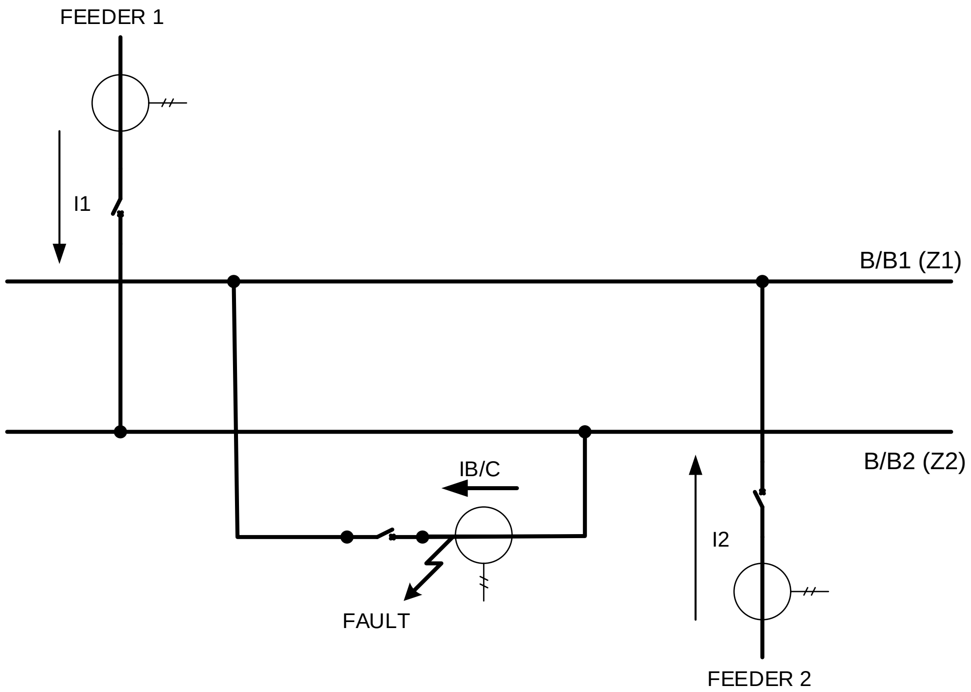

Figure 10: Fault in the dead zone of the bus coupler

5.1.1 Protection with fault in the "Dead Zone" of the Bus Coupler

A dead zone is the zone between the current transformer and the circuit breaker, it can achieve an improved behaviour of protection through detection of the circuit breaker position when the circuit breaker is open. In this case, the protected zone is extended by the dead zone due to the device internal measures.

5.1.2 Bus coupler with two current transformers

If the bus coupler bay is equipped with two transformers as discussed in section 3.5.3, the two busbar Z1 and Z2 will be switched off immediately, since the fault is located in the overlapping protected area of both zones. The detection of the circuit breaker position does not provide any advantage.

5.1.2.1 Detection of the circuit-breaker position, circuit breaker open

The advantage of detection of the circuit breaker open status, is that the device-internal treatment of the coupler current immediately and selectively switches off the busbar feeding the fault and interrupts the fault current, irrespective of the number of current transformers.

The position of the circuit breaker shall be detected by means of the circuit breaker auxiliary contact. The processing of the circuit breaker OPEN status must not start until the main contacts have opened or parameter setting shall be used to set a time delay, where necessary.

5.2 Current Controlled Trip Reset

To reset TRIP command, it must be ensured that the tripped circuit breaker has been opened and that the trip circuit of the bay unit has been interrupted by the circuit breaker auxiliary contact.

If the trip relay interrupts the tripping current prematurely, its contacts are overloaded and destroyed.

A TRIP command from the busbar protection shall only be transmitted to the circuit breaker of the faulted feeder if the feeder current exceeds the current threshold for TRIP release.

5.3 Bay out of service: Operating State of Bay Units

The allocation of a feeder bay current to a selective measuring system (= bus zone) takes place due to the disconnector image ("disconnector replica"). The service function "bay out of service" causes that this allocation is cancelled. In 2-bay couplers, this status is automatically assumed for both coupler bay units. For this purpose, the busbar and feeder disconnectors of the affected bay unit are processed as being open in the internal disconnector replica. The positions of the sectionalizing switch-disconnectors are still acquired. If the bay unit is not available for the central unit, the old position of the sectionalizing switch-disconnector shall be retained.

Further the disconnector supervision of the bay and resulting messages shall be blocked. Even if all disconnectors of a feeder are open, the allocation of the feeder to the check zone (=disconnector-independent measuring system) remains however, if the bay unit is still switched on.

The service function "Bay out of service" shall naturally be used, if for the test of the feeder protection, which uses the same transducer core, a test current will be injected.

If for example, a busbar side disconnector remains closed and only the circuit breaker and the line side disconnector (without being monitored by the bus bar protection) are open, a test current would be assigned to a measuring system. With "Bay out of service" a processing of this test current (by the selective measuring systems) and thereby a possible false tripping is prevented.

That test current remains in the check zone measuring system and may lead to a pick-up of the "differential current supervision of the check zone". Therefore, it shall be recommended to set the reaction on a pick-up of the "differential current supervision of the check zone" to "alarm only".

In additionally, the binary inputs for the breaker failure protection shall no longer processed.

An inadvertent tripping of a busbar, e.g. in the operating mode "*external*", is thus prevented.

"Bay out of service" represents thus a precautionary measure for the bus bar protection with secondary work in the bay and no test function of the bus bar protection, particularly the bay unit.

Condition of bay unit "Bay out of service" shall be left switched on if possible. The safety function of the check zone is thus still available. Switching off is only necessary with defect of the bay unit or the optical fibre connection. The bay is shall be taken out of the protection completely and resulting annunciations or blockings prevented.

As preparation, the feeder bay must be switched off primary and be faded out by "Bay out of service" from the busbar protection. If the switching off happens without previous "Bay out of service", a blocking according to the selected settings of the bus bar protection takes place.

5.4 Bay on Maintenance: Operating State of Bay Units

During disconnector adjustments the feedback does not correspond to the switching status of the disconnectors (e.g. with maintenance of the auxiliary contacts or switched off power supply for disconnector position signal).

In such a case, the existing disconnector status will be frozen during maintenance and maintained until the maintenance function is finished. The start of the maintenance mode and the switching off the disconnector status indication are usually done simultaneously.

To prevent erroneous annunciations, a short delay of 0.5 s shall be set for the responses and the signalling of auxiliary voltage failure.

The protection function, however, remains operational. It is also possible to exclude individual switchgear of a bay unit from the maintenance mode via the parameter settings.

The main points to be observed for maintenance mode are:

- In 2-bay couplers, maintenance must be selected for one coupler bay only.
- To ensure a selective functioning of the protection, the disconnector status shall not change during maintenance mode; this is because the individual protection zones shall be managed based on the frozen disconnector replica.
- The circuit breaker monitoring and the disconnector status monitoring are closed.
- A warning annunciation “DcoProhib/Maint “output throughout the maintenance work shall displayed.

5.5 Testing the Tripping Circuits and the Circuit Breakers

This function shall test the tripping circuits and the circuit breakers under live conditions by initiating a CB test trip from the bay unit. The CB test live trip function shall be performed with the software or directly from the bay unit operator panel.

The following conditions shall be met:

- The required test trip commands have been marshalled to the trip relays during configuration.
- The feeder current must not exceed the set threshold setting.

The circuit breaker test live trip shall be initiated from the bay unit by one of the following inputs as shown in figure 11 below

- Pressing function key for 3-phase or
- via binary input”>CB Test” 3-phase or
- with the parameter setting CB TEST LIVE TRIP for 1-/3-phase.

The CB test trip command is cancelled after a fixed time of 2s.

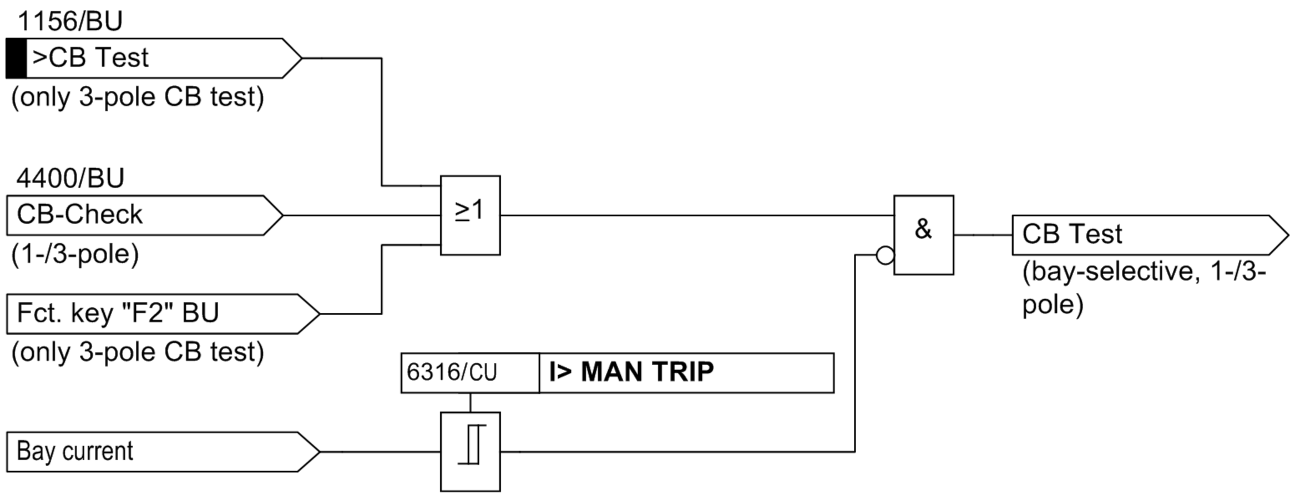

Figure 11: Circuit breaker test live trip function

5.6 Differential Current Supervision

The differential current of each measuring system shall be monitored individually. Under no-fault conditions, the differential current of each measuring system is approximately zero.

If no feeders are assigned to a measuring system, the differential current and the stabilizing current are set to zero. The differential current supervision picks up if the mean value of the differential current exceeds a certain threshold within an interval set with the parameter setting. This threshold can be set individually for the check zone with the parameter, and for the selective protection with the parameter

If the differential current falls below the threshold before the set time, the time delay shall be restarted if it occurs again.

The differential current supervision shall be activated with the via parameter setting.

5.7 Circuit Breaker Supervision Time

Buscoupler and Bussection circuit breakers statuses shall be monitored using Circuit Breaker Supervision Time parameter setting, to set the threshold for the circuit breaker runtime. If no final position check back signal is received for the circuit breaker after the set time, the protection assumes this circuit breaker to be faulty and issues an alarm. This threshold shall be determined by the longest circuit breaker runtime to be expected.

5.8 Combi-Coupler

The arrangement of the different feeder bay elements is usually free and subject mainly to the operational requirements. Occasionally, the switching elements such as circuit breaker, current transformer and disconnectors are used doubly, either as bus coupler or as feeder bay.

This special operation of the bus coupler bay is possible due to a combined bus coupler parameter in the configuration of the bay units. It is valid for all bus coupler types with circuit breakers. In two-bay couplings, it is effective per bay.

The pre-parameter setting is set to ***No***, the bus coupler acts as described in the introduction. With the configuration ***Yes*** and in the coupled state (disconnector closed on both sides), there are also no differences.

If disconnectors are closed only on one side of the bus coupler in this configuration, the current is assigned to the corresponding busbar and the check zone. The bus coupler behaves like a feeder bay. The protected zone ends behind the current transformer. An extension of the protected zone or an increased selectivity can be achieved by the end fault protection.

5.8.1 CLOSE Command of the Bus Coupler Circuit Breaker

If the bus coupler circuit breaker is open, the current of the coupler bay is set to zero for the protection of bus zones B/B1 Z1 and B/B2 Z2 in Figure 10 above.

If the bus coupler circuit breaker is closed onto a short circuit in busbar zone 2, the protection trip may be faster than the circuit breaker status processing.

This may cause spurious tripping of the healthy busbar zone 1. To avoid this, a leading contact for closing the circuit breaker that integrates the current of the coupler current transformer into the protection algorithm.

The circuit breaker position shall be detected by the binary input “>CB man. close”

As soon as an active signal is detected at the binary input, a time delay of 200ms is started. After the expiration of this time delay, the auxiliary contact of the circuit breaker must no longer be in the OPEN position.

The leading recognition of the coupler CT current must be ensured for all possible applications of the CLOSE command.

5.9 Fault recordings

During a fault event, the instantaneous values of the measured values shall be stored at intervals of 1 ms at 50Hz and 0.83 ms at 60 Hz respectively in a buffer of the central unit or of the bay units. The central unit calculates from the instantaneous values the differential and restraint currents of each phase for all busbar sections and the check zone. The bay units calculate from the instantaneous values the currents and the binary tracks.

Starting the fault recording, the fault data shall be stored in a range from max. 500 ms before the TRIP command to max. 500 ms after it. The central units can store up to 8 faults with a maximum of 80 fault events each, and each bay unit can store 8 faults with a maximum of 100 fault events each. Where more events are generated, the oldest shall be overwritten in the order of their generation.

A busbar short circuit and breaker fail shall start fault recording, for instance, by a binary input or through the software.

5.10 Check Zone (Mode of Operation)

The measuring system for the check zone shall detects a short-circuit in all bays, regardless of the disconnector status.

In some special circumstance, the disconnector status may however be considered for the check zone.

If the stabilizing current is calculated in the same manner as for the buszone-specific busbar protection, overstabilisation results in multiple busbar systems. This overstabilisation is caused by those bays which are not connected to the faulty busbar.

To avoid overstabilisation, the stabilizing current is calculated as follows:

Σ | Ip | = sum of the magnitudes of the currents which flow in the direction of the busbar

Σ | In | =sum of the magnitudes of the currents which flow away from the busbar

Istab = lesser of the above two sums

By forming the stabilizing current in this manner, only half of the total through-flowing load current acts as stabilizing current.

The short-circuit current does not stabilize the “check zone” and only acts as differential current.

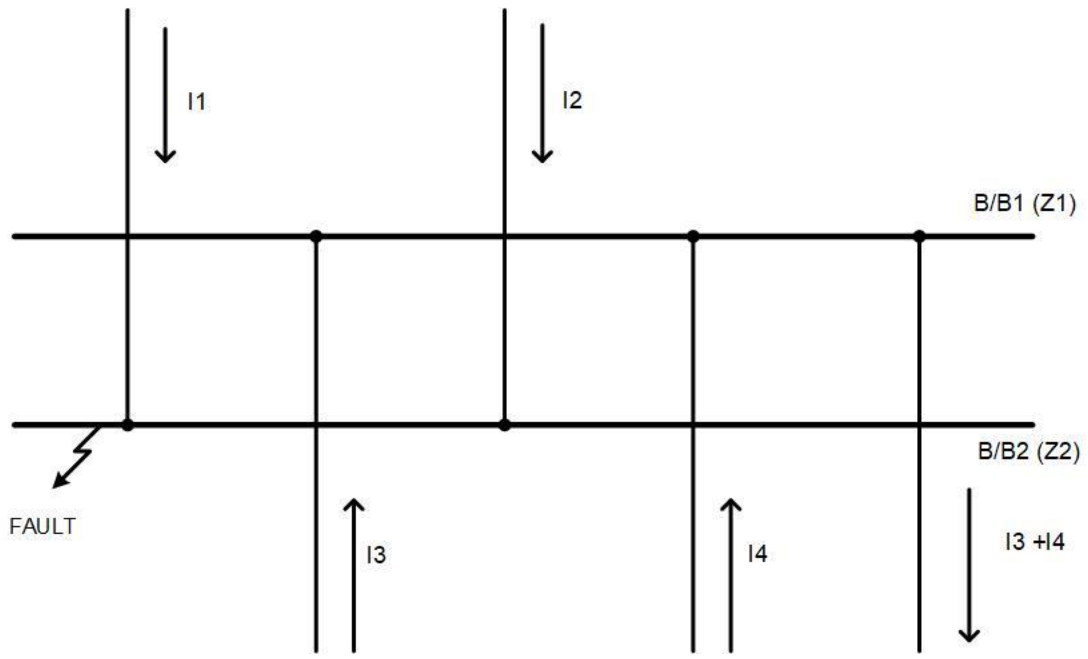

Figure 12: Treatment of the stabilizing current for the check zone

This procedure how to treat overstabilisation current for the check zone has been illustrated in Figure 12 and the equations below illustrate the procedure thereof

$Id = | I1 + I2 + I3 + I4 - I3 - I4 | = | I1 + I2 |$

Stabilizing current without special treatment:

$Is = | I1 | + | I2 | + | I3 | + | I4 | + | I3 + I4 |$

The load currents I3 and I4 are considered twice in the stabilizing current. This leads to over stabilisation.

Special treatment of the stabilizing current results in the following conditions:

$\Sigma | Ip | = | I1 | + | I2 | + | I3 | + | I4 |$

$\Sigma | In | = | I3 + I4 |$

$Is = \Sigma | In | = | I3 + I4 |$ (= is equal to half the magnitude of the load current)

This stabilizing current is modified for evaluation of the characteristic.

6. Busbar Protection Settings Philosophy

These are typical protection settings should therefore be considered when setting up the phase VI low impedance distributed Busbar / Breaker Failure Protection scheme. Central and bay unit busbar protection settings are presented in table1 and 2 respectively.

6.1 Stabilizing Factor k (BZ)

kob = Isc max /(In x K´ssc)	kob = overburdening factor
k = 0.60	with kob < 2
k > 1.2 x kob/4x √kob -1	With kob ≥ 2

For calculation of k´ssc see CT dimensioning guideline. The smallest k´ssc of all ct’s shall be considered

6.2 Stabilizing Factor k (CZ)

6.2.1 Single busbar application

Same as 6.1 above

6.2.2 Multi bars application

K = 0.5 to reduce the stabilizing by load current of healthy busbars (“overstablization”)

6.3 Stabilizing Current Threshold BZ – EF

The EF-characteristic must cover the maximum stabilizing current

Is<BZ-EF = 1.2x (I load max + IEF) where I load max is the total through-flowing current (towards and away from busbar)

6.4 Stabilizing Current Threshold CZ – EF

Due to the special treatment of the stabilizing current of the check zone

Is<CZ-EF = 1.2 x (0.5 x I load max) where I load max is the total through-flowing current (towards and away from the busbar)

Table 1: Central Unit Busbar Protection Settings

Setting Title	Function	Setting options	Setting	Comments
Bay Status	General	Out of service In service Maintenance	In service	Bay Status
I>trip	General	0.00 to 25.00 I/In	0.00 I/In	Current threshold for trip release
End fault Prot	General	On Off	Off	End fault Protection (End fault protection function requires CB aux contacts)
AUT LED ACK	General	Yes No	Yes	Automatic acknowledgement of LED
FREQUENCY	General	50 Hz 60 Hz	50 Hz	Nominal frequency
Test mode SK	General	OFF ON	OFF	Test mode for module SK (On for testing only)
Language BU	General	German English French Italian Russian	English	Language of bay units
Prot TR Bus	General	Released blocked	Released / blocked	Selective protection for transfer busbar (parameter only relevent with transfer bus
Tmin TRIP	General	0.01 to 32 s	0.15s	Minimum duration of TRIP command (the current for tripping the CB coil has to be cut by CB aux contact, not bt the trip relay contact of the bay unit to avoid damage
ISOL RUN TIME	General	1.00 to 180.00 s	7.00	Max. isolator operating time (1.2 x maximum isolator operating time)
ISOL Malfunct	General	Alarm without blocking Blocking during the fault Blocking until release Blocking until acknowledgement	Alarm without blocking	Reaction on isolator malfunction

Setting Title	Function	Setting options	Setting	Comments
ISOL DC FAIL	General	Old isolator status ON	Old isolator status	Treatment isolator status on DC fail
ISOL ST 1/1	General	Old isolator status on	Old isolator status	Treatment isolator status not plausible
BLOCKING MODE	General	Buszone and phase selective Entire protection system	Bus zone and phase selective	Blocking mode on failure
DIFF SUPERV	General	ON OFF	ON	Differential current supervision
T-Idiff SUPERV	General	1 to 10s	2.00s	Time delay for diff-current supervision
Id> SUPERV BZ	General	0.05 to 0.80 I/In	0.1 I/In	Limit value diff-current supervision - BZ
Id> SUPERV CZ	General	0.05 to 0.80 I/In	0.1 I/In	Limit value diff-current supervision - CZ
DIF SUP mode BZ	General	Alarm without blocking Blocking during the fault Blocking until release	Blocking during the fault	Diff-current supervision - BZ
DIF SUP mode CZ	General	Alarm without blocking Blocking during the fault Blocking until release	Alarm without blocking	Diff-current supervision – CZ (otherwise the entire system would be blocked)
ZERO CR SUPERV	General	ON OFF	ON	Zero crossing supervision (necessary only with TPZ-type CTs, nut disturbing with other types)
I>ZERO CR	General	0.15 to 4.00 I/In	0.5 I/In	Threshold for zero crossing supervision
I> MAN TRIP	General	0.00 to 0.50 I/In	0.05 I/In	Limit value for CB test
CTRL REL BU	General	Released blocked	released	Control release for bay units
EF Charact	General	Released blocked	blocked	Earth fault characteristic switchover (EF characteristic only for increased sensitivity; release during earth fault only

Setting Title	Function	Setting options	Setting	Comments
STAB FAC BZ	BBP	0.10 to 0.80	0.65	Stabilizing factor – BZ 1)
Id>BZ	BBP	0.2 to 4.00 I/Ino	0.2 I/Ino	Diff-current threshold - BZ
STAB FAC CZ	BBP	0.10 to 0.80	0.65	Stabilizing factor – CZ 2)
Id>CZ	BBP	0.2 to 4.00 I/Ino	0.2 I/Ino	Diff-current threshold - CZ
Is< BZ - EF	BBP	0.00 to 25.00 I/Ino	5.00 I/Ino	Stabilizing current threshold – BZ –EF 3)
Id> BZ - EF	BBP	0.05 to 4.00	0.25 I/Ino	Diff-current threshold BZ –EF (80% of minimum 1-pole earth fault current)
Is< CZ - EF	BBP	0.00 to 25.00 I/Ino	5.00 I/Ino	Stabilizing current threshold – CZ –EF 4)
Id> CZ - EF	BBP	0.05 to 4.00	0.25 I/Ino	Diff-current threshold BZ –EF (70% of minimum 1-pole earth fault current)

Table 2: Bay Unit Busbar Protection Settings

Setting Title	Function	Setting options	Setting	Comment
BF BI MODE	BFP	1 BI, without supervision of duration 1 BI, with supervision of duration 2 BI, without supervision of duration 2 BI, with supervision of duration	2 BI, with supervision of duration	For maximum security: 2 BI, with supervision of duration. 2BI mandatory with BFP mode “external BFP”.
BF OP MODE	BFP	Non existent Trip from external CBF Buszone unbalance Trip repetition with following unbalance current query Trip repetition with current query	Trip from external CBF	Operation mode BF
BF I<	BFP	On	OFF	Low-current mode BF

Setting Title	Function	Setting options	Setting	Comment
		OFF		
TRIP REP. MODE	BFP	Single-phase 3pole	3pole	TRIP repeat mode
BF	BFP	0.10 to 2.00 I/In	0.5 I/In	Current threshold
BF-EF	BFP	0.05 to 2.00 I/In	0.25 I/In	Current threshold for BF-EF
T-BF-1P	BFP	0.05 to 10.00s	0.25s	Time delay for BF with 1-pole faults
T-BF-3P	BFP	0.05 to 10.00s	0.25s	Time delay for BF with 3-pole faults
T-BF I<	BFP	0.05 to 10.00s	0.25s	Time delay for BF low-current mode
T-BF IMP	BFP	0.05 to 10.00s	0.5s	Time delay for BF pulse mode
T-BF CB fault	BFP	0.05 to 10.00s	0.10s	Time delay BF CB not ready
T-TRIP repeat	BFP	0.05 to 10.00s	0.12s	Time delay for TRIP repeat
T-CB open	BFB	0.05 to 10.00s	0.00s	Time delay fot CB open
T-BF rel sup	BFP	0.05 to 15.00s	1.00s	Supervision bin. Input BF-release (According to max. tripping time of feeder protection)
t-BF 2chan	BFP	0.06 to 1.00s	0.06	Supervision time BF start / release
STAB FAC:BF	BFP	0.00 to 0.80	0.5	Stabilizing factor BF protection
Is< BF.EF	BFP	0.00 to 25.00 I/In	5.00 I/In	Stabilizing current threshold – BF - EF

7. Scheme Design Requirements

7.1 Scheme Layout

The following schematic diagram depicted in figure 13 below represents the design and functionality requirements of the phase VI buszone protection scheme.

The distributed schemes comprise of a Central Unit with multiple Bay Units (BU). The analogue bay current transformer inputs wired from junction box to the Bay Unit (BU). The binary inputs for the busbar isolator position and circuit breaker position shall be hard wired to the specific bay Bay Unit (BU) unit. The binary output for Bay tripping shall be hard wired from the Bay Unit (BU) to the Protection scheme. The binary inputs for breaker fail start and breaker fail initiate shall be hard wired from the bay protection to the Bay Unit (BU)

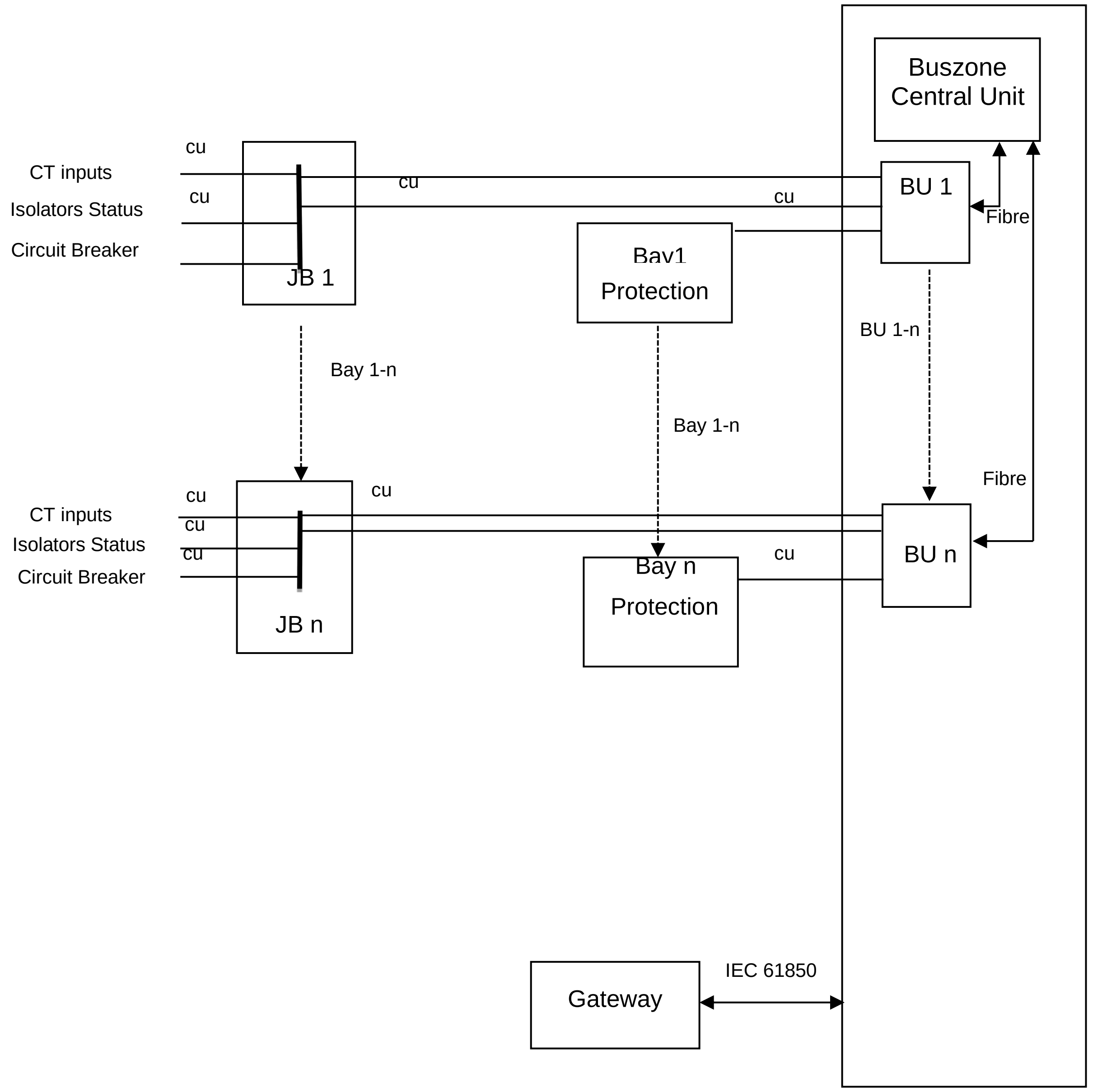

Figure 13: Distributed bus zone scheme functional requirements

7.2 Isolator Status Inputs

Substation busbar isolators are normally fitted with auxiliary contacts of a variety of timing configurations. The phase VI buszone utilize these contacts: ‘make’ (normally open) and ‘break’ (normally closed) types only.

Isolator status shall not monitored by the action of isolator mimic (or repeat relays). The buszone scheme shall scheme detect isolator status intelligently, directly from the auxiliary contact input signals. Typical application is to make use of one normally closed, and one normally open isolator auxiliary contact, rather than to use a single contact.

7.3 Trip Outputs

The three-pole trip output contacts shall be used for all types of breaker failure and bus zone operations.

The scheme shall have two trip outputs per connected bay, to be utilised for energising discrete bay Main 1 and Main 2 circuit breaker trip coils.

The trip contacts shall remain closed for the duration of trip until is physical reset, the duration of the contact shall be set via parameter setting. Following this seal-in period, the contacts shall be self-resetting. Notwithstanding the requirement for contacts to remain closed for a specific period, the contacts shall remain closed so long as the fault condition remains present.

7.4 Local Indications

The following indications shall display in the central unit:

- Bus zone trip indication
- Breaker failure trip indication
- Zone-specific trip indication (e.g. Z1, Z2, Z3, Check zone, etc)
- Faulted phase indication
- Indication of Buszone trip isolated from bay unit
- Indication of Breaker failure trip isolated from bay unit
- Protection unhealthy indication
- CT supervision indication
- Isolator status supervision indication (indicates unbalance due to loss of isolator auxiliary contact or contact connection error)
- Scheme power supply failure and/or secure supply operation indication

The following Bay Unit visual indications are necessary:

- Bay-specific trip indication (e.g. Fdr 1, Fdr 2 etc, for both B/F inputs and BZ outputs)
- Bay specific isolation indication
- Indication Bay Busbar Isolator position (open and close)
- Indication of breaker failure trip
- Indication of Bussection or Buscoupler circuit breaker (open and close)
- Indication of Bussection isolator position (open and close)

In the case of tripping indication, this indication shall be operative only once a protection operation has occurred, in other words, ‘no trip, no flag’. All tripping indications shall be red in colour, and latching, reset possible only after local operator acknowledgement, i.e. push-button. If two tripping operations occur directly after another (before acknowledgement from the local operator), then the trip indication shall indicate both operations.

7.5 Alarms

The scheme shall consist of comprehensive internal alarming facilities.

The scheme internal alarms shall be arranged as per Eskom Transmission requirements, i.e. any number of specific internal alarms combined (marshalled) to produce a single external alarm. Where such marshalling of alarms to external takes place, the internal source of an external alarm must remain detectable.

As a minimum, the following major external quiescent alarms are required to Station Gateway (IEC61850):

- Bus Zone Trip
- Breaker Failure Trip
- Protection Unhealthy (Protection relay failure)
- Bus Zone Blocked

- CT unhealthy alarm
- Isolator Status invalid
- Circuit Breaker status invalid
- Bus Zone DC Fail
- Protection On Test (during BZTI, BFTI and Off switching)

7.6 Functional Testing and Trip Blocking

The buszone protection schemes shall allow for functional testing while is in-service via Test Normal Switch (TNS) whist yet ensuring that all trip outputs are blocked.

Where the buszone is fully commissioned, one often needs to be able to test one of the protection systems while the buszone is in service. This shall be done in Eskom's case via a switching mechanism whereby the TNS switch can be selected to off position to prevent from tripping any of the in-service breakers.

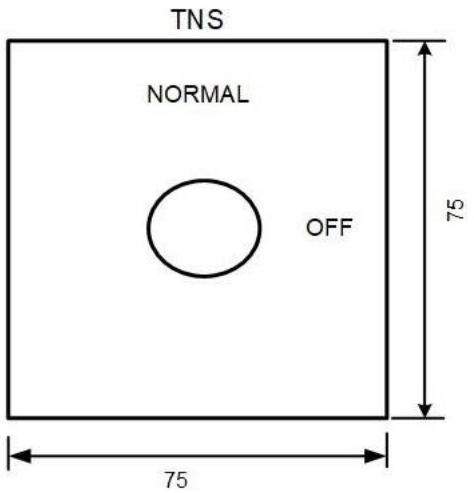

Figure 7: Layout of two-position TNS switch

With the "new technology" relays, careful analysis would have to be undertaken such that an acceptable mix of protection is retained (online) during in service functional testing of the protection systems.

TNS switches shall provide the following positions:

Normal: In this position, the switch provides the following:

- Shall allow all circuit breaker-fail functions.
- Shall allow all zones buszone trips functions.
- Shall allow hardwired tripping to the circuit breakers.
- Shall be remotely reported
- Position shall be visible indicated on the local switch label.

OFF: In this position, the switch provides the following:

- Shall block all circuit breaker-fail functions.
- Shall block hardwired tripping to the circuit breakers.
- Shall be remotely reported
- Position shall be visible indicated on the local switch label.

7.7 Lamp Check Switch (LCS): 3 Position Switch

The function of this switch is to enable, test or switch off all panel lamp/LED indications. The LCS shall have the following positions as shown below:

- **OFF** – Switch all panel lamp/LED indications off with alarms
- **NORMAL** – Enable all panel lamp/LED indications
- **TEST** – Test all panel lamp/LED indications by applying relevant supply to all panel lamp/LED indications – spring return on release to the OFF position

7.8 Isolation: DC circuit breaker

The scheme shall be provided with a 2-position DC circuit breaker with the following functions as shown below:

- **OFF** – Isolate the relevant DC voltage from the system/tripping circuits and secure supply control unit
- **ON** – Apply the relevant DC voltage to the main protection system/tripping circuits

8. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Andre de la Guerre	Middle Manager – Protection Technology & Support - PTM&C
Tony Sheerin	Middle Manager – Projects and Planning Technology & Support - PTM&C
Nombuso Msibi	Middle Manager – Application Technology & Support - PTM&C
Bongani Qwabe	Chief Technologist – Protection Technology & Support - PTM&C
Andrew Craib	Chief Engineer – Protection Technology & Support - PTM&C
Matankiso Mohlokoana	Chief Engineer – Protection Technology & Support - PTM&C
Lungie Nogela	Chief Technologist – Project and Planning Technology & Support - PTM&C
Johan Pieterse	Chief Engineer – Transmission Special Projects – Grids
Nelson Luthuli	Senior Manager – PTM&C
Anita Oommen	SCOT/SC Chairperson

9. Revision History

Date	Rev	Compiler	Remarks
July 2022	Draft 0.1	P.T Mashigo	First Issue

10. Development Team

The following people were involved in the development of this document:

- P.T Mashigo – Chief Technologist (Buszone Custodian)

11. Acknowledgements

Not applicable.