Eskom	Standard	Technology

Title: **Transmission Philosophy for Application of point on Wave Switching of Circuit Breakers**

Unique Identifier: **240-75566441**

Alternative Reference Number: **<n/a>**

Area of Applicability: **Engineering**

Next Review Date: **STABILISED**

COE Acceptance

Nelson Luthuli

Senior Manager: PTMC (Acting)

Date: 01 March 2021

DBOUS Acceptance

Amelia Mtshali

Senior Manager: Power Delivery Engineering (DBOUS)

Date:17/03/2021

This document is **STABILISED.** The technical content in this document is not expected to change because the document covers: *(Tick applicable motivation)*

1	A specific plant, project or solution	
2	A mature and stable technical area/technology	X
3	Established and accepted practices.	

PCM Reference: **240-42722776**

SCOT Study Committee Number/Name: **PASC**

Eskom	Standard	Technology

Title: **TRANSMISSION PHYLOSOPHY FOR APPLICATION OF POINT ON WAVE SWITCHING OF CIRCUIT BREAKERS**

Unique Identifier:	**240-75566441**
Alternative Reference Number:	**41-992**
Area of Applicability:	**Engineering**
Documentation Type:	**Standard**
Revision:	**1**
Total Pages:	**11**
Next Review Date:	**April 2019**
Disclosure Classification:	**Controlled Disclosure**

Compiled by	Approved by	Authorized by
Joe Fischer	Prince Kara	Richard McCurrach
Chief Technologist	PTM&C Protection T &S Manager	PTM&C COE Manager
Date: 26/3/2014	Date: 26.3.2014	Date: 31/3/2014

Supported by SCOT/SC

Graeme Topham
SCOT/SC Chairperson
Date: 27/3/2014

PCM Reference: **<xxxxxx>**
SCOT Study Committee Number/Name: **<Number or name>**

Content

1. Introduction

The purpose of this philosophy is to describe Eskom Transmission's requirements for high accuracy point on wave switching of circuit breakers to be applied on shunt capacitor banks, filter capacitor banks and shunt reactors ranging from 88kV to 765kV.

The document provides a record of the point of wave philosophy used on the ESKOM Holdings Transmission circuit breakers and also provides a general guideline for point on wave switching.

2. Supporting clauses

2.1 Scope

This document is based on TRANSMISSION PHYLOSOPHY FOR APPLICATION OF POINT ON WAVE SWITCHING OF CIRCUIT BREAKERS (TPL41-992).

2.1.1 Purpose

This document outlines the requirements of control of point on wave devices on the circuit breakers of primary reactive and primary capacitive equipment.

2.1.2 Applicability

This document applies to Eskom Transmission on controlled switching of primary reactive and primary capacitive equipment. This document covers the controlled closing of shunt capacitors and controlled closing and opening of shunt reactors.

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] ISO 9001 Quality Management Systems.

[2] HV Shunt reactor secrets for protection Engineers by Zoran Gajic, Birger Hillström and Fahrudin Mekic

[3] Transient Analysis of Shunt Reactor Switching (December 2005) by Ariel Riviera-Colon, Juan L. Vargas-Figueroa, Lionell R Orama-Exclusia

[4] Seminar/Workshop on Controlled Switching, Benefits for Shunt Reactor Applications WGA3-07, Julio Munoz Florez

2.2.2 Informative

[5] Eskom Standard ESKASAA04 “Standard for Electronic Protection and Fault Monitoring Equipment for Power Systems” Revision 1, July 1996.

[6] Eskom Specification NWS 1582 “Specification for Labels on Control Panels, Relay Panels and other Indoor and Outdoor Equipment”.

[7] Eskom Specification NWS 1575 “Specification for Control, Selector, Isolation and Test Switches”

[8] Eskom Procedure NWP 3031 “Performance Testing and Test Result Recording of Control, Selector, Isolation and Test Switches”

[9] Eskom Policy ESKPBAAH5, Revision 1; “The control of numerical/software driven products used in the protection field with respect to version changes to the software, firmware or hardware of the device, and to any associated technical PC software” October 1999.

[10] ARC Philosophy for Lines with Shunt Reactors TPL41-10

2.3 Definitions

2.3.1 General

None

2.3.2 Disclosure classification

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

2.4 Abbreviations

Abbreviation	Description
POW	Point on Wave
LED	Led Emitting Diode
IS	Isolating Switch
CT	Current Transformer
CTR	CT Ratio – primary to secondary turns ratio of a CT
CVT	Capacitive Voltage Transformer
L1	Red Phase, A Phase or Phase 1
L2	White Phase, B Phase or Phase 2
L3	Blue Phase, C Phase or Phase 3
CB	Circuit Breaker
TTR	Transient recovery voltage
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
DC	Direct current
VT	Voltage transformer

2.5 Roles and responsibilities

Primary plant custodians are responsible to supply a list with primary equipment that must be closed, opened or closed and opened with point on wave switching.

The System Operator is responsible for calculating, distribution and storage of the settings.

Transmission Services Protection Technology & Support are responsible for the design, development for point on wave switching device on shunt capacitor and shunt reactor schemes.

Transmission Services Applications are responsible to apply from January 2009 the point on wave device on all circuit breakers for capacitive and reactive schemes.

The grids are responsible to obtain the necessary breaker speed test results.

The grids are responsible for the implementation of the settings and confirmation that the device switches the breaker correctly.

Transmission Services Protection Technology & Support are responsible for product training.

2.6 Process for monitoring

Document Centre

2.7 Related/supporting documents

Not applicable

3. Document content

3.1 Document Specification

Point on wave switching devices are applied in Eskom Transmission since 1997 on circuit breakers for controlled closing of shunt capacitor banks and controlled opening of shunt reactors. This practice mainly protects the circuit breaker and all primary plant must be capable of being operated without point on wave switching.

The shunt capacitor bank circuit breaker is switched on closing to limit energising transients and the shunt reactor circuit breaker is switched on opening to prevent re-ignition over the circuit breaker contacts when de-energising.

There are a few installations where point on wave switching is used on closing a shunt reactor breaker. The reason for this is to limit inrush current due to the mismatch of current transformers in differential protection circuits causing imbalances in the protection device.

3.1.1 Shunt Capacitor

3.1.1.1 Shunt Capacitor bank closing

Point on Wave devices reduces the magnitude of the inrush currents during closing of shunt and filter capacitor installations.

The point on wave device must use phase 1 (L1) as a reference voltage to trigger the point on wave action. The point on wave device must then close the other two phases dependant on the closing program selected in the device.

For capacitor banks with grounded neutral, the aim is to have zero voltage across the contact per phase when circuit breaker contacts are closed. The POW relay then takes the breaker closing time into account to ensure that closing on phase 1 (L1) takes place with zero volt across the phase 1 breaker contacts. Phase 3 (L3) is closed 3.3ms later and phase 2 (L2) is closed 6.6 ms later. Closing sequence L1-L3-L2.

For capacitor banks with ungrounded neutral, phase 1 (L1) and phase 3 (L3) should close simultaneously and phase 2 (L2) later. Phase 1 (L1) should close 1.7ms after reference voltage passed through zero volt. Phase 3 (L3) must close at the same time as Phase 1 (L1). Phase 2 (L2) must close 6.7ms later after the reference voltage passed through zero volt. The closing sequence L1/L3 – L2.

The ideal is to have single pole driven mechanisms on the circuit breaker. The advantages with this type of breaker are that one can accommodate any system changes without mechanically setting the breaker poles.

The aim is to make the contacts conduct current within a 2 ms range when the voltage pass zero.

Very Important - The operating sequence must not be confused with the normal phase sequence. This is to ensure the correct voltage condition is obtained across each phase of the circuit breaker at the instant of closing.

The advantages for closing shunt capacitors with point on wave:

- zero voltage over circuit breaker contacts when closing,
- lower inrush currents when closing circuit breaker,
- increase capacitor life
- Reduced reflected disturbances in the sourced network.

3.1.2 Shunt Reactor

3.1.2.1 Shunt Reactor Opening

3.1.2.1.1 Three-Limb Shunt Reactor with earthed neutral

The aim is to open the breaker contacts when the current has just passed through zero, to allow maximum arcing time to prevent re-ignitions taking place. The breaker must develop a adequately long arcing time to give the contacts time to separate enough to avoid electrical breakdown when recovery voltage appears across the interrupting elements.

A voltage signal (Normally phase1 (L1) passing through zero) is used to trigger the point on wave action. The POW relay takes the breaker tripping time and the selected opening program into account to ensure that opening on phase 2 takes place 1.7ms after reference voltage passed through zero, then phase 1 open 5ms later and phase 3 open 8.3ms later with reference to phase 2. Opening sequence L2-L1-L3.

The POW relay takes the opening time of the circuit breaker per phase into account to ensure the circuit breaker has a long enough arcing time over the primary contacts, this must be a few milliseconds less than 1/2 cycle (10 milliseconds) to avoid re-ignitions happening. Too short an arcing time (usually 1 to 5 ms) means the breaker can re-ignite. This must taken into account when setting the POW relay. The arcing time is normally set between 6 to 8 ms per phase.

An oil circuit breaker cannot clear reactive current at the first current zero as it re-ignites and must be delayed until the next current zero crossing. Further delays might be necessary to obtain current zero. This is why a POW relay cannot be used on an oil circuit breaker.

Very Important - The operating sequence must not be confused with the normal phase sequence in order to ensure the correct arcing time duration is obtained in each phase of the circuit breaker at the instant of opening.

The advantages for opening shunt reactor with point on wave:

- Prevent re-ignition over circuit breaker primary contacts
- Shunt Reactor Closing

3.1.2.1.2 Three-Limb Shunt Reactor with earthed neutral

Current practice in Eskom Transmission is not to use point on wave switching to close the circuit breaker.

Closing the breaker phases at the point where the voltage waveform is at maximum limits the inrush currents. This will stress the reactor winding insulation with a steep voltage transient when current starts to flow through the circuit breaker contacts.

Closing the breaker phases at the point where the voltage waveform is at minimum eliminates the steep voltage transient. This method of energisation may cause excessive electromagnetic stresses in the winding of the reactor, causing saturation of the shunt reactor magnetic core and zero sequence protective relays can malfunction.

Advantages for using point on wave closing where voltages are at maximum per phase:

- Reduce inrush currents.
- Reduce zero sequence currents.
- Limit mechanical vibration in reactor.
- Improve power quality

Advantages for using point on wave closing where voltages are at minimum per phase:

- Eliminates the steep voltage transient caused by the breakdown of the contact gap when current starts to flow.

It is not possible to eliminate both inrush current and transient stresses simultaneously and this is the reason why Eskom Transmission does not adopt closing using POW relays on reactors.

3.2 Commissioning Procedure

Verify external wiring corresponds to the relevant point on wave device used for closing or opening.

Check DC supply voltage to point on wave switching device.

Check VT Reference voltage to point on wave switching device.

Check close/opening pulse wiring from point on wave switching device

Check “By-pass” wiring from point on wave switching device.

Apply breaker speed test results, arcing time, switching program.

Perform off load testing to verify phase switching.

During initial commissioning use a portable recorder to record the voltages, currents and breaker auxiliary contacts to prove exact circuit breaker contact switching position. Analyse captured event on closing or tripping.

3.3 Technical Requirements

3.3.1 Overview

Point on wave switching devices are intended to be used for controlled closing of circuit breakers on capacitive plant and controlled opening of circuit breakers on reactive plant from 88 kV to 765 kV.

Point on wave switching devices on shunt capacitors, filter capacitors and shunt reactors shall comprise of a device to be added to an existing scheme in the case of already installed plant or protection schemes.

Point on wave switching devices must be included in all new shunt capacitor protection schemes and shunt reactor protection schemes on contract.

3.3.2 Point On Wave Switching options

Algorithms to fulfil the switching requirements:

- Point on Wave switching device on Shunt Capacitor Schemes.
- Point on Wave switching device on Filter Capacitor Schemes.
- Point on Wave switching device on Shunt Reactor Schemes.
- Point on Wave switching on Transformers (Optional)
- Point on Wave Switching on Series Compensated Lines (Optional)

3.4 Point on Wave Device

3.4.1 Composition

Equipment shall be mountable in standard 19-inch rack. Equipment module shall be of a modular design. All plug-in circuit boards and modules shall be fitted with guide pins. Equipment enclosures shall be equipped with card guides to prevent damage resulting from misalignment of connectors and sockets during insertion and removal of circuit boards and modules. Circuit cards and modules must be easily replaceable without requiring removal of the entire device, or other circuit cards or modules of the device, from the device rack. Modular units of the device shall be self-supporting and require no external supports or bracing other than the ones specified in the 19" standard.

In Service/Bypass switch to have the device in Service or on Bypass.

3.4.2 Inputs

3.4.2.1 Current and Voltage Transformer Inputs

The IST PK2 type 4 way test block shall be used in both current and voltage circuits.

3.4.2.2 Circuit Breaker Auxiliary Contacts inputs

Three normally open and three normally closed contacts must be available from the circuit breaker auxiliary contacts for three mechanism, circuit breakers.

A single normally open and a single normally closed contact must be available from each of the circuit breaker mechanisms in the case of single mechanism breaker.

3.4.3 Adaptive Control

A microprocessor based feature adapting the device to program itself to correct circuit breaker switching times in the event of contact drift when supply DC changes, ambient temperature changes and or breaker Sf6 pressure changes.

The operating time of the last operation must be compared to the actual operating time and the time shift discrepancy shall be limited to maximum 1 millisecond from one operation to another.

3.4.4 DC supply

DC supply from the back-up DC circuit shall supply the DC circuit of the POW device.

3.4.5 Communication

A front Serial port must be available for local communication to the device. A rear serial port must be available for remote access, and data retrieval.

An ethernet port for future remote access, and data retrieval can be available (optional).

Transmission of data over a good quality voice grade channel or microwave system must be possible (optional).

3.4.6 Alarms

Two isolated potential free relay outputs shall be provided as alarm outputs. These alarm outputs shall be capable of driving an annunciation system, or sequence of events' recorder. The alarms shall be internally activated until the alarm condition returns to normal.Data Integrity and Storage

All operating parameters shall be stored in non-volatile memory so that the POW shall return to normal operation after a power-up cycle.

Data shall remain at the POW memory in a fault file until the local operator enables overwriting.

The recorder must be able to store a minimum of 10 recordings on a flash disk hard drive.

3.4.7 Time Synchronising (Optional)

The device shall incorporate a real-time clock that shall not drift more than 60s in one month when not connected to a GPS. The clock may be synchronised to the system frequency or a crystal oscillator circuit. The crystal shall be within the accuracy limits for the total temperature range specification of the device.

A facility to synchronise the clock using an external source can be provided. The preferred format is the DC modulated IRIG-B (002).

Correction of the device time shall be performed without adversely affecting the operation and/or parameters of the device. The synchronisation event shall be recorded by the internal sequence of event recording feature.

In the event of the loss of supply to the device, the time of the clock shall be maintained for a minimum period of up to 8 hours.

3.4.8 Communication Detail

One front serial port (EIA-232-D) shall be provided for local use in direct communication.

3.4.9 Panel switch

This panel control switch shall perform the following functions:

- POW: 2 position switch

The function of this switch shall be to switch the POW In service or Bypass.

In Service:	Apply the relevant DC voltage through POW device to tripping circuits
Bypass:	Apply the relevant DC voltage to tripping circuits and bypass the POW device

3.4.10 Environmental Characteristics

3.4.10.1 Operating Temperatures

All equipment shall be designed to operate over the temperature range of -10°C to 55°C and a humidity range from 5% to 95% non-condensing.

3.4.10.2 Electromagnetic Interference (EMI)

The POW equipment shall be installed in high voltage substations. It is the supplier's responsibility to ensure that the EMI shielding is adequate to assure reliable operation of all equipment furnished under this specification.

3.4.10.3 Module and Component Replacement

All logic cards or modules should be field replaceable and interchangeable with other cards or modules with the same system function. Sufficient information shall be affixed on each module to enable a user to decide definitely whether or not two similar modules are actually interchangeable. Equipment shall be designed such that defective modules can easily be replaced without moving other equipment units or disconnect wiring.

3.4.10.4 Standard for Electronic Protection and Fault Monitoring for power systems. (ESKAASA04)

Device must comply with Standard for Electronic Protection and Fault Monitoring for power systems (ESKAASA04)

3.5 Revision Control

Amendments to this document shall only be made upon receipt of an official request.

Request must include:

- Brief description relating to reason for amendment
- Latest applicable revision number
- Equipment applicability
- When required

After incorporating amendments, Section 5 of this document must be completed accordingly.

4. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Nico Kleynhans	Performance Manager
Prince Kara	Protection Manager
Roger Cormack	HV Engineering Manager
Anita Oommen	OPS Performance Manager
Richard McCarrach	PTMC Manager
Eric Shunmagum	Project Execution Manager
Gavin Bruce	Asset Strategy and Investment Planning Manager
Fiona Havenga	Environmental Manager
Johan Harmse	Industry Intelligence Manager
John Masson	Business Planning and Direction Manager
Themba Shange	Strategic Performance & Projects Manager

5. Revisions

Date	Rev.	Compiler	Remarks
April 2014	1	Joe Fischer	Change document TPL41-992 to new standard
Oct 2009	0		New Philosophy document – 41-992

6. Development team

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

Name	Designation
Richard Hopkins	Corporate Consultant HV Switchgear
Neels van Staden	Corporate Consultant HV Capacitor
Roger Cormack	Corporate Consultant HV Transformers

Joe Fischer	Secondary Plant Custodian Point on Wave, HV Feeders and Disturbance Recorders
Bongani Qwabe	Secondary Plant Custodian Transformers
Amelia Mtshali	Secondary Plant Custodian Capacitors
Leon Kotze	Corporate Consultant Secondary Plant

7. Acknowledgements

Not applicable.