Eskom	Standard	Technology

Title: **FUNCTIONAL SPECIFICATION FOR A SMART SUBSTATION**

Unique Identifier: **240-131732683**

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

Area of Applicability: **Engineering**

Documentation Type: **Standard**

Revision: **1**

Total Pages: **17**

Next Review Date: **June 2023**

Disclosure Classification: **Controlled Disclosure**

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PCM Reference: **240-53459042**

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

Content

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1. Introduction

The concept of a “smart substation” is to build a completely intelligent substation environment where all the devices can work and collaborate on the same network. With intelligent electronic devices (IED), it’s possible to add control and automation capability to the substation and empower remote users to manage system devices using remote control commands.

- An intelligent substation has the following features:
- All primary devices have been upgraded as intelligent devices.
- All secondary devices have been networked.
- Substation operation and management have all been automated.

This functional specification aims to provide a networking and computing solution for constructing a smart substation. Figure 1 below illustrates a smart substation that implements IEC 61850 for common communication models and IEEE 1588 for precise time synchronization among smart devices.

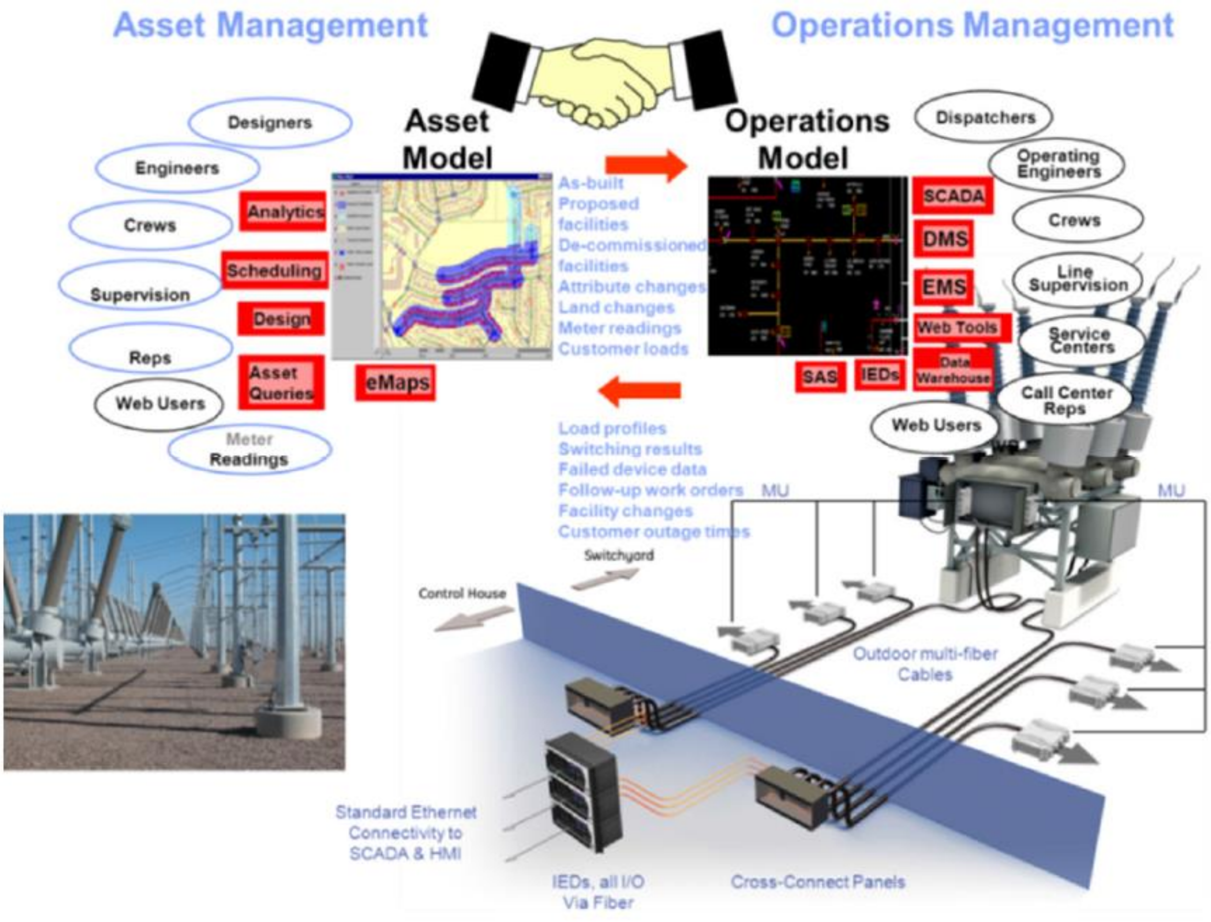

Figure 1:The Smart Substation [5]

2. Supporting clauses

2.1 Scope

This document lists the functional requirements for a smart substation as envisioned by Eskom. It lists foreseeable inputs that could be used to automatically manage a substation. These will cover remote monitoring, visualization and operating of plant within a substation.

The standard does not address detailed specifications or methods of achieving this monitoring, visualization or operating, but merely addresses capability to achieve them.

2.1.1 Purpose

This specification tries to capitalise on the ability to add intelligence to all primary plant equipment, manage this intelligence via fully networked secondary plant systems and automate all routine operations as far as possible.

2.1.2 Applicability

This document shall apply throughout Power Delivery Engineering.

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] User Requirements for an Enhanced Unattended Substation, 240-89279901.

2.2.2 Informative

[3] Omid Alavi, Current Measurement with Optical Current Transformer, Department of Electrical Engineering, K.N. Toosi University of Technology, Tehran, Iran, alavi.omid@mail.com.

[4] Deba Kumar Mahanta & Shakuntala Laskar, Transformer Condition Monitoring using Fiber Optic Sensors: A Review, debamahanta@gmail.com, shakuntalalaskar@gmail.com

[5] Jorge Cárdenas, Alberto López De Viñaspre, Hamzah Farooqui, Rodrigo Argandoña, Camilo De Arriba, The next generation of Smart Substations. Challenges and Possibilities, CIGRE 2012 Paper number B5-110 Jorge.cardenas@ge.com.

[6] M. Lindgren, M. Kharezy, Fiberoptic sensors for high-voltage applications: MTe4P00647-1, Mikael.Lindgren@sp.se

[7] T.BUHAGIAR RTE, L.SCHMITT ALSTOM, V.ADDI ALCATEL-LUCENT, Smart Substation Project, European Utility Week, 05/11/2014, www2.ademe.fr, www.smartgrids-cre.fr, www.alstom.com, www.rte-france.com

[8] Mallesh Gadeppanavar & Vinay Pattanashetti, Design of Future Substation, International Journal of Emerging Technology and Advanced Engineering, Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 3, March 2013), Electrical and Electronics Engineering department, Angadi institute of technology and management Belgaum-590008, India

[9] Remote device communication standard for data retrieval and remote access, 240-64038621

[10] Technology Plan for Transmission and Distribution, 240-91559934

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
AC	Alternating Current
CB	Circuit Breaker
CT	Current Transformer
DC	Direct Current
DGA	Dissolved Gas Analysis
E	Electric field
FACTS	Flexible Alternating Current Transmission Systems
FLIR	Fault Location, Isolation and power Restoration
FOCT	Fibre Optic Current Transformer
FOCVT	Fibre Optic Current/Voltage Transformer (combined unit)
FOTMS	Fibre Optic Temperature Monitoring System
FOVT	Fibre Optic Voltage Transformer
GIS	Gas Insulated Switchgear
IED	Intelligent Electronic Device
IP	Internet Protocol
LPATS	Lightning Positioning And Tracking System
MES	Motorised Earth-switch
MIS	Motorised Isolator
MK	Marshalling Kiosk
NCIT	Non-Conventional Instrument Transformers
PAC	Programmable Automatic Controller
PC	Personal Computer
RTD	Resistance Temperature Devices
SA	Surge Arrester
SCADA	Supervisory Control And Data Acquisition
SVC	Static VAr Compensator
VT	Voltage Transformer

2.5 Roles and responsibilities

It will be the responsibility of the Equipment specialist or area matter experts to incorporated requirements of this document into relevant equipment or area specifications.

2.6 Process for monitoring

All products considered for smart substations should be evaluated against the guidelines set out in this document. This document shall be reviewed as new technology is introduced to the market and updated as and when required.

2.7 Related/supporting documents

Not applicable.

3. Smart substation concept

Substation automation may be only 1-2% of the asset value of the whole substation, but it has a big impact on the efficiency of operations and maintenance.

Areas that contribute to the smart substation concept includes installing sensors to collect the quantities in the field, process the signals, and send them to a data concentrator unit. Normally, the sensors installed are voltage transformers (VTs), current transformers (CTs), resistance temperature devices (RTDs), moisture sensors, position sensors, signal transducers, and so on.

The monitoring system is constituted by three major units, namely:

- Data processing and transmitter unit
- Load and Measurement Systems
- Receiver and PC display unit

More information from the substation components is required, with pre-processing already taking place in the substation.

3.1 Common bay equipment requirements

a) In-service pollution sensors on as much equipment as practically possible

b) Equipment condition sensors built into primary side for continuous monitoring

c) All signals are to be available digitally for remote interrogation

d) All insulators should be composite type wherever possible. The electric (E) field levels must be limited to avoid permanent corona from the metal parts and water drop corona located on the composite insulator surface.

e) Vibration meters on busbars, particularly on outdoor round tubular busbars

3.2 Switching equipment: circuit breakers, isolators & earth-switches

The following are requirements for all circuit breakers, isolators and earth-switches as applicable:

a) All switching equipment to be motorized irrespective of voltage

b) All existing requirements of motor drive operation philosophy as per the appropriate Eskom standards are to be retained

c) To include a self-supervision system

d) Interlocking between isolator and earth-switch operation

e) Both fault condition and normal current switching

3.2.1 All switching equipment to have contact wear indication

The switchgear manufacturer must provide a maintenance curve listing the number of close-to-open operations and the interruption current levels. The function of this curve is to predict the switchgear contact wear. It must be possible to configure some of the points of this curve, where normally the highest and lowest number of operations and an average point can be chosen. For each operation, the IED should integrate the interrupted current with the operation number to update the contact wear value. This parameter is crucial to estimate the need for maintenance.

3.2.2 Total number of operations

Incremental counters for close-to-open operations are to be implemented to make that information available to the system history. In case of Hydraulic operated switchgear, this system must be able to record the Hydraulic motor pump-starts as well.

3.2.3 Mechanical operating time

The mechanical operating time of circuit breakers are to be calculated by measuring the time interval between the trip command or the close command and the asserting of the digital inputs of the IED connected to the circuit breaker status contacts (deviations in this value may indicate problems in the drive mechanism).

3.2.4 Electrical operating time (similar to the mechanical operating time)

Electrical operating time measurement required to measure the time interval between the trip or the close command and the clearing or normalization of current measurements in the circuit breaker (if this parameter tends to increase over time, it could indicate failures in the contacts).

3.2.5 Switching time for opening and closing of isolators

For isolators, it is required to measure the time interval between the open or close command and the asserting of the digital inputs of the PAC connected to the isolator auxiliary (status) contacts, to calculate the time of the operation of the switch (deviations in this value may be used to evaluate the drive mechanism). Similar durations for Earth switch operation can be used to monitor drive mechanism efficiency.

3.2.6 Fault recording

This system must integrate the voltage and current waveform characteristics recorded by the Digital Fault Recorder (DFR's) for each particular switching equipment, and capture the faulty incident information accordingly

3.2.7 Inactivity time

By monitoring the activity of the number of operations, it must be possible to calculate the number of days in which the breaker has been inactive (long periods of inactivity degrade its reliability for the protection system).

3.2.8 Average and Maximum power during operation

The motor power is to be measured by the PAC using transducers. These samples are to be used to calculate the average and maximum values (upward trending of these two parameters to indicate pending mechanical problems in the structure or motor failure).

3.2.9 Angular position

The PAC is to provide this information for evaluation using angular positioning sensors. The information to be flagged should be:

a) If the angle recorded exceeds the nominal position, it is indicative of an overload of the mechanical structure and motor.

b) If the angle is smaller, this may indicate a failure in the operation.

3.2.10 Spring-loading time

The time to assert the digital inputs of the IED connected to the circuit breaker loaded spring contact must be measured just after the circuit breaker closes (An increase in time as the number of operations increases to indicate a possible problem in the spring-loading mechanism).

Quick disconnection system from busbars for DCB's

3.2.11 Holistic view of switchgear

3.2.11.1 Superimpose data values

a) Provide the most critical switchgear within a substation to be shown from provided function values.

b) Trending functionality to be monitored and sent to the SCADA/MicroSCADA system and analysed

   1) Opening time
   2) Closing time
   3) Total Break time which includes Opening time and arcing time.
   4) Insulation gas density
   5) contact wear
   6) contact travel (giving information about speed, over-travel and damping)
   7) coil currents
   8) motor current including spring charging time etc..

c) Continuous SF6 monitoring where applicable

d) Arc monitoring where applicable

e) Switchgear monitoring and alarming

f) Switchgear operating mechanism heater monitoring and alarming

3.2.12 Specific to GIS and Mixed Technology Switchgear

Partial discharge sensors that can be monitored remotely for all GIS or mixed technology installations. This SMART system must be able to integrate with the measurement that comes from the arc-flash detection sub-system which monitors internal arcing in the GIS during fault on the line.

3.3 Non-Conventional Instrument Transformers (NCIT's)

All existing accuracy of protection, buszone, metering and measurements requirements as in

3.3.1 Current transformers

a) FOCTs

b) In-service Tan Delta measurements

3.3.2 Voltage transformers

a) Fibre Optical VTs

3.3.3 FOCVT units

a) Combined fibre optical current/voltage transformer unit

3.4 Power Line Carrier Equipment

Require a system to allow for remote access to the power line carrier equipment which is IEC61850 compliant, and that supports a sequence of events functionality.

3.5 Surge arresters

3.5.1 Digital surge counters

a) On-line leakage current measurement, giving a real-time view of the condition of the surge arrester and provide trend analysis of the resistive leakage current

b) Measurement of the surge impulses through the arrester due to over-voltages and estimate the over-voltage across the apparatus within the arresters protective zone

c) On-line pollution measurements: As above, but a view of pollutants, independent of insulation length, type, etc

d) On-line surge arrester monitor for metal-oxide surge arresters on insulated bases

3.6 Oil filled power equipment

All existing requirements pertaining to oil filled power transformers, auxiliary transformers and shunt reactors to be digitally available and data storage for remote scrutiny:

- Superimposed data values
- Measured ambient temperature
- Oil temperature and compensation algorithm
- Oil flow
- Measured and calculated top-oil temperatures
- Winding temperature
- Measured and calculated winding hot-spot temperatures: Fibre optic temperature monitoring system
- Oil level indication – a single device that can digitize oil levels and perform leak detections
- On-line gas analyser and data storage
- Cooling control software that can perform predictive cooling based on load trend
- Arc detection and location
- Moisture levels
- Buchholz monitoring
- Neutral current monitoring
- Partial discharge monitoring of bushings and data storage
- Daily loss-of-life rate
- Accumulated loss-of-life rate
- Efficiency of the forced ventilation system
- Insulation aging acceleration factor
- Estimated insulation life service
- Detection of electrical and mechanical stresses caused by through faults
- Self-drying breathers with moisture sensor (self-controlled)
- Breather moisture sensor information
- Moisture and drying statistics

- Trending and functionality
- Valve positions
- Trending gas and fault algorithm
- A suitable on-line DGA for system health indicator
- Automated online bushing monitoring and alarming system
- Automated bushing monitoring system with specific reference to tan delta and capacitance

3.6.1 Transformers

a) Transformer tapping statistics

b) Tap-changer motor drive operation philosophy with vacuum tap-changers

c) Fibre links between the auxiliary equipment applied to the transformer, i.e. temperature meter

d) A tool for remote transformer value position monitoring

3.6.2 Auxiliary transformers

a) Neutral current on star connection

3.6.3 Reactors

a) Shunt reactors

All items as listed under paragraph 3.6

b) Series reactors (oil filled)

All items as listed under paragraph 3.6

3.7 Air core reactors

a) Air core reactors are either fault current limiting or neutral end reactors on EHV feeders. These are contained within a bay and can be monitored through the appropriate current transformers.

b) Turn-to-turn insulation fault condition monitoring (variation of impedance)

3.8 Capacitors

a) All existing requirements and operation philosophy to be IEC 61850 compliant

b) Measurements to be digitally available for remote scrutiny

   1) Phase current

   2) Voltage (especially for trapped charge on the bank)

c) Earth current for earthed banks

d) Neutral unbalance current for star-star connected banks

e) Provide a holistic view of a capacitor with regard to superimposed data values:

1) Voltage variation
2) Voltage unbalance
3) Current harmonics
4) Voltage harmonics

f) Trending functionality – can be fed back to the substation SCADA system and trended there via a data historian (trending) function

3.9 FACTS devices (SVCs, STATCOMs, etc.)

a) To be IEC 61850 compliant in monitoring and protection.

b) Visual and IR scanning in valve rooms

c) Web interface for alarms and controls

d) Remote restoration functionality and operation

3.10 Common yard

3.10.1 Earthing monitoring system

a) Monitors metallic infrastructure for change due to cutting, removal, damage or degradation

b) System looks for changes in the monitored infrastructure inductance characteristics

c) The monitored infrastructure is to be coupled into a sensing circuit via sense wire inputs which detects minor changes (down to below 0.02μH)

d) When change occurs beyond the adjustable thresholds, the unit alarm must be activated

e) Filter thresholds to include extent of change detected and duration of change in order to cope with site faults and other events

3.10.2 Pollution monitoring system

a) Air Quality Monitoring Systems (AQMS)

3.10.3 Cameras

a) For real time normal monitoring, infra-red sensing (thermal imaging) and flash detection, temperature measurement

b) Strategically placed to be able to view power equipment, i.e. transformers, reactors capacitors, SVCs and confirm switching operations

c) At access control building motion triggered recording to view main access gate area

d) Day and night be able to pan, tilt and zoom-in on and view:

1) Bay equipment
2) Fence perimeter

3.10.4 Alarm triggered and remotely activated lighting (motion or heat signature triggered):

a) General flood lighting

b) Barrier fence lighting

c) Electric fence monitoring equipment

d) Local and remote control of Main Access Gates

e) Remote pollution monitoring system

f) Copper theft monitoring

3.11 Outdoor weather conditions

a) Wind speed

b) Solar radiation

c) Ambient temperature

d) Rainfall

e) Relative humidity

f) Lightning detector – LPATS system for remote interrogation of lightning flashes

3.12 Buildings

a) Control room temperature monitoring

b) Control room pressure monitoring

c) Air conditioner monitoring

d) Protection Schemes/Panels

  1) Protection schemes are to be IEC 61850 compliant

  2) Automatic Fault Location, Isolation and power Restoration (FLIR)

  3) All relays to have digital signals for remote viewing

  4) All meters and measurements to have digital signal for remote viewing

  5) Cyber security

3.13 Protection, Telecommunications, Metering and Measurements

The apparatus installed must be compatible with Eskom infrastructure and signalling philosophies. All Protection, Telecommunications, Metering and Measurements systems are to be IEC 61850 compliant.

a) Tele-protection

b) Power Line Carrier

c) DC Equipment-Batteries

  1) Battery measurements to be digital for remote interrogation: voltage and current

  2) Battery charger measurements to be digital for remote interrogation: on/off, voltage, current, automatic chop-over system

  3) Information with regard to the State-of-health

  4) Battery room ambient temperature monitoring

  5) DC voltage and/or positive and negative poles: A difference between the measurements of the poles may indicate a leakage current to ground and possible damage to the charger and/or rectifier.

  6) DC voltage level: A high or low level of dc voltage can damage the dc battery system or not maintain a proper charging.

7) Detection of leakage current to ground: If the installation of the dc battery system has a central grounding, it is possible to measure the leakage current to ground and predict problems in the bank battery cabling.

8) AC ripple in the rectifier: High levels of the ac component of voltage delivered by the rectifier can irreversibly damage the batteries.

9) Supply emergency DC lighting

10) Remotely controllable substation AC and/or DC lighting

11) Remote DC isolation per scheme/panel

d) AC/DC Distribution Boards

1) AC/DC distribution board to support the following functionality:
   i. Visualization
   ii. Monitoring of circuit breaker position
   iii. Alarming of circuit breaker position

2) Able to monitor energy usage by recording the AC and DC current drains at strategic points

3) AC/DC boards to support the classification of load into essential and non-essential equipment

4) The AC/DC boards are to support selective tripping of identified loads

5) Automated chop-over between transformer AC supplies

e) Physical Security and Surveillance

1) Perimeter breaching system

2) Physical security system to allow the following:
   i. Relay alarms to the control centre
   ii. Relay camera footage to the control centre
   iii. Remote access to the security equipment on site
   iv. Automatic control and activation of site equipment based on the type of alarm and trigger source
   v. Multiple levels of authentication

f) Remote Substation Video Surveillance and Management Software

1) High resolution video over IP system to the control centre

2) Cameras to support the pan, tilt and zoom functionality

3) Camera to link to propriety management software

4) Camera to link to generic management software

5) Provide thermal cameras with time-based scanning functionality

6) Thermal camera to link to propriety management software

7) Thermal camera to link to generic management software

8) Management software to be scalable

9) Software to support the automatic reporting of temperature variances to the control centre

10) It must also support on-demand

11) The system must be able to be configured with pre-set points

12) Software to support user defined time-based scanning schedules for thermal and video cameras

13) Management software to allow for a full thermal image of the substation

14) The software is to support:

    i. Image enhancement

    ii. Setting up of parameters with regard to bandwidth, storage and file size management

15) To provide real-time data with regards to condition monitoring and visualization over a bandwidth constrained network

16) Provide infra-red and video images with regards to condition monitoring and visualization over a band width constrained network

17) To handle and ensure minimal label distortion caused by lighting and adverse weather

g) Engineering and Data Server

Modularity and flexibility are key elements in allowing for a data storage system to grow and change over time. The data server modules are to be engineered, standardized building blocks according to Eskom requirements that can be easily configured and moved as needed.

h) Data Network

i) Data Network and Cyber Security Monitoring

4. Authorization

This document has been seen and accepted by:

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5. Revisions

Date	Rev	Compiler	Remarks
June 2018	1	B Groenewald	Creation of a functional specification to guide PDE in design, procuring and constructing its first Smart Substation. Incorporation of specialist comments.

6. Development team

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

- Braam Groenewald
- Mark Peffer

7. Acknowledgements

PTM&C team that put together the "User Requirements for an Enhanced Unattended Substation", document - 240-89279901.

Annex A – Typical Single Breaker Double Busbar Bays

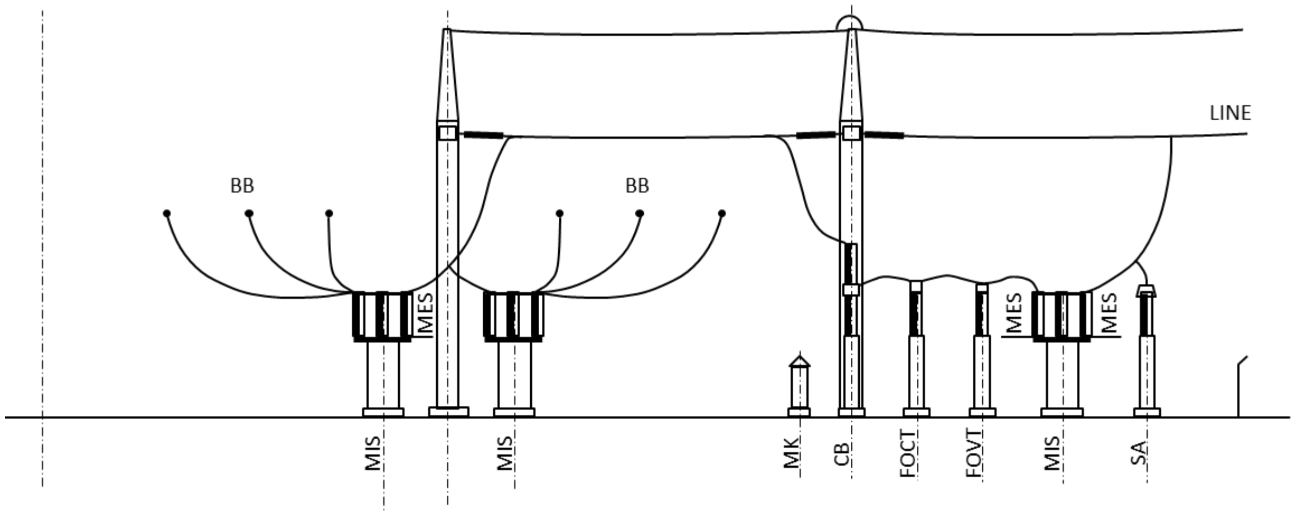

Figure A.1: Typical Double Busbar Selection Arrangement with separate FOCTs and FOVTs

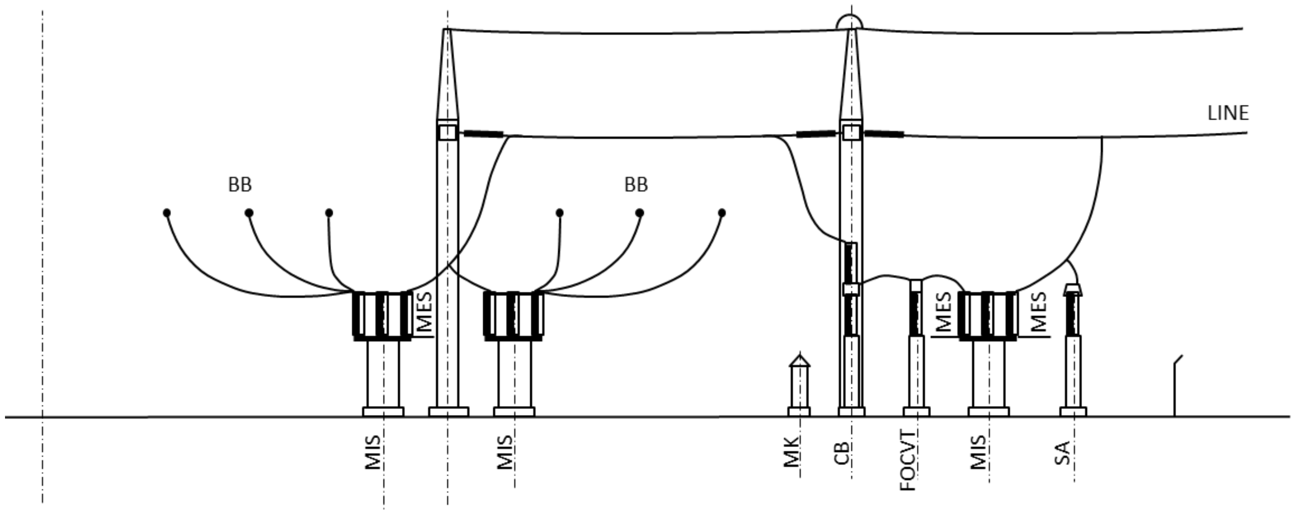

Figure A.2: Typical Double Busbar Selection Arrangement with combined FOCT/FOVTs (FOCVTs)