Eskom	Standard	Generation Engineering

Title: **Metering and Measurement Systems for Power Stations in Generation Standard**

Unique Identifier:	**240-56359083**
Alternative Reference Number:	**N/A**
Area of Applicability:	**Generation Engineering**
Documentation Type:	**Standard**
Revision:	**2**
Total Pages:	**33**
Next Review Date:	**August 2028**
Disclosure Classification:	**CONTROLLED DISCLOSURE**

APPROVED FOR AUTHORISATION
GENERATION ENGINEERING
DOCUMENT CENTRE ☎ X4962

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1. INTRODUCTION

This standard specifies the requirements for metering and measurement systems for Eskom generating plants to ensure that accurate, reliable and auditable metering and measurements can be provided to Power Stations and other Eskom entities.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

The purpose of this document is to describe the requirements of metering and measurement systems, in order to comply with National Regulatory requirements, industry practices and related Eskom standards.

2.1.2 Applicability

This document shall apply to all existing and future electrical generating plant throughout Eskom Holdings Limited Divisions, including but not limited to:

a) Fossil-fuelled plant (coal, gas, diesel),

b) Hydro plant,

c) Renewable Energy plant (CSP, PV, Wind, and Geothermal),

d) Nuclear plant.

2.2 NORMATIVE/INFORMATIVE REFERENCES

The following documents contain provisions that constitute requirements of this document. At the time of publication the documents indicated were valid. These documents are subject to revision and users are responsible to ensure that the most recent edition of the documents listed below are used/referenced. Where specified values differ the most stringent specification will apply.

2.2.1 Normative

[1] 240-51999977: Specification for Digital Transducer-based Measurement System for Electrical Quantities

[2] IEC 61869-1: Instrument transformers - Part 1: General requirements.

[3] IEC 61869-2: Instrument transformers - Part 2: Additional requirements for current transformers.

[4] IEC 61869-3: Instrument transformers - Part 3: Additional requirements for inductive voltage transformers.

[5] IEC 61869-4: Instrument transformers - Part 4: Additional requirements for combined transformers.

[6] Act No. 85 of 1993: Occupational Health and Safety Act.

[7] SANS 10142-1: The wiring for premises Part 1: Low-voltage installations.

[8] SANS 62052 Part 11: General Requirements, tests and test conditions - Metering Equipment.

[9] SANS 62053 Part 22: Electricity metering equipment (ac) - Particular requirements - Static meters for active energy (classes 0.2S and 0.5S).

[10] SANS 62053 Part 31: Electricity metering equipment (ac) – Particular requirements - Pulse output devices for electromechanical and electronic meters (two wires only).

[11] SANS 62053 Part 61: Electricity metering equipment (ac) - Particular requirements - Power consumption and voltage requirements.

[12] SANS 1091:2013: National Colour Standard. (Panel colour e.g., G29)

[13] SANS 60529 Degrees of protection for enclosures (IP code)

[14] 240-86973501 Eskom drawing standard.

[15] 240-71432150 Plant Labelling Standard.

2.2.2 Informative

[16] NRS 057 (SANS 474) Electricity Metering - Code of Practice.

[17] The South African Grid Code: The Metering Code.

[18] The South African Grid code: The Information Exchange Code.

[19] The South African Grid Code: The Transmission Tariff Code.

[20] SANS 10142-1 The Wiring for Premises Part 1: Low Voltage Installations.

[21] Customs and Excise Act No 91 of 1964 (Government Gazette no: 32310)

[22] Electricity Act 41 of 1987 as amended. Section 6

[23] Electricity Regulation Act 2006. (Act no 4 of 2006)

[24] External Standard Operating Procedure – Electricity Levy (01/09/2009)

[25] NRS 047-1 Electricity Supply – Quality of Service Part 1: Minimum Standards

[26] Republic Of South Africa: National Energy Bill: Notice 710 of 2008

[27] IEC/SANS DLMS/COSEM standard IEC/SANS 62056 Electricity metering data exchange.

2.3 DEFINITIONS

Definition	Description
Billing	The process of producing and delivering a bill (an account) for payment by a customer, calculated from the tariff schedule, and for the majority of customers, the consumption measured and recorded by the metering system.
Calibration	The set of operations that establishes, under specified conditions, the relationship between the values indicated by a measuring system and the corresponding values of a quantity realised by a reference standard or a working standard.
Check Metering	A redundant metering system (a completely separate installation) that has a separate and dedicated CT core but may have only one dedicated VT winding, shared with the Main metering system.
Data	Information that is contained in electronic format.
Four Quadrant metering	A metering system that is capable of determining the direction of active and reactive energy transfer, measuring these quantities and correctly differentiating the quantities in accordance with the geometrical representation as per standards IEC 60375 and DST 32-326. (Export and Import).
Generating unit	Generator, generator transformer and unit transformers where applicable.
Generator measurements	Measurement scheme applicable to the generator/motor.
Generator transformer	Step up transformer that connects the generator to the national grid system.
Gross Generated	The electrical energy produced by a generator, metered at the star point CTs of the generator.
Gross Output	The electrical energy produced at the terminals of a generator.
Loop supply	The power supply between the generators and between generators and the station boards.
Main and Check metering	A dual redundant dedicated metering system with a minimum of two independent precision energy meters capable of metering four quadrant active energy and reactive energy fed from two dedicated CT cores and two (or may be one) dedicated VT winding/s (Note the recording equipment is also duplicated).
Main metering	A dedicated metering system with a single precision energy meter that can measure export and import active and reactive energy quantities in four quadrants each quadrant having a separate and independent cumulative register and where applicable a suitable recorder for summating purposes. Note: This meter or assembly of meters is fed from one dedicated current transformer core and one dedicated voltage instrument transformer winding.

Definition	Description
Maintenance function	Maintenance is the function of restoring failed/worn components to a state where it is capable of meeting its design intent and performance expectations, by repair or rework achieved through the application of material and human resources in an efficient and cost effective manner.
Measurement	Detection of real-time electrical quantities to determine the instantaneous behaviour of an electrical system. Typical parameters of interest are Voltage, Current, Active Power and Reactive Power, measured in units of Volts (V), Amperes (A), Megawatts (MW) and Megavars (Mvar) respectively. Measurement also means quantities that are actually detected by measurement devices connected to instrument transformers in the field, as opposed to quantities that are calculated theoretically.
Meter	Device for measuring and totalling the variable consumption of a product. Note in general a meter consists of a sensor and an integrating device that displays the total consumption in metrological units. (integrated values).
Metering	Recording of active and reactive energy, with units of MWh and Mvarh respectively.
Renewable Energy Plants	Systems such as Concentrated Solar Plant (CSP), Photovoltaic (PV) Plant, Wind Plant and Geothermal Plant.
Sent Out Energy	The energy metered at the high voltage side of the Generator Transformer.
Sent Out of a Power Station	The Net Output of a power station less the power supplied by external networks in assisting with generation.
Unit transformer/s	The step down transformer/s that connects the generator system to the unit boards.
Validation	The confirmation through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled. The term “validated” is used to designate the corresponding status. The conditions used for validation can be real or simulated.

Definition	Description
Verification	The confirmation through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled. [ISO 9000:2000] Note 1: The term “verification” is used to designate the corresponding status. Note 2: Confirmation can comprise activities such as performing alternative calculations comparing a new design specification with a similar proven design specification undertaking tests and demonstrations, and reviewing documents before issue.

2.3.1 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
A	Ampere
AC or ac	Alternating Current
AGC	Automatic Generation Control
C&I	Control and Instrumentation
CALC	Calculated
COSEM	Companion Specification for Energy Metering
CPU	Central Processing Unit
CT	Current Transformer
DC or dc	Direct current
DCS	Distributed Control System
DLMS	Device Language Messaging Specification
EMDAS	Energy Management Data Acquisition System
EOD	Electrical Operating Desk
EOW	Electrical Operating Workstation
FAT	Factory Acceptance Test
FTP	File Transfer Protocol
GPSS	Generation Power Sales System
HMI	Human Machine Interface

Abbreviation	Description
HV	High Voltage > 1000 V AC
Hz	Hertz
IDF	Intermediate Distribution Frame
IED	Intelligent Electronic Device
ILAC	International Laboratory Accreditation Cooperation
kVA	Kilo Volt Ampere
Kvarh	Kilovar hour (Integral of reactive power with respect to time)
kWh	Kilowatt hour (Integral of active power with respect to time)
MDMS	Metering Data Management System
Ms	milli-second
MV	Medium Voltage
Mvar	Megavar
Mvarh	Megavar-hour
MW	Megawatt
MWh	Megawatt-hour
NERSA	National Electricity Regulator of South Africa
PS	Power Station
PV	Photovoltaic
RTU	Remote Terminal Unit
SANAS	South African National Accreditation Service
SAP	System Analysis Program software
SARS	South African Revenue Service
SAT	Site Acceptance Testing
SCO	Synchronous Condenser Operation
SCOT	Study Committee of Technology
UPS	Uninterruptible Power Supply

2.5 ROLES AND RESPONSIBILITIES

Generation Engineering is responsible for ensuring that this standard is adhered to.

2.6 PROCESS FOR MONITORING

Generation Engineering is responsible for monitoring and maintaining this standard through SCOT governance processes.

2.7 RELATED/SUPPORTING DOCUMENTS

This document incorporates and supersedes the following documents:

a) 240-56357421: Measurements and Metering Standard.

b) 240-56356537: Eskom Generator Electrical Measurements Philosophy for All Power Stations Standard.

c) EST_32-324: Standard arrangements for metering at hydro & coal fired PS.

d) ESKASAAN3: Standard Arrangements for Metering and Measurement at Hydro and Coal Fired Power Stations.

e) 36-1187: Standard Requirements for Measurement and Metering Systems for all Eskom Power Stations

3. METERING AND MEASUREMENT

3.1 GENERAL

All electrical energy generating plants owned by Eskom shall be metered and measured to evaluate and monitor the production and consumption of electricity. These include but are not limited to the following:

a) Coal-fired Plants

b) Nuclear Plants

c) Gas Turbine Plants

d) Hydro and Pump Storage Plants

e) Concentrated Solar Plants

f) Photo Voltaic plants

g) Wind farms

h) Diesel Generators

The fundamental approach to the Generation metering and measurement system shall be such that it covers all aspects of safety and complies with the existing legal and regulatory requirements.

SANS474 (NRS057) Code of Practice for Electricity Metering is a national standard, governing electrical metering systems used for billing purposes. In this regard, it is important to note that the Generation metering system is used to cross-check the monetary exchange between Generation and Transmission/Distribution, for electricity exported to or consumed from the national grid or local network. In short, Generation's metering system is not a billing system, as the official billing equipment belongs to Transmission/Distribution. Therefore, although SANS474 will be adhered to as far as particular conditions permit, it is used primarily as a guideline for Generation metering.

The following shall be adhered to as a minimum:

a) Equipment used in the metering installation shall be certified as compliant with relevant standards and only Eskom approved metering equipment shall be used.

b) A list of approved metering equipment shall be maintained and used by Generation to ensure that metering equipment is of acceptable quality and standard, having been tested and approved by both a SANAS approved laboratory and the appointed authority in Eskom.

c) Metering and measurement equipment such as EMDAS, meters and transducers shall be registered in SAP Plant Maintenance and all maintenance shall be recorded. Maintenance strategies and schedules shall also be entered into SAP Plant Maintenance and be issued as per reliability-based requirements.

d) A checklist shall be used for recording of information during design, installation and commissioning.

The operational reliability and security of supply to all metering and measurement equipment are vital aspects of the design for all operating modes, which would require modular systems, applied in a manner that common mode failures are minimised. Due to the complexity of the power station environment, the metering and measurement approach should be standardised.

The following metering and measurements criteria shall be specified and recorded for all metering and measurements equipment:

a) The type of equipment or system

b) Accuracy required

c) Position where measurement is made

d) Voltage level

e) Load level

f) The mode of operation (where applicable)

- Generating
- Pumping
- Synchronous Condenser Operation (SCO)
- Standstill (back-energised)

3.1.2 Metering and Measurement Arrangements

Figure 1 provides a general overview of a typical generating unit, showing the naming conventions for power and energy quantities at various points.

In the event that there is no excitation transformer supplied directly from the generator terminals, it should be noted that Gross Gen and Gross Out will be the same.

However, if an excitation transformer is supplied directly from the generator terminals, and this transformer requires metering as per Section 3.2.3, then Gross Gen and Gross Out will not be the same, and in this case Gross Out shall be used for the generator output value (in some cases, Gross Out value is measured directly and in other cases, where it is not measured, it shall be calculated).

Metering quantities Sent Out MV Calc and Sent Out HV Calc are calculated values, due to there being no Generation CTs installed at those points. The official Sent Out value is supplied to EMDAS from tariff meters in the HV Yard, owned by the HV Yard operator.

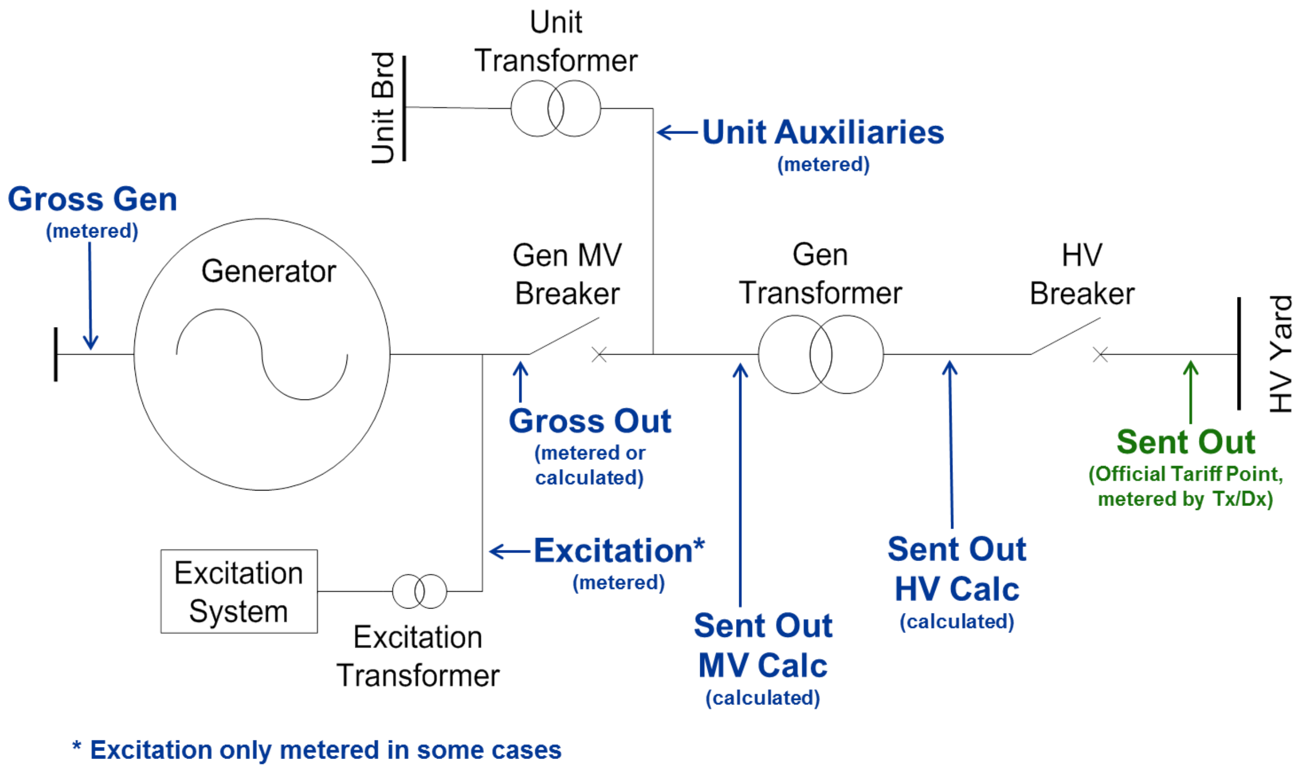

Figure 1: Unit single line overview

Table 1 provides the minimum requirements for metering and measurements. Additions to this table can be made where required, according to the specific site conditions. The accuracy of equipment shall be as specified in Table 2.

To achieve the required accuracy, the three-phase four-wire measurement principle shall be used in all cases. Individual components, where applicable, shall be calibrated by an accredited calibration laboratory before installation.

NOTE: Instrument transformers, metering and measurements on Station Transformers and Generator Transformers are usually owned by the network operator, with Generation being supplied with the required quantities. In cases where such equipment is owned by Generation, Table 1 and 2 shall apply.

Table 1: Metering and Measurement Requirements

Plant	Instrument Transformers		Meters		Transducers	
	Main	Check	Main	Check	Main	Check
Generating Plant	Required	Required above 1 MVA	Required	Required above 1 MVA	Required x 2	Required 2 x above 1 MVA
Unit Auxiliaries	Required	Required above 1 MVA	Required	Required above 1 MVA	Required	Not required
Excitation Transformers	Required	Required above 1 MVA	See Section 3.2.3	See Section 3.2.3	Required	Not required
Static Frequency Converter	Required	Required above 1 MVA	Required	Required above 1 MVA	Required	Not required
Station Transformers (Tx/Dx)	Required	Required above 1 MVA	Required	Required above 1 MVA	Required	Not required
Generator Transformers (Tx/Dx)	Required	Required above 1 MVA	Required	Required above 1 MVA	Required	Not required
Station Boards	Required	Required above 1 MVA	Required	Required above 1 MVA	Required	Not required
Loop Supplies	Required	Not required	Required	Not required	Required	Not required
MV Boards	Required	Not required	Not required	Not required	Required	Not required
Diesel Generators	Above 200kVA	Not required	Required above 200kVA	Not required	Required	Not required
Extraneous Supplies	Required	Not required	Required	Not required	Required	Not required
LV Boards	Required	Not required	Not required	Not required	Required	Not required
Renewable Energy Plant *	Required	Required above 1 MVA	Required	Required above 1 MVA	Required	Not required

* Note: Only applicable to Renewable Energy plant owned by Generation and/or which provide direct supply to any of the power stations in Generation.

Table 2: Metering and Measurement Accuracy Class Requirements

	SIZE OF LOAD	
	< 50MVA	50MVA and above
Active Energy Meters	0.5S	0.2S
Reactive Energy Meters	1	0.5S
Transducers	0.5	0.5
Current Transformer	0.5	0.2
Voltage Transformer	0.2	0.2

3.1.3 Reliability

No component or unit shall exhibit a failure rate of 10% or greater for identical components during the guarantee period. If such failure rate occurs, the issue shall be dealt with via the relevant Quality Assurance process.

High reliability shall be achieved by the following means:

a) Field-proven and off the shelf equipment, technology and configuration.

b) Quality assurance procedures.

c) Design reviews and factory inspections.

d) Supervision of installation.

e) Participation in commissioning.

f) Operation of equipment in a controlled operating environment, as per equipment specification.

3.1.4 System Lifespan

The Metering and Measurement system shall have a lifespan of at least ten years.

3.1.5 Redundancy

Failure of a single device shall not cause a common mode failure to the detriment of the asset management of the power station, in which case redundancy shall apply to the metering and measurement hardware. The system shall have no less than 99.95% availability, which equates to 4 hours of downtime per annum.

Where measurement redundancy is required, two or more separate transducers shall be used i.e. it is not sufficient to use two outputs of one multi-output transducer.

Redundancy is required for the following:

1. Where a measurement is used for control purposes, for example governor control of generator active power.
2. Where the system integrity may be compromised by failure, for example on points where device failure has a financial impact and/or influences the calculated efficiency of the power station.
3. All auxiliary power supplies to metering and measurement equipment shall be redundant and UPS based as stipulated in points 1 and 2 above.

4. Where meters and EMDAS are connected via a data communication protocol, with separate cable routing for each cable per redundant pair.

NOTE: Redundancy is not required in cases where meters communicate to EMDAS via hard-wired analogue pulses.

3.1.6 Calibration

Calibration certificates from a SANAS accredited laboratory are required for all energy meters, as well as for CTs and VTs used at the following points, where installed:

a) Gross Generated

b) Excitation

c) Gross Output

d) Unit Auxiliaries

e) Station Boards

f) Extraneous Supplies

Where SANAS calibration certificates are not available, calibration certificates from international calibration laboratories that are part of the ILAC agreement, accredited in terms of IEC17025, shall be provided. All other metering and measurement instrument transformers require the manufacturer's calibration certificate as a minimum. These values shall be verified using SANAS calibrated equipment as part of the Factory Acceptance Test (FAT) and Site Acceptance Test (SAT).

In order to minimise the risk of damage to metering equipment, no further calibration is necessary unless the equipment fails the on-site in-situ verification tests during an outage. In cases where such failure occurs, metering equipment shall be replaced or removed for further off-site testing.

3.1.7 Periodic Verification and On-Site In-Situ Accuracy Tests

It is required that all metering and measurement devices are checked and verified for class accuracy. This shall be done in accordance to Table 3 and / or according to generation plants official outage schedules (whichever is the shortest time interval) and loaded on the SAP maintenance system. Where accuracy of energy devices are of class 0,5S or better, the devices shall be tested and verified using a calibrated instrument with an accuracy of at least 2 times better than the device under test.

Where a meter or transducer is out of calibration and there is no possibility of adjusting the device to within its accuracy limit, the device shall be removed for further tests at an accredited laboratory. If the device fails such testing, replacement with a similar calibrated device with the same characteristics shall be carried out.

A report shall be generated with a summary of all test results, which shall be available on request.

Table 3: Intervals for periodic verification of metering installations (SANS 474)

1	2
Load	**Maintenance interval** (years)
> 100 MVA	5
10 MVA to < 100 MVA	5
1 MVA to < 10 MVA	10
100 kVA to < 1 MVA	10
< 100 kVA	20

3.1.8 Current Transformers (CTs)

As a general rule, P1 shall face towards the breaker. In the case of a generator or motor star point CT, P1 shall face towards the star point.

CT quantities and accuracies shall be in accordance with the requirements of Tables 1 and 2, with these CTs dedicated to metering and measurement purposes only.

In cases where multicore CTs are installed, two separate cores shall be used for Main and Check where required as per Table 1.

In cases where Main and Check metering is required, but where space constraints prevent the installation of conventional CTs, fibre-optic CTs shall be installed.

CT ratios shall be determined by the nominal load range, with secondary output of the CTs rated at 1A at a nominal frequency of 50 Hz. The connected burden shall be between 25% and 100% of the rated burden of the CT. No additional resistive burdens shall be added.

The rated insulation level of the primary winding shall be based on the maximum RMS value of the applicable system. Cabling for connection to metering equipment shall be such that the current density under fault conditions does not exceed $3A/mm^2$. In addition the cabling resistance is likely to represent an appreciable component of the CT burden and care should be taken to ensure that the CT overall burden is not exceeded. The CT secondary circuit shall only be earthed at a single point and shall be terminated in the metering panel.

CTs shall be manufactured according to relevant sections from Parts 1 through 4 of IEC 61869. Type test results shall be provided to prove compliance with the standard.

3.1.9 Voltage Transformers (VTs)

VTs shall be installed on systems that are 690V and above. On MV boards, the voltage input for metering shall be wired to the incomer panel and separately fused. In the case of 400V systems, no VTs are required as the voltage input for metering purposes shall be taken directly from the 400V bus bars. The only exception to this is for diesel generator synchronisation.

For Main and Check VT requirements, there shall either be two separate VT cores or separate fused/protected circuits from a single VT core, supplying the main and check meters. The VTs shall be of the induction type with a rated secondary output of 110 V RMS phase-to-phase or 63.5 V RMS phase-to-neutral at a nominal frequency of 50 Hz. The VTs shall be operated between 25% and 100% of rated burden, optimised per phase at a power factor of 0.8 lag, with a Voltage Factor not less than 1,2 Continuous. No additional resistive burdens shall be added.

The rated insulation level of the primary winding shall be based on the maximum RMS value of the applicable system. VT cabling shall be such that the volt drop across the voltage circuit does not contribute to the overall measurement error by more than half the accuracy class of the installed meter. For example, the maximum allowable error shall be 0.1% for a class 0.2 installed meter (63.5 mV). Earthing of the VT secondary circuits shall be terminated as close as possible to the VT, usually in the VT junction box.

In cases where a VT is used for supplying a breaker spring rewind circuit, it is preferable not to use this VT for metering and measurement purposes, as the functioning of the breaker spring rewind interferes with the functionality of the metering and measurement equipment. Where a common mode fault, such as a VT fuse failure, could cause incorrect voltages on both main and check meters this shall be identified by means of an alarm indicating phase-failure.

VTs shall be manufactured according to relevant sections from Parts 1 through 4 of IEC 61869. Type test results shall be provided to prove compliance with the standard.

3.1.10 Metering and Measurements Panels

Where practical, the Substation Meter Panels Standard (240-65292589) shall be used as a guideline for Metering and Measurements panel design and layout. Each Metering and Measurements panel shall operate independently, with dual secure supplies. Panel colour (e.g. G29) as per SANS 1091:2013 and IP rating as per SANS 60529. Also use 240-71432150 Plant Labelling standard.

Where both energy meters and measurement transducers are situated in the same panel, these circuits shall be separated with their own set of test blocks. For CT circuits, approved 6-way test blocks shall be used. For VT circuits, approved 4-way test blocks shall be used. Single pole circuit breakers shall be used for all voltage circuits, with circuit breakers rated to ensure correct grading of the circuits.

All communication cabling (analogue, pulse and/or bus) leaving or entering the Metering and Measurements panel shall be connected to a dedicated terminal strip mounted in the panel, with this terminal strip serving as the interface to other systems, such as the HMI, RTU, EOD and DCS.

The Metering and Measurements panel shall incorporate a bus connection for a local personal computer, to allow communication with devices on the bus.

3.1.11 Spares

Each Generation site shall hold spares of the following as a minimum:

a) Each type of energy meter,
b) Each type of transducer,
c) Each type of test block,
d) Each type of circuit breaker,
e) Each type of EMDAS input module if applicable,
f) Each type of Ethernet switch.

Furthermore, each Generation site shall consider the supplier’s recommended spares list for any additional spares holding, based on individual site conditions.

3.1.12 Drawings

Maintenance of metering and measurement systems is entirely dependent on all drawings being accurate, up-to-date and available. A master copy shall be held centrally, with three sets of copies available at the respective power station. A drawing register shall be maintained by all responsible departments at the power station. One copy shall be held at the power station Documentation Centre/Drawing Office. Two copies shall be held by the responsible maintenance department at the power station, with the first copy being used for working purposes and the second copy kept as a backup.

At times, changes to drawings will be required. In the event that drawings are marked up, the following procedure shall be followed:

a) When marking up printed drawings, red pen shall be used for insertions and yellow highlighter shall be used for deletions.

b) One copy of the marked-up drawing shall be sent to the central Documentation Centre/Drawing Office, so that the master copy can be revised.

c) These changes must be reviewed before approval, with the initiator of the revised drawings to be included in the review process.

d) After approval, three sets of drawings shall be issued to the power station as stipulated above.

e) All drawing registers shall be updated to reflect the latest revision.

f) Drawings shall comply to the requirements of IEC 60617 and provided in a format that can be viewed and edited using Micro station used by Eskom.

NOTE: Relevant design review engineering change procedures shall be adhered to before changes to a design and the related drawings are carrying out.

3.1.13 Training

Metering personnel shall be provided with training in accordance with the specific requirements specified in this section, as well as generic project requirements not specified here. Training shall include knowledge of the philosophy and hardware configuration.

3.1.13.1 Engineering Training

Engineering training shall consist of a formal training programme prior to and during the implementation of a project. In the event that work is outsourced, the Engineer shall work with and assist contractors and service providers during engineering, implementation and commissioning phases of a project. This opportunity shall be used to gain valuable on-job training and experience to ensure competence on the Plant.

3.1.13.2 Maintenance Training

The maintenance training shall include the following as a minimum:

a) Familiarisation with documentation, maintenance plan and procedures.

b) Hardware familiarisation and maintenance.

c) Maintenance of control, instrumentation and synchronisation.

d) Software, configuration, testing and debugging.

e) Database management.

3.1.13.3 Operator Training

The operator training shall include the following as a minimum:

a) Familiarisation with documentation including operating manuals and drawing configuration logic.

b) Operator interface familiarisation such as system layout, operational functions and alarms.

c) Data usage, management, storage and archiving, as well as associated system logs.

3.2 METERING

A conceptual arrangement for energy metering required for operational, reporting and accounting purposes within Generation is depicted in Figure 2. Where power stations have different configurations these should be considered on an individual basis.

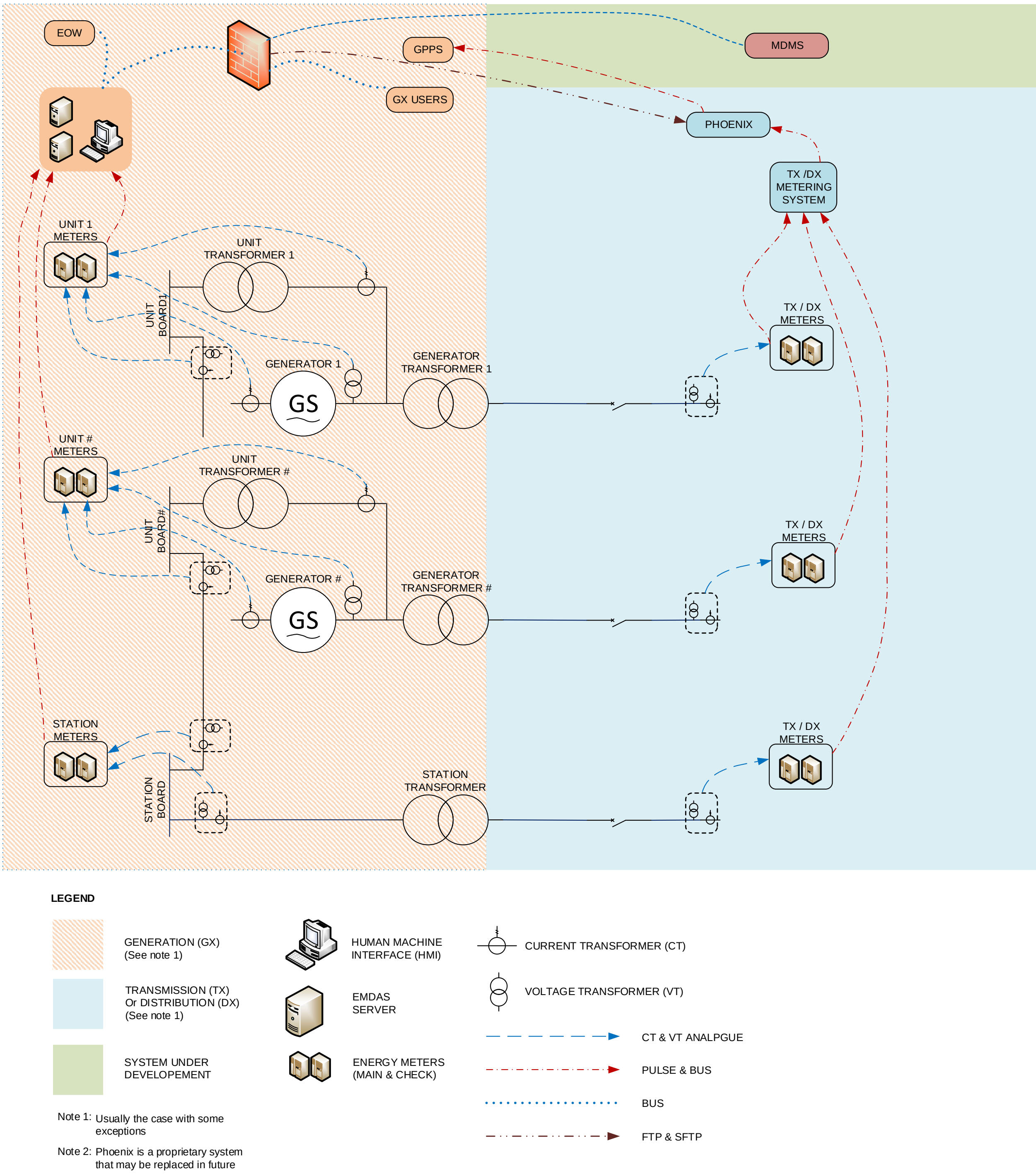

Figure 2: Metering system overview

3.2.1 Energy Meter Requirements

All Active Energy meters described in this document shall meet the requirements of IEC 62053-22 Class 0.2S/0.5S. All Reactive Energy meters described in this document shall meet the class 0.5 requirements of IEC 62053-24.

3.2.1.1 Pulse Requirements

Energy meters shall be able to generate pulse outputs in each quadrant, proportional to a fixed quantity of units of electrical energy. These pulses shall be transmitted to the EMDAS for immediate and automatic evaluation of the energy conversion process. Each of the pulse outputs from the meters will be assigned in such a manner that the above cumulative registers can be checked and verified during operation in EMDAS.

The characteristic of the pulse is such that the rising edge of the pulse is detected. This is because the normally open contact is a fixed time period (nominal 80 millisecond). Where a change–over type pulse is used, as for parity checking purposes, care must be exercised not to use the normally closed pulse for counting because the delay in closing and opening can cause large time deviations and give incorrect count values.

The Mark/Space ratio of the pulse characteristic is 1:1.5 (typically 80:120ms, i.e. 5 pulses per second). The pulse rate is such that the resolution is at least half the meter accuracy class at full load for both active and reactive energy.

3.2.1.2 Operating Mode Requirements

Meters are required to meter the various operating modes of the Generator, for import and export watt-hours and var-hours in all four quadrants. There shall be a cumulative energy register enabled for each mode of operation.

Meters shall be user-configurable to cater for the modes describes in Table 4.

Generating, Pumping and SCO modes are direct signals from the energy meters.

Standstill mode is a conditional logic within EMDAS, so that energy values are correctly stored.

This logic is as follows:

When energy inputs from generator meters are all zero, then energy metered on related unit transformer/s must be recorded as standstill mode energy.

3.2.1.3 Communication Requirements

Energy meters shall have bus interface capabilities, using open published communication protocols, such as Modbus, DLMS COSEM or DP. Applicable driver software and sample source code with which to access the meter via the relevant protocol shall be provided.

IEC 61850 is not widely-used for metering applications and shall not be specified as a minimum requirement, as this would limit the range of available energy meters unnecessarily.

Table 4: Operating Modes

Mode	Possible Condition
Generating	• Generator is generating, with active energy (Mwh) exported and reactive energy (Mvarh) exported. • Generator is generating, with active energy (Mwh) exported and reactive energy (Mvarh) imported.
Pumping	• Generator is motoring, with active energy (Mwh) imported and reactive energy (Mvarh) exported. • Generator is motoring, with active energy (Mwh) imported and reactive energy (Mvarh) imported.
Synchronous Condenser Operation (SCO)	• Generator is spinning, with negligible active energy (Mwh) imported and reactive energy (Mvarh) exported. • Generator is spinning, with negligible energy (Mwh) imported and reactive energy (Mvarh) imported.
Standstill (back-energised)	• Generator is at standstill (or on barring), where only auxiliary plant is running, with active energy (Mwh) imported and reactive energy (Mvarh) imported. • Generator and Unit transformer meters need to communicate and be configured such that dedicated registers are used.

3.2.1.4 Time Synchronisation Requirements

Time synchronisation is required for all energy meters and the source of synchronisation shall be EMDAS via a suitable bus interface and protocol.

3.2.2 Generator Metering

Energy meters, VTs and CTs shall conform to the requirements of Tables 1 and 2.

3.2.2.1 Metering of Gross Generated Energy (Generator Star-point)

a) Gross Generated energy shall always be metered using CTs that are installed on the star-point side of a generator, with P1 facing towards the star-point.

b) VTs on the generator terminals (line side) shall be used as input for Gross Generated metering.

3.2.2.2 Metering of Gross Output Energy (Generator Line-side)

With reference to Figure 1:

a) Where metering CTs are installed on the generator breaker, Gross Output shall be metered directly. In this case, P1 shall face towards the breaker.

b) Where metering CTs are not installed on the generator breaker and static excitation is supplied from the generator terminals:

   i. Gross Output = Gross Generated – Excitation Energy Usage.

c) Where static excitation is not supplied from the generator terminals:

   i. Gross Output = Gross Generated.

d) VTs on the generator terminals (line side) shall be used as input for Gross Output metering.

3.2.2.3 Metering of HV Sent Out Calculated Energy

The Generator Transformer HV bushings are the interface between Generation and Transmission/Distribution, with tariff metering installed on the HV side of the Generator Transformer by Transmission/Distribution. A main and check/backup configuration is required for metering purposes and interfacing to these meters shall be via a suitable interface, such as an IDF or a bus interface, to the EMDAS.

With reference to Figure 1, two calculations are done within EMDAS to verify the active portion of the HV Sent Out data provided by Transmission/Distribution (disregarding Generator Transformer energy losses):

MV Sent Out Calc (MWh) = Gross Output (MWh) – Unit Auxiliaries (MWh),

HV Sent Out Calc (MWh) = percentage loss factor × MV Sent Out Calc (MWh),

where percentage loss factor will vary depending on Generator Transformer characteristics and loading (a default value of 0.997 is typically used in absence of this information).

Two further calculations are done to determine the variance between Calculated Sent Out and Sent Out values:

Variance = HV Sent Out Calc – Sent Out.

% Variance = (Variance/Calculated Sent Out) × 100 %.

The Calculated Sent Out value should always be slightly greater than the Sent Out value (due to Generator Transformer losses), meaning that both Variance and % Variance should always be positive, within a tolerance value calculated using the transformer datasheet.

An alarm shall be raised and an investigation carried out under the following conditions:

a) % Variance is less than or equal to zero.

b) % Variance is greater than the calculated tolerance value plus 1%.

3.2.3 Excitation Transformer Metering

Where applicable, the excitation transformer connected to the generator bus bar shall be metered on the same voltage level as the generator.

VTs and CTs shall conform to the requirements of Tables 1 and 2.

3.2.3.1 Excitation Load ≥ 1MVA

When the load on the excitation transformer/s is larger than 1MVA, Main and Check metering shall be installed in all cases.

3.2.3.2 Excitation Load < 1MVA

When the size of the excitation transformer (expressed as a percentage of the generator) is less than half the accuracy class percentage used for the generator meter, then metering of the excitation transformer is not required.

For example,

1. In the case of a 100 MVA generator with a Class 0.2 meter,

   $0.5 \times 0.2\% \times 100$ MVA = 0.1 MVA.

   Therefore, excitation transformer metering shall only be required if the combined size of the excitation transformer/s is equal to or greater than 0.1 MVA in this case.

2. In the case of a 500 kVA generator with a Class 0.5 meter,

   $0.5 \times 0.5\% \times 500$ kVA = 1.25 kVA.

   Therefore, excitation transformer metering shall only be required if the combined size of the excitation transformer/s is equal to or greater than 1.25 kVA in this case.

3.2.4 Unit Auxiliaries Metering

3.2.4.1 Unit Transformer Metering

The Unit Transformer/s connected to the generator bus bar shall be metered on the same voltage level as the generator, with P1 of the CTs facing towards the Unit Transformer/s. Energy meters, VTs and CTs shall conform to the requirements of Tables 1 and 2.

3.2.4.2 Unit Board Loop Supply Metering

Metering shall be installed on each loop supply, with energy meters, VTs and CTs conforming to the requirements of Tables 1 and 2.

3.2.4.3 Static Frequency Controller Metering

The unit transformer/s connected to the generator bus bar shall be metered on the same voltage level as the generator. Energy meters, VTs and CTs shall conform to the requirements of Tables 1 and 2.

3.2.5 Station Transformer Metering

The high voltage side of the Station Transformers is the interface between Generation and Transmission/Distribution, with tariff metering installed on the HV side of the station transformers by Transmission/Distribution. A main and check/backup configuration is required for metering purposes and interfacing to these meters shall be via a suitable interface, such as an IDF or a bus interface, to the EMDAS.

If additional CT and VT cores are available on the high voltage side of the Station Transformers for use by Generation, then meters shall also be installed at the power station in the Station Boards metering panel, with these energy meters conforming to the requirements of Tables 1 and 2. Any additional cabling required shall be supplied by Generation.

3.2.6 Station Boards Metering

For Station Boards, the incomers and loop supplies shall be metered, with the energy meters, VTs and CTs conforming to the requirements of Tables 1 and 2.

3.2.7 MV Metering

3.2.7.1 Motors and Drives

Where metering is required for site-specific purposes, the energy meters, VTs and CTs shall conform to the requirements of Table 2.

3.2.7.2 Extraneous Supply Metering

All extraneous supplies shall be metered with energy meters, VTs and CTs conforming to the requirements of Tables 1 and 2.

3.2.8 Energy Efficiency Metering

The requirements of energy efficiency metering installed under the Energy Efficiency Drive Initiative are not included in this standard.

3.2.9 Diesel Generator Metering

Diesel generators with individual ratings above 200kVA shall be metered with energy meters, VTs and CTs conforming to the requirements of Tables 1 and 2.

3.2.10 Renewable Energy Plant Metering

For Renewable Energy plants that are owned by Generation and/or which provide direct supply to any of the generating sites in Generation, the metering requirements are specified in Tables 1 and 2.

3.2.11 Energy Management and Data Acquisition System (EMDAS)

A standardised dedicated stand-alone Energy Management and Data Acquisition System (EMDAS) shall be installed at all Eskom's generating plants, as per the latest EMDAS Standard (240-62581162). The purpose of EMDAS is to ensure that accurate, reliable and auditable metering data is stored, archived and provided to the power station and Eskom as a whole.

The data that is captured and stored by EMDAS will be available for the following purposes:

a) Provision of energy data for Plant Performance management, operational purposes and economic evaluation of Power Station generators, unit transformers and auxiliaries,

b) Confirmation of payment amounts for energy consumed by the Power Station for operational requirements, as well as for energy generated and sent out to Transmission/Distribution,

c) Quarterly reporting of energy generated to NERSA.

d) For stations that contribute towards the carbon footprint, an environmental tax levy is payable to SARS, based on the amount of active energy generated (Gross Generated Output).

The Generation metering system is also used to cross-check the energy transfer between Transmission/Distribution for electricity, exported to or consumed from the national grid by Generation, with the official billing points being under the control of Transmission/Distribution.

All data captured by EMDAS shall be stored for a minimum period of 5 years and archived for the lifetime of the station.

3.2.12 Metering Interface Requirements

The following interface connections, as shown in Figure 1, shall be provided:

a) Hardwired voltage and current signals from CTs and VTs to Energy Meters.

b) Where fibre-optic CTs are used, hardwired current signals (via suitable converters) shall be used. In future, when suitable meters are available on the Approved List, direct bus connections from CTs may be used.

c) Pulse or bus interface between Energy Meters and EMDAS.

d) Alarms from Energy Meters to EMDAS.

e) From a GPS clock source (using NTP and/or SNTP) to EMDAS for time synchronisation of EMDAS and meters.

f) From the station GPS clock source (using NTP and/or SNTP) to EMDAS for time synchronisation of EMDAS and meters.

g) Dual 220V UPS AC supplies to the metering panels and EMDAS from a secure supply.

h) The Transmission and/or Distribution tariff metering systems shall be interfaced via pulse or bus interface (bus preferred) from the network to the EMDAS system.

3.3 MEASUREMENTS

3.3.1 Transducer Requirements

Any transducers used for measurement, control and alarm purposes shall comply with IEC 60688 as well as the Specification for Digital Transducer-based Measurement System for Electrical Quantities Standard (240-51999977) as a minimum. Furthermore, only transducers that appear on Eskom Approved Lists shall be used.

Transducers shall be based on digital technology with a minimum of four analogue outputs, programmable for 4 to 20 mA into a circuit with a maximum resistance of 500Ω. Transducers shall also be programmable, allowing for the support of legacy systems described in Section 3.3.2.

The transducers shall have a live zero feature so that there is a greater than zero value of output for the low limit of measurement. For example, 4 to 20 mA for zero to full value of measurement respectively. The live-zero feature shall be used to detect signal failure. For bi-directional quantities of Watt and Var, 12 mA will be zero, 4 mA maximum negative and 20 mA maximum positive. All transducers with a 4 to 20 mA output shall have a calibration over-scale of 120%. For example, 4 mA equals zero or minimum and 20 mA equals maximum or 120%.

Transducers shall have communication functionality, such as Modbus, Profibus or IEC61850, IEC 61850 is not widely used for metering applications and shall not be specified as a minimum requirement.

Auxiliary Power Supply for transducers shall be from a 230V UPS Supply. Auxiliary Fail alarms shall be implemented in the design of measurement systems.

3.3.2 Measurements for Legacy Systems

In many cases, legacy systems are installed in the Generation fleet, still used for a variety of purposes, some of which are critical for power station operations. Work on such systems is usually dependent on outages and upgrade strategies might not be clearly defined.

It is therefore of crucial importance that the design, upgrade and/or installation of new measurement equipment takes into account the requirements of related legacy systems. Such instances shall be treated on a case by case basis. Table 5 provides a few examples still used at some Generation sites:

Table 5: Legacy System Examples

Inputs Values		Output Values	
-200 Watt	+200 Watt	-10 mA	+10 mA
-100 Var	+100 Var	-10 mA	+10 mA
0V	132V	0 mA	10 mA

3.3.3 Generator Measurement Indications

3.3.3.1 Real-time Measurements

A real-time transducer measurement scheme for indication purposes is required for each generator. Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2. The real time measurements shall be as shown in Table 6.

Table 6: Real Time Measurements for Generators

Required by	Analogue Signals
Electrical Operating Desk (EOD)	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV) Generator frequency (Hz) Power factor (cos phi) ------------------------------------- Provided by Tx/Dx: Active power per generator (MW) Reactive power per generator (MVar) 3 x System Voltage (kV) System Frequency (Hz) -------------------------------------- Generator Transformer: Apparent power (MVA) calculated
Unit Operating Desk	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV) Generator frequency (Hz) Power factor (cos phi) Excitation current (A) Excitation voltage (V)
Governor Control	4 x Active power bi-directional (MW)
National Control, Automatic Generator Control (AGC)	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Voltage (kV) Generator frequency (Hz)
Performance & Condition Monitoring Note: Values received via DCS	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV) Generator frequency (Hz) Power factor (cos phi) Excitation current (A) Excitation voltage (V)

3.3.3.2 Requirements for Monitoring and Supervision Purposes

Signals required for AGC purposes shall be interfaced to the AGC RTU or suitable gateway.

All real time signals (for a generator and units sent out) to National Control Centre for network operation and management shall be routed directly via the AGC RTU or gateway.

The signals required for business purposes (Generation Morning Report) shall also be routed through the same RTU/gateway system on the protocol IEC60870-101.

3.3.3.3 Requirements for Governor Control Purposes

For Governor Control, the only quantity required is Watt bi-directional. Transducers, VTs and CTs for governor control shall conform to the requirements of Tables 1 and 2.

Four separate transducers shall be used, two for Main and two for Check i.e. it is not sufficient to use two (or four) outputs of one multi-output transducer.

These transducers shall be housed in a dedicated panel, next to the Generator Measurement Panel, or alternatively within the Generator Measurement Panel itself, provided that the transducers are securely separated from other equipment to prevent accidental interference.

3.3.4 Excitation Transformer Measurements

The real time measurements for each excitation transformer shall be as per Table 7.

Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 7: Real Time Measurements for Excitation Transformers

Required by	Analogue Signals
Unit Operating Desk	Active power bi-directional (MW) 3 x Current (kA) 3 x Voltage (kV)
Performance & Condition Monitoring Note: Values received via DCS	Active power bi-directional (MW) 3 x Current (kA) 3 x Voltage (kV)

3.3.5 Unit Transformer Measurements

The real time measurements for each unit transformer shall be as per Table 8.

Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 8: Real Time Measurements for Unit Transformers

Required by	Analogue Signals
Unit Operating Desk	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)
Performance & Condition Monitoring Note: Values received via DCS	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)
National Control, Automatic Generator Control (AGC)	Active power bi-directional (MW) Reactive power bi-directional (MVar)

3.3.6 Static Frequency Controller Measurements

Static Frequency Controllers shall be measured as per Table 9.

Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 9: Real Time Measurements for Static Frequency Controllers

Required by	Analogue Signals
Unit Operating Desk	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)
Performance & Condition Monitoring Note: Values received via DCS	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)

3.3.7 Loop Supply Measurements

Both ends of each loop supply shall be measured as per Table 10.

Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 10: Real Time Measurements for Loop Supplies

Required by	Analogue Signals
Unit Operating EOD	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)
Performance & Condition Monitoring Note: Values received via DCS	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)

3.3.8 Station Transformer Measurements

Station Transformers shall be measured on the incomers of the Station Boards, as per Table 11.

Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 11: Real Time Measurements for Station Transformers (HV Side, to be supplied by Tx/Dx)

Required by	Analogue Signals
Electrical Operating Desk (EOD)	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)
Performance & Condition Monitoring Note: Values received via DCS	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV)

3.3.9 MV Measurements

Real time measurements for operational purposes shall be provided for MV switchgear. For remote indications, dedicated transducers shall be used, while protection IEDs shall be used for local indications only. All measurement requirements must be included in the MV board Specifications.

All incomers to MV boards shall have measurements to indicate the busbar voltage, as well as voltages and currents of the incomer cable/s.

Measurements of MV circuits greater than 1 MVA shall be supplied from the local IED. Any additional measurement requirements of MV circuits shall be site-specific.

MV measurements shall conform to Table 12. Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 12: Real Time MV Measurements

Required by	Analogue Signals
Unit Operating Desk	Busbars: 3 x Voltage (kV) Incomers: Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Cable voltage (kV)
Performance & Condition Monitoring Note: Values received via DCS	Busbars: 3 x Voltage (kV) Incomers: Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Cable voltage (kV)

3.3.10 Diesel Generator Measurements

Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2. Diesel generator measurements shall conform to Table 13.

Table 13: Real Time Diesel Generator Measurements

Required by	Analogue Signals
Electrical Operating Desk (EOD)	Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Voltage (kV) Generator frequency (Hz) Power factor (cos phi)

3.3.11 LV Measurements

Real time measurements for operational purposes shall be provided for LV switchgear. For remote indications, dedicated transducers shall be used, with protection IEDs used for local indications only. All measurement requirements must be included in the LV board specifications.

All incomers to LV boards shall have measurements to indicate the voltages and currents of the incomer cable/s. LV measurements shall conform to Table 14. Transducers, VTs and CTs shall conform to the requirements of Tables 1 and 2.

Table 14: Real Time LV Measurements

Required by	Analogue Signals
Electrical Operating Desk (EOD)	Busbars: 3 x Voltage (kV) Incomers: Active power bi-directional (MW) Reactive power bi-directional (MVar) 3 x Current (kA) 3 x Cable voltage (kV)

4. AUTHORISATION

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5. REVISIONS

Date	Rev.	Compiler	Remarks
May 2015	0.1	R Brayshaw	Standard revised by SCOT Metering work group to address inconsistencies between other standards, new regulatory requirements and comments from Eskom Metering and Measurement personnel. Final Draft document for Comments Review Process
May 2015	0.2	R Brayshaw	Updated Draft document after Comments Review Process
May 2015	1	R Brayshaw	Final Document for Authorisation and Publication
July 2023	1.1	AJ le Roux	Point 3.1.5 : Revise to “During an Outage” Point 3.1.6 : Revise to “Table 3 and during an Outage” Remove “Group technology” and replace with “Generation Engineering”. Update all “Tables” numbers. Point 4: Revise table contents. Point 6: Revise names. Table 1: Revise table contents. Point 3.2: Revise Drawing.
July 2023	1.2	AJ le Roux	Final Draft after Comments Review Process
July 2023	2	AJ le Roux	Final Rev 2 Document for Authorisation and Publication

6. DEVELOPMENT TEAM

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

- Johan le Roux

7. ACKNOWLEDGEMENTS

- None