H.V. TEST (PTY) LTD

Leaders in High Voltage Test Equipment

UEDU SWAKOP, 2019

Presented by: Johans Haarhoff

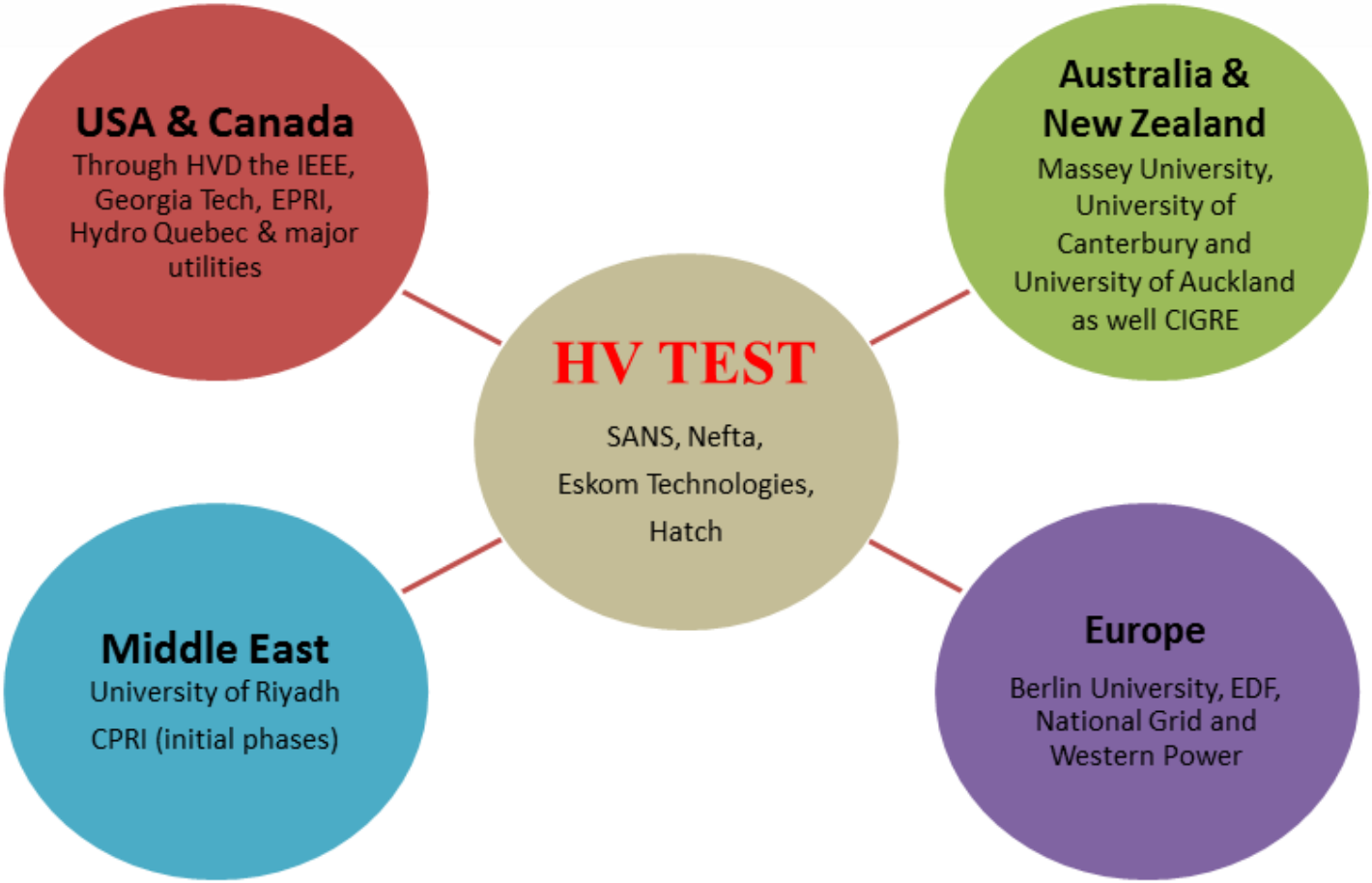
AGENDA

- Introduction: Who are we?
- Recent Developments: DV Power, Gossen
- MV and HV testing options, both On-Line and Off-Line as a means of Preventative Maintenance
- Closer Look: Transformer, MV Cable Testing
- Questions

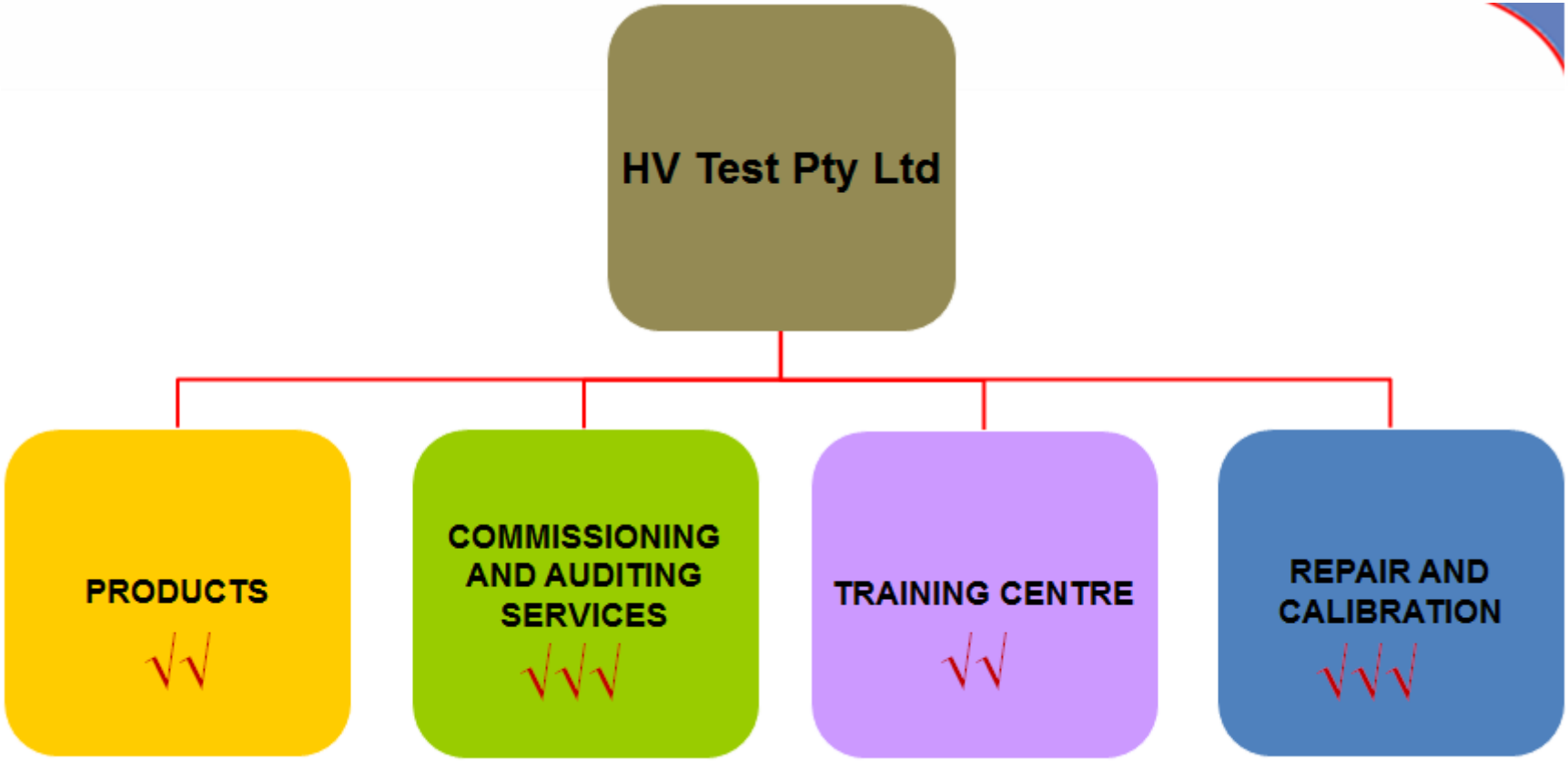
WHO ARE WE

- Incorporated in 1982
- International Ties
- Projects in Guatemala, Oman and Ireland
- Specialist projects:
  - Oil Cable Leak location – Sandton: Unique Technology
  - Off Line Cable Diagnostics – TD and PD
  - On Line Diagnostics – Eskom 400kV cables
  - Overhead Line Fault location – Eskom, Nampower, EDM, BPC
  - Transformer Rewind Test Facility – Rotek: 800MVA
  - Motor Rewinding – Actom
  - Traction Motor facilities - Transnet

INTERNATIONAL TIES



INTERNAL DIVISIONS OF HV TEST



RECENT DEVELOPMENTS

We recently added the following Manufacturers to our stable:

- DV Power (Sweden)
- Gossen Metrawatt (Germany)

DV POWER

- Swedish Company
- 3 Year Warranty
- Battery Testing
- Circuit Breakers
- Transformer / Motor
- CT’s and VT’s
- Handheld Devices

H.V. TEST (PTY) LTD
Leaders in High Voltage Test Equipment

Product Sales | Commissioning and Auditing Services | Training Centre | Repair and Calibration

GOSSEN METRAWATT

- German based Company
- Quality Multimeters
- 5kV and 10kV Insulation
- Substation Earthing
- 3 Phase Socket Factories
- Solar Panel Efficiency

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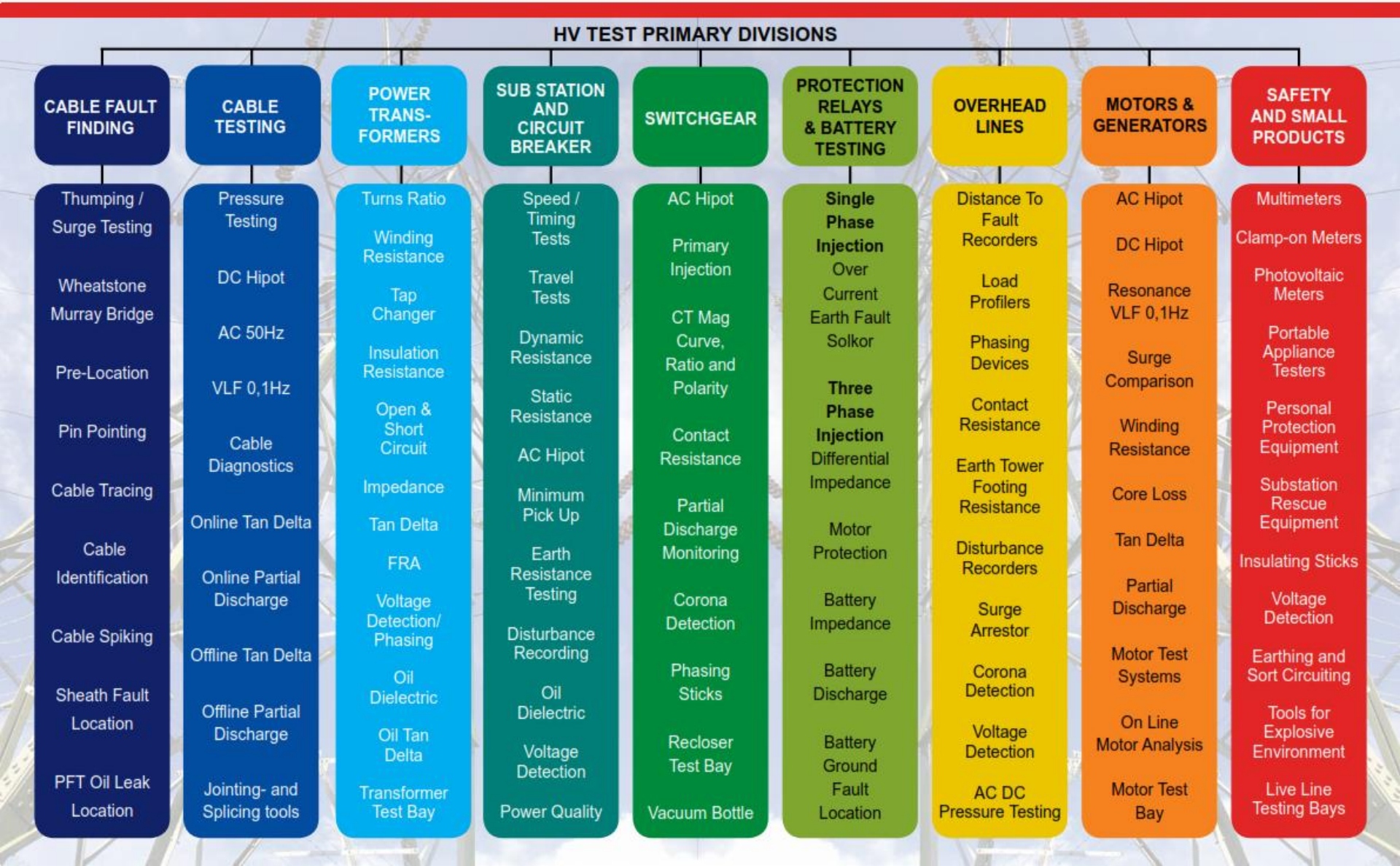
HV TEST PRIMARY DIVISIONS



CABLE FAULT FINDING

- Thumping / Surge Testing
- SSG500, SSG1500
- 16kV, 11kV networks
- 32kV, 11-33kV networks
- 500J, 1100J – 3000J

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CABLE FAULT FINDING

- Wheatstone /
- Murray Bridge
- Shirla
- Great for 0 Ohm faults
- Build into the Shirla

CABLE FAULT FINDING

- Pre-Location
- IRG2000 / IRG4000
- TDR
- ICM
- SIM / ARC Reflection

CABLE FAULT FINDING

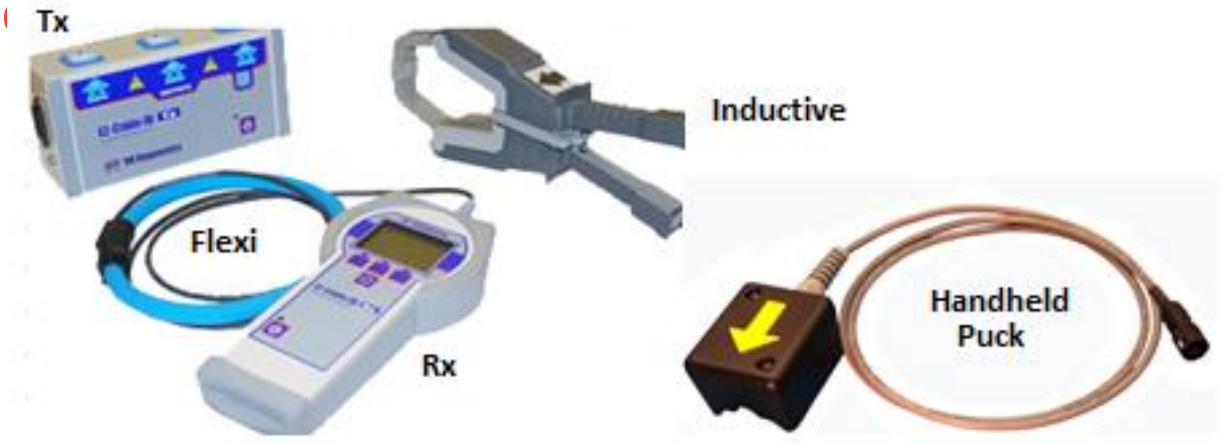
- Pin Pointing
- Protrac
- Bluetooth
- Receiver
- Ground Microphone
- Headset

CABLE FAULT FINDING

- Cable Tracing
- Ridgid SR-24
- Transmitters 10W, 5W
- 4” Clamp – Live Cables
- GPS – marking location
- Bluetooth to Android device

CABLE FAULT FINDING

- Cable Identification
- EZID
- Phasing is also possible
- Must have access to one side
- Best to ID dead (



CABLE FAULT FINDING

- Cable Spiking
- Schermer (Utilities)
- Picoup400 (Mines)
- Hydraulic as optional
- This saves lives !!
- Remote firing of th

CABLE FAULT FINDING

- Sheath Fault Location
- Shirla
- 5kV DC Test
- Spikes

CABLE FAULT FINDING

- PFT Oil Leak Location
- The oil cable is “Tagged”
- A GC is used to locate the leaking gas
- De-gassifier Trailers

CABLE TESTING

- Pressure Testing
- DC
- AC, 50Hz
- VLF, 0.1Hz
- Testing the insulation
- Test according to the std.

AC, Cascade Type, 400 kV, 800 kVA

CABLE TESTING

- DC Hipot
- PGK50
- Still used on PILC cable
- Cheaper Equipment
- Meaningless on AC cables

CABLE TESTING

- AC 50Hz
- Equipment is large
- Expensive
- 44kV cables and up
- Back energise on open-circuit

Variable Frequency, 265 kV, 22 MVA

CABLE TESTING

- VLF 0.1Hz
- Using VLF or 0.1Hz pure sine
- Only test for XLPE up to 33kV
- Commissioning
- Maintenance
- Joints and Terminations

CABLE TESTING

- Cable Diagnostics
- Combine a Tan-Delta test
- Footprint
- Indication of deterioration
- PD Test

CABLE TESTING

- Online Tan Delta
- TD Guard
- absolute Tan-δ values in on-line permanent monitoring
- Innovative instrument for Capacitance, Tan-δ and Δtan-δ recording, storage & processing

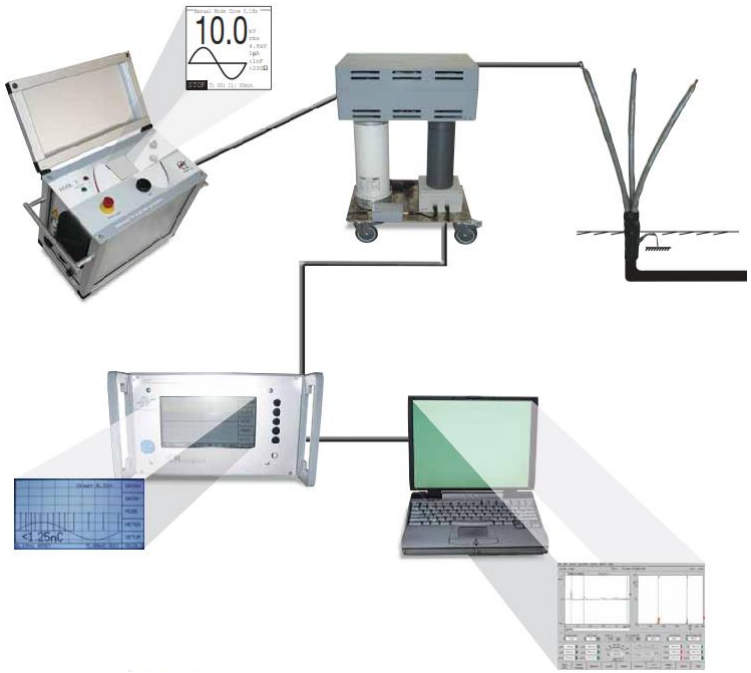
CABLE TESTING

- Online Partial Discharge
- PD detection at 50Hz
- Can’t increase the voltage
- Cable Voltage not Relevant

CABLE TESTING

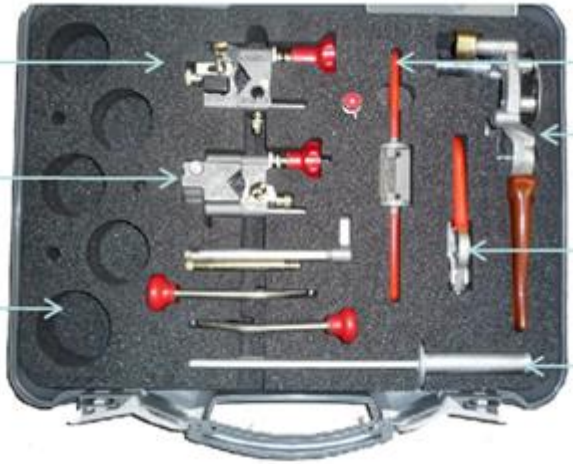
- Offline Tan Delta
- Tests are performed at 0.1Hz, Voltage is manually controlled
- Foot printing and cable deterioration

CABLE TESTING



- Offline Partial Discharge
- Inception and Extinguishing voltage

CABLE TESTING



- Jointing- and Splicing tools

POWER TRANSFORMERS

- Turns Ratio
- Comparing the ratio can easily show faults
- Field or Maintenance Test
- 1 Phase or 3 Phase Testing

POWER TRANSFORMERS

- Winding Resistance
- DC Resistance Test
- Temperature Measurement Possible
- 1 Phase or 3 Phase

POWER TRANSFORMERS

- Tap Changer
- Dynamic Resistive plot of the taps
- 3 Phase option with Winding

POWER TRANSFORMERS

- Insulation Resistance
- Metriso Prime10
- 5kV, 10kV, 15kV options
- PI, DAR
- Megger

POWER TRANSFORMERS

- Variac and Multimeter
- Nameplate verification
- % Impedance
- Open & Short Circuit

POWER TRANSFORMERS

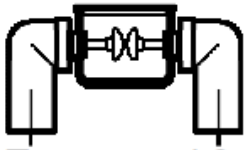
- Tan Delta
- Bushings
- Tank
- 2 Separate units
- 1 Dedicated TD unit

POWER TRANSFORMERS

- FRA
- Verify that the windings did not move around during transport
- Tests is performed before on loading
- Repeated after installation
- Sweep: 5Hz to 45MHz

POWER TRANSFORMERS

- Oil Dielectric
- 60kV, 75kV, 80kV, 100kV
- Water in Oil (Karl Fischer)



Test vessel 0.4 l in acc. with
IEC 60 156 Fig. II with cover

POWER TRANSFORMERS

- Oil Tan Delta

POWER TRANSFORMERS

- Transformer Test Bay

CIRCUIT BREAKER

- Speed / Timing Tests
- Indoor / Outdoor
- 3 Channels / 1 Break / Ph
- 6 Channels / 2 Break / Ph
- 12 Channels / 4 Break / Ph
- On-Line

CIRCUIT BREAKER

- Static Resistance
- CAT61 or CAT-P
- Typical 10A, 50A, 100A, 200A
- Up to 800A
- Loose equipment or build in to the Circuit Breaker Analyser
- Handheld up to 30(

CIRCUIT BREAKER

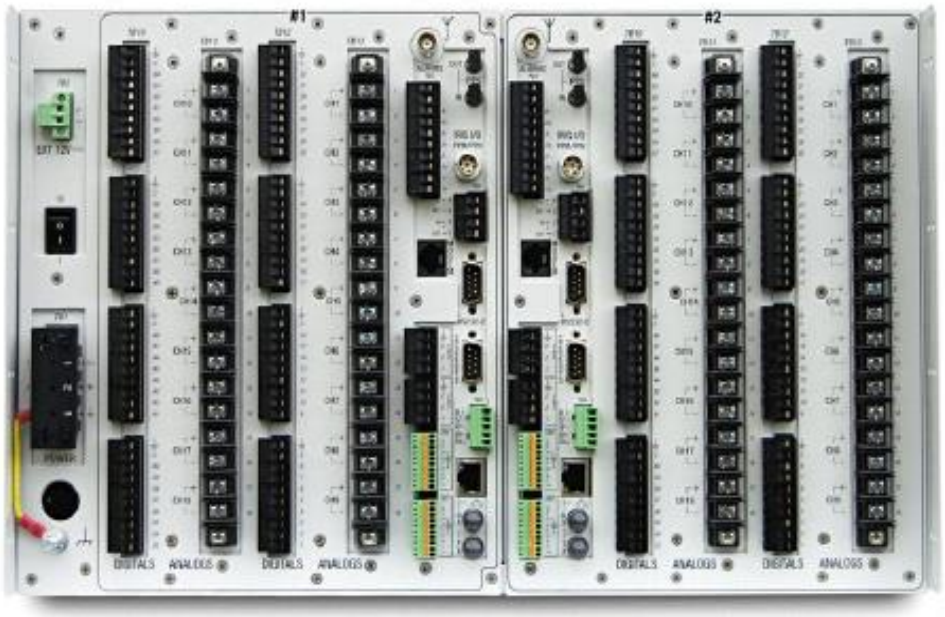
- Minimum Pick Up
- POB30
- Test to verify that the breaker coils will still fire even at 70% of station battery voltage
- Variac might damage the coil during the ramping

SUB STATION

- Earth Resistance Testing
- Soil Resisivity
- 4-Wire Method
- Step and Touch (current)

SUB STATION

- Disturbance Recording
- 9, 18, 36 Analogue Channels
- 32, 64, 96, 128 Digital Channels
- IEC 61850



SUB STATION

- Power Quality
- IEC 61000-4-30 Class A
- 19” Rack / Portable
- PQ and DFR

SUB STATION

- Voltage Detection
- Contact
- Non-Contact
- Up to 765kV

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SWITCHGEAR

- AC Hipot
- Busbar Testing
- 50Hz Test
- 3mA per panel
- Consider the current

SWITCHGEAR

- Primary Injection
- Customer has to specify the max current
- 200A is still regarded as secondary injection
- 12000A or more

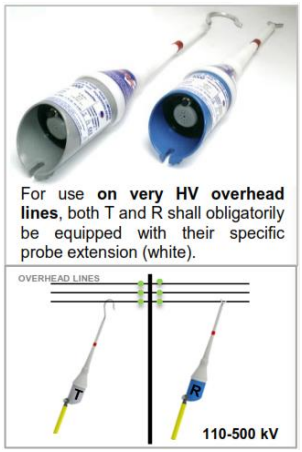
SWITCHGEAR

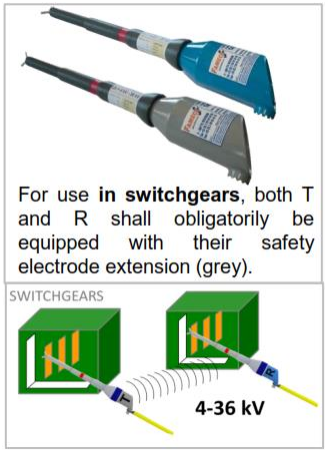
- CT Mag Curve, Ratio and Polarity
- Single or multiple tap

SWITCHGEAR

- Partial Discharge Monitoring
- Handheld
- Permanent monitor of GIS and transformers
- Cloud Storage

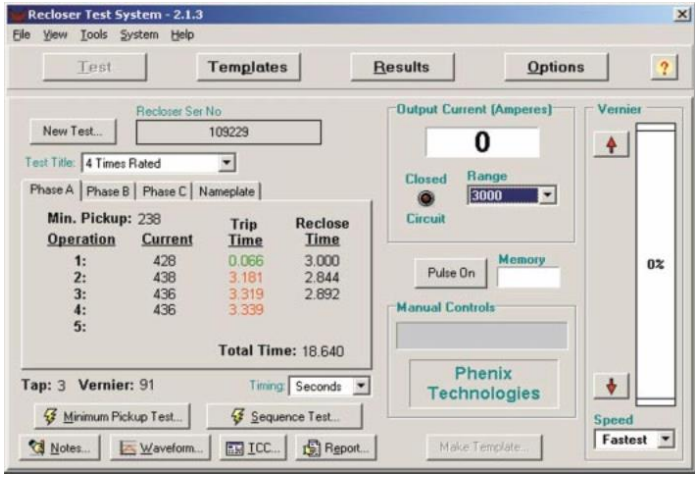
SWITCHGEAR





- Phasing Sticks
- Switchgear

SWITCHGEAR



- Recloser Test Bay
- 0 – 7.50, 2500A
- 19kVA, 47kVA

SWITCHGEAR

- Vacuum Bottle
- 40kV, 60kV

PROTECTION RELAYS

- Single Phase Injection
- CDG Electromechanical relay
- High VA relays
- Manual Testing

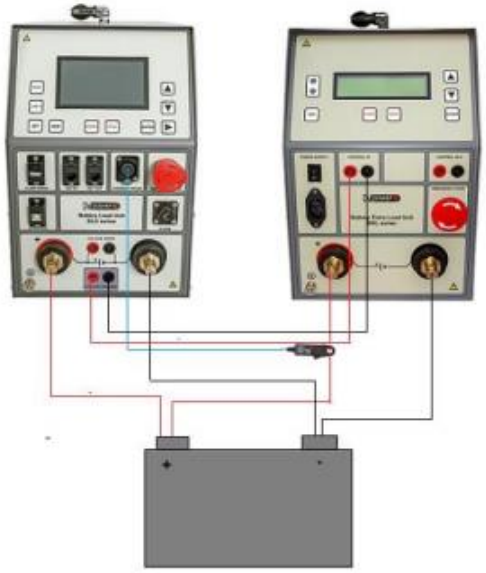
PROTECTION RELAYS

- Three Phase Injection
- 3 Currents 3 Voltages
- 3 Currents 4 Voltages
- 6 Currents 4 Voltages
- 6 Currents 6 Voltages
- IEC 61850
- Transcope

BATTERIES

- Battery Resistance
- Battery Resistance
- Test a string of cells
- Record results to a database

BATTERIES



BLU + BXL to battery connection diagram

- Battery Discharge
- Additional load units available

OVERHEAD LINES

- Distance To Fault Recorders (NAMPOWER)
- FL8 and FL1
- For Lines of voltages 66kV and up
- +/- 120m accuracy
- Software automatically calculates distance to fault
- Save money on costly Line investigations

OVERHEAD LINES

- Earth Tower Footing Resistance
- ER25K
- Measuring earth resistance of electrical pylons
- High frequency measurement current (25kHz)

OVERHEAD LINES

- Surge Arrestor
- SCAR10
- True rms of the total current.
- Peak value of the total current.
- True rms of the third harmonic

OVERHEAD LINES

- Contact
- Non-Contact
- Up to 765kV
- Voltage Detection

OVERHEAD LINES

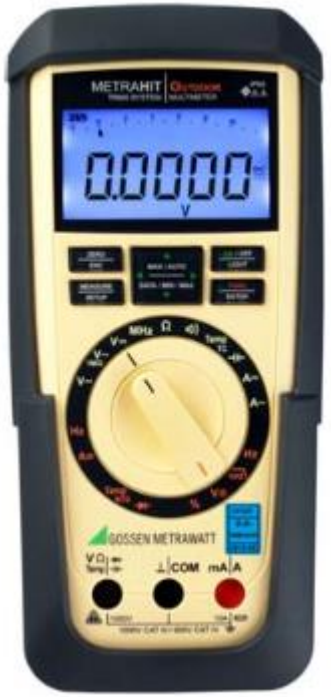
- PGK50
- AC / DC Pressure Testing

MOTORS & GENERATORS

- Resonance
- We can provide
- 50Hz pressure test
- PD Test
- Recent work includes Ingula, Drakensberg

SAFETY AND SMALL PRODUCTS

- Multimeters
- Entry Level
- Mid Range
- High End
- Calibrators
- 1kV Insulation Testers



SAFETY AND SMALL PRODUCTS

- Clamp-on Meters
- Non-Invasive Current Measurement

SAFETY AND SMALL PRODUCTS

- Photovoltaic Meters
- PV condition
- Insulation measurement
- Polarity testing
- Ground fault testing
- Protective conductor continuity

PROFITEST PVSUN

PROFITEST PVSUN MEMO

SAFETY AND SMALL PRODUCTS

- Portable Appliance Testers
- Testing for N-PE reversal
- Tripping test with nominal residual current, trip time measurement
- Earthing Resistance RE
- Selective Earthing Resistance RE
- Earth Loop Resistance RE loop
- Soil Resistivity Rho

SAFETY AND SMALL PRODUCTS

- Substation Rescue Equipment
- Electrical safety kit 25kV 36kV

SAFETY AND SMALL PRODUCTS

- Tools for Explosive Environment
- Voltage, Resistance, Current, Frequency
- Intrinsically safe electric circuits up to 1000 V
- CAT IV, 1000 V

SAFETY AND SMALL PRODUCTS

- Live Line Testing Bays
- 1 or 2 Gloves
- Complete Bay

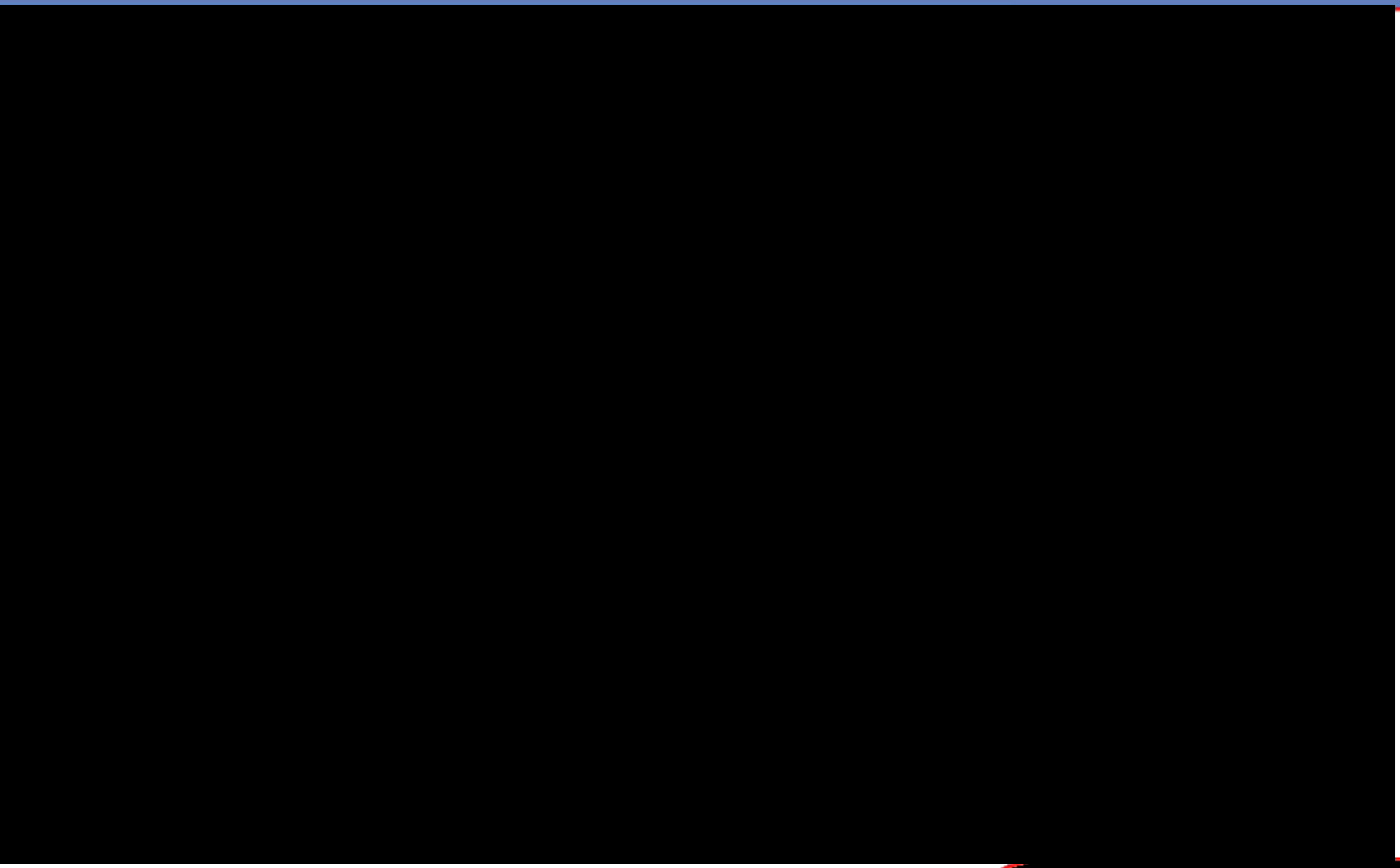
Model TGM-022

TRANSFORMER & CABLE TESTING

Reasons for Preventative Maintenance Testing:

- Extend the live of the asset
- Prevent unexpected outages
- Prevent catastrophic failures

VANDERBIJL, MARCH 2019



TRANSFORMER TESTING

- Different tests have been implemented for different scenarios. They consist of routine testing, type testing and special testing. We will be looking at a summary of routine testing.

- Routine tests are tests required for each individual transformer.

TRANSFORMER TESTING

- Test Standards:

- IEC 60076 -1, IEC 60076 -2, IEC 60076 -3,
- IEC 60076 -4, IEC 60076 -5, IEC 60076 -6,
- IEC 60076 -7, IEC 60076 -8, IEC 60076 -9,
- IEC 60076 -10, IEC 60076 -11

ROUTINE TESTING

Transformer Ratio Test

- The ratio test ensures that the transformer windings have the proper turns to produce the voltages required. The ratio is a measure of the voltage applied to the primary terminals to the voltage measured at the secondary terminals.

ROUTINE TESTING

Vector Group and Polarity

- The polarity and vector group of the transformer must be tested and checked to match the vector group on the nameplate.

ROUTINE TESTING

Impedance Test

- Also known as, Load or short circuit test.
- This test is performed to ensure the stated nameplate impedance and the measured transformer impedance match.

ROUTINE TESTING

No-Load Test (Magnetisation)

- This test verifies the design and core performance by indication of the no load current drawn by the transformer.
- The magnetisation current is a factor of losses in the electric circuit, losses in the magnetic circuit, and losses in the dielectric circuit.

ROUTINE TESTING

Winding Resistance

- The winding resistance is performed to determine the resistance of the conductors in the transformer winding, and the tap-changer contacts resistances.

ROUTINE TESTING

Tap-change Continuity

- The tap-changer contacts are tested for electrical continuity during tap-changing.

- By applying a constant current while tapping the tester looks for open circuit transients during tap-changing.

ROUTINE TESTING

Insulation Resistance Test (Popular Test)

- The purpose of this DC test indicates the degree of dryness of the insulation and ground circuits that may exist.

ROUTINE TESTING

Dielectric Absorption (DA) and Polarization Index (PI)

- Evaluating the windings for the following:
  - Build up of dirt or moisture.
  - Gradual deterioration of the insulation (comparing results)
  - Suitability for operation.

ROUTINE TESTING

Tan Delta Test on the transformer and the Bushings (where possible)

- The Tan Delta is a measure of the insulation loss
- The bushings of the transformer are tested before fitting and/or transport

ROUTINE TESTING

Frequency Response Analysis (FRA) Test

- This technique is designed to detect winding shifts through non-destructive methods, before and after transport of the transformer

ROUTINE TESTING

Other Tests

- Oil Testing - Dielectric Strength
- Dissolved Gas Analysis
- Water Content
- Acidity

THESE ARE USUALLY SENT AWAY TO A LAB.

PRACTICAL TESTING OF MV CABLES

- Introduction
- The new Standard (SANS 10198-13:2016) overview
- Testing On Site

PRACTICAL TESTING OF MV CABLES

Recommended methods of Testing

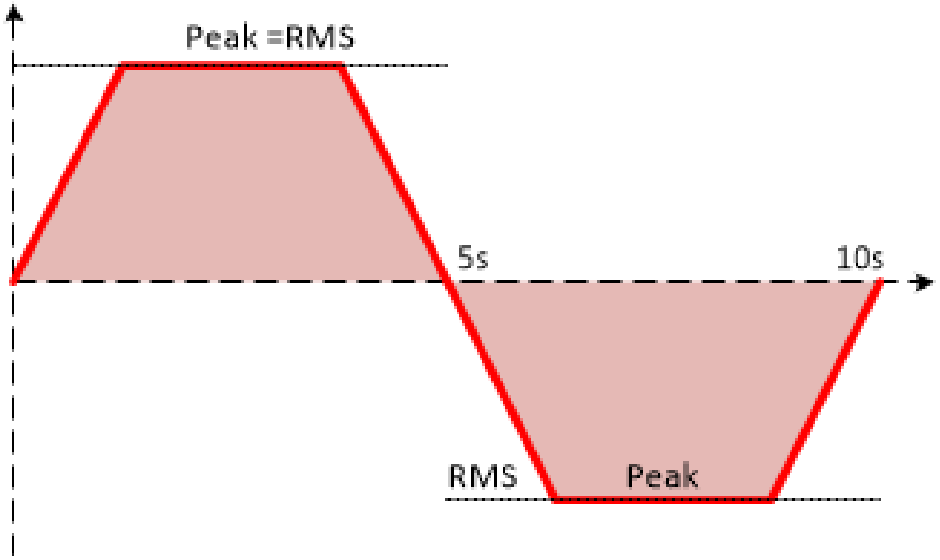
- 50 Hz Testing
- Very Expensive

- Very low Frequency (VLF) Testi

PRACTICAL TESTING OF MV CABLES

VLF Wave Shapes:

- **Cosine Rectangular Waveform**

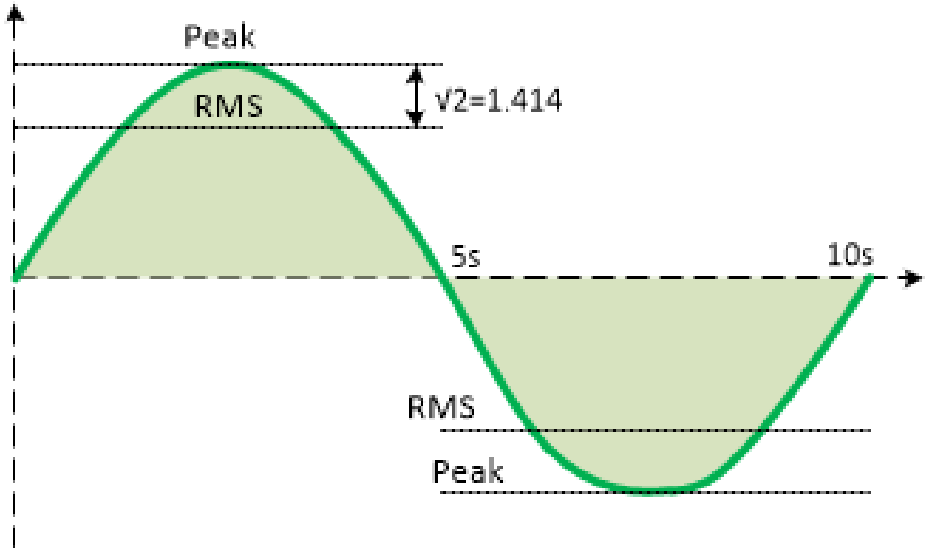


- **<u>Disadvantage:</u>** No diagnostic possible

PRACTICAL TESTING OF MV CABLES

VLF Wave Shapes:

- **Sinusoidal Wave form**



- Wave Shape are equally positive and negative.
- **Advantage:** Diagnostic possible

PRACTICAL TESTING OF MV CABLES

Direct Current (DC) Testing:

SANS 10198: 2016 Part 13 excludes DC Testing

"D.C. Overvoltage is likely to cause irreversible damage on aged cables"

- Why exclude DC from PILC Cables?
  - Because we are using "solid dielectrics" (Heat Shrink) on joints or terminations (almost 90%)

PRACTICAL TESTING OF MV CABLES

Summary of Changes (SANS 10198-13:2016):

- Incorporates all cables up to less than 33kV
  - PILC – screened and bolted
  - XLPE
  - EPR
  - Bundle
  - PVC

- Additional Test: Conductor Resistance

- Insulation Resistance Test : before and after testing

PRACTICAL TESTING OF MV CABLES

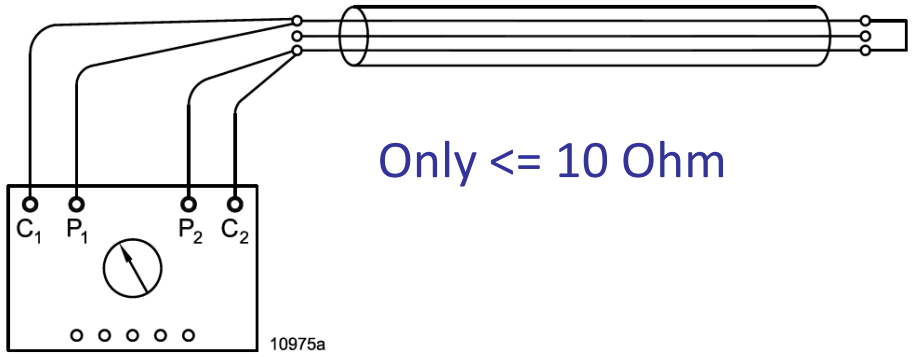
Recommended Test Requirements (Commissioning)

- Insulation Resistance Test (DC 1000V)
- Conductor Resistance Test (DC)
- Overvoltage Test
- Outer Sheath Test
- Diagnostic Tests: (fingerprinting & future trending)
- Insulation Resistance Test (DC 1000V)

PRACTICAL TESTING OF MV CABLES

Conductor Resistance Test:

- This is a new requirement (check Joints).
- Use two cores, loop for end, and divide result by 2
- Instrument to use is the “Ductor” – 4 wire method
- Aberdare and CBI Cable Brochures provide conductor resistance tables



Only <= 10 Ohm

Example:
10km of 240mm2 Cable
is 7.8 Ohm

Key

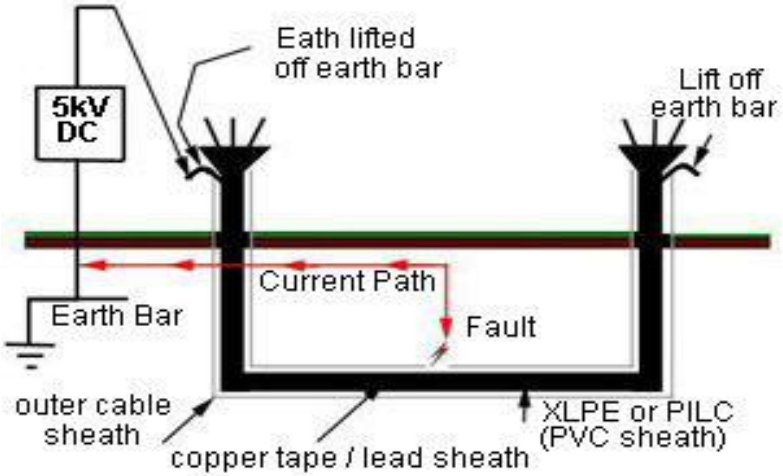
C_1 and C_2	current lead connections
P_1 and P_2	potential lead connections

PRACTICAL TESTING OF MV CABLES

Cable Sheath Testing:

After overvoltage testing cable sheath testing is recommended:

- 5 kV for 1 minute (Recommended)
- NB: Lift the far end of the earth bar!
- Roughly guide 1 mA per km test source



PRACTICAL TESTING OF MV CABLES

Overvoltage Commissioning Testing:

Newly Installed Individual screened (Radial field) (cores) on M.V. Cables

Table 1 – Commissioning test voltages for newly installed individually screened MV cables

1	2	3	4
Cable operating voltage kV	**VLF Test voltage sine kV**	**VLF Test voltage cosine rectangular kV**	**Power-frequency test voltage kV**
6.6	11	16	8
11	19	27	13
22	38	54	25
33	57	80	38
NOTE 1 The voltages given are root mean square (r.m.s.) values. The r.m.s. value of a cosine rectangular voltage is equal to the peak voltage. NOTE 2 Where the test levels cannot be achieved or where limitations are placed on the maximum test voltage by the equipment (for example, switchgear) connected to the cable, a reduced voltage for an extended duration may need to be considered and agreed to.			

Notes:

- Test time 60 minutes/core
- Only for individual screen cables (radially stressed)
- This table applies to XLPE, EPR and PILC (non-belted and individual screen cables).
- More than one core can be tested simultaneously provided the test set has the capacity.

PRACTICAL TESTING OF MV CABLES

Overvoltage Maintenance Testing:

Individual screened (Radial field) (cores) on M.V. Cables

Table 7 – Commissioning test voltages for individually screened MV cables

1 Cable operating voltage kV	2 VLF Test voltage sine kV	3 VLF Test voltage cosine rectangular kV	4 Power-frequency test voltage kV
6.6	8	11	5
11	13	18	9
22	25	35	17
33	38	54	25

NOTE 1
The voltages given are root mean square (r.m.s.) values. The r.m.s. value of a cosine rectangular voltage is equal to the peak voltage.

NOTE 2
Where the test levels cannot be achieved or where limitations are placed on the maximum test voltage by the equipment (for example, switchgear) connected to the cable, a reduced voltage for an extended duration may need to be considered and agreed to.

NOTE 3
The test used for maintenance are two-thirds (2/3) of the test voltages for newly installed cables.

Notes:

- Test time is 60 minutes/core
- Only for individual screen cables (XLPE + PILC)
- Not Belted PILC cable
- Multiple cores can be tested simultaneously provided the test set has the capacity

PRACTICAL TESTING OF MV CABLES

Diagnostic Testing (TD)

- Not specified as mandatory but recommended
- TD is a excellent and easy test
  - Simple and today part of Pressure Test Set
  - Very meaningful for ageing cables
  - Excellent “Fingerprint”
  - Temperature, site conditions, moisture sensitive
  - Water trees are only detected by T.D. (not P.D.)
  - TD is an indication of the TD of the whole cable
  - Unlike P.D. - location of poor T.D. source is not possible

PRACTICAL TESTING OF MV CABLES

Diagnostic Testing (PD)

- Not specified as mandatory but recommended
- PD provides location of source of discharge
- PD requires highly skilled technician with experience

PRACTICAL TESTING OF MV CABLES

TD Variables

- Tan Delta (TD)
  - Calculate the TD using the average value calculated at U_o

- Delta tan delta (DTD)
  - Calculate the DTD using the average values calculated at $0.5U_o$ and $1.5U_o$

- Tan delta stability (TDS)
  - Calculate the TDS using the following formula at U_o
  - $$TDS = \sqrt{\frac{\sum(TD - \overline{TD})^2}{(n-1)}}$$

TD : a measured TD point in the test series
$\overline{TD}$: the average tan delta of the series
n : the number of TD points in the test series

PRACTICAL TESTING OF MV CABLES

TD Testing (Commissioning)

Table 3 – Guidelines for the condition assessment of cables based on 0,01 Hz VLF-TD, DTD and TDS for newly installed XLPE cables[a]

1	2	3	4
Condition Assessment	**TD at Uo [10^{-3}]**	**DTD [10^{-3}]**	**TDS at Uo [10^{-3}]**
No action required	<2.5	<0.6	<0.2
Further study advised	2.5 to 5	0.6 to 1	0.2 to 0.5
Action required	>5	>1	>0.5
[a] XLPE cables in operation for less than five years			

Table 5 – Guidelines for the condition assessment of cables based on 0,01 Hz VLF-TD, DTD and TDS for newly installed PILC Cables[a]

1	2	3	4
Condition Assessment	**TD at Uo [10^{-3}]**	**DTD [10^{-3}]**	**TDS at Uo [10^{-3}]**
No action required	<25	-20 to 20	<0.5
Further study advised	25 to 50	-20 to -50 or 20 to 50	0.5 to 1
Action required	>50	>-50 or >50	>1
[a] PILC cables in operation for less than five years			

PRACTICAL TESTING OF MV CABLES

TD Testing (Maintenance)

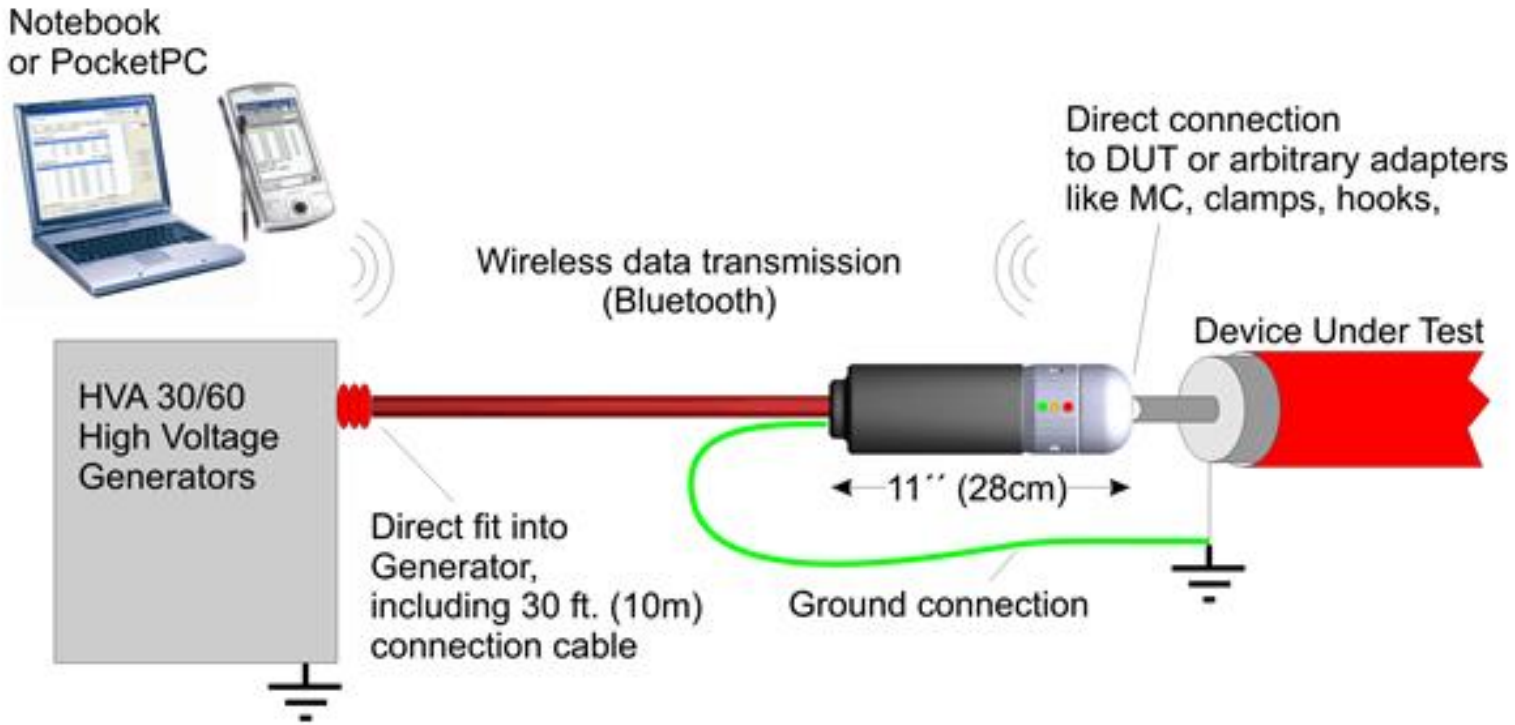
Table 4 – Guidelines for the condition assessment of cables based on 0,01 Hz VLF-TD, DTD and TDS for aged (in service) XLPE Cables

1	2	3	4
Condition Assessment	**TD at Uo [10^{-3}]**	**DTD [10^{-3}]**	**TDS at Uo [10^{-3}]**
No action required	<2.5	<3	<0.5
Further study advised	2.5 to 25	3 to 30	0.5 to 1
Action required	>25	>30	>1

Table 6 – Guidelines for the condition assessment of cables based on 0,01 Hz VLF-TD, DTD and TDS for aged (in service) PILC Cables

1	2	3	4
Condition Assessment	**TD at Uo [10^{-3}]**	**DTD [10^{-3}]**	**TDS at Uo [10^{-3}]**
No action required	<50	-35 to 10	<0.5
Further study advised	50 to 200	-35 to -50 or 10 to 50	0.5 to 1
Action required	>200	>-50 to 50	>1

PRACTICAL TESTING OF MV CABLES



PRACTICAL TESTING OF MV CABLES

Thank you, any Questions?