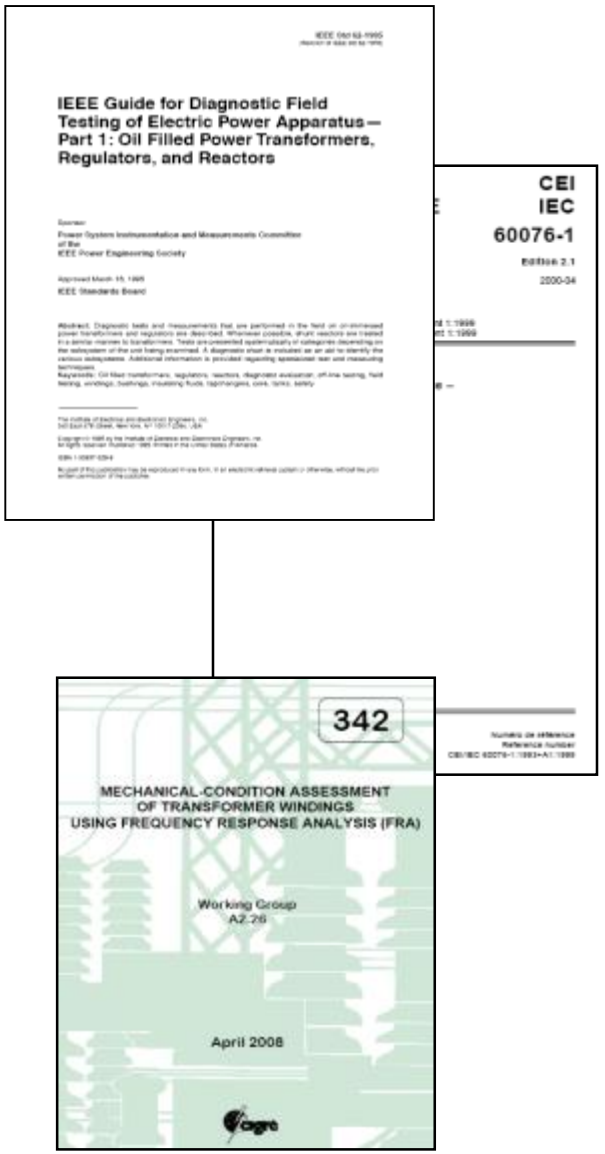
Transformer condition assessment with an integrated test van


VERSALIFT

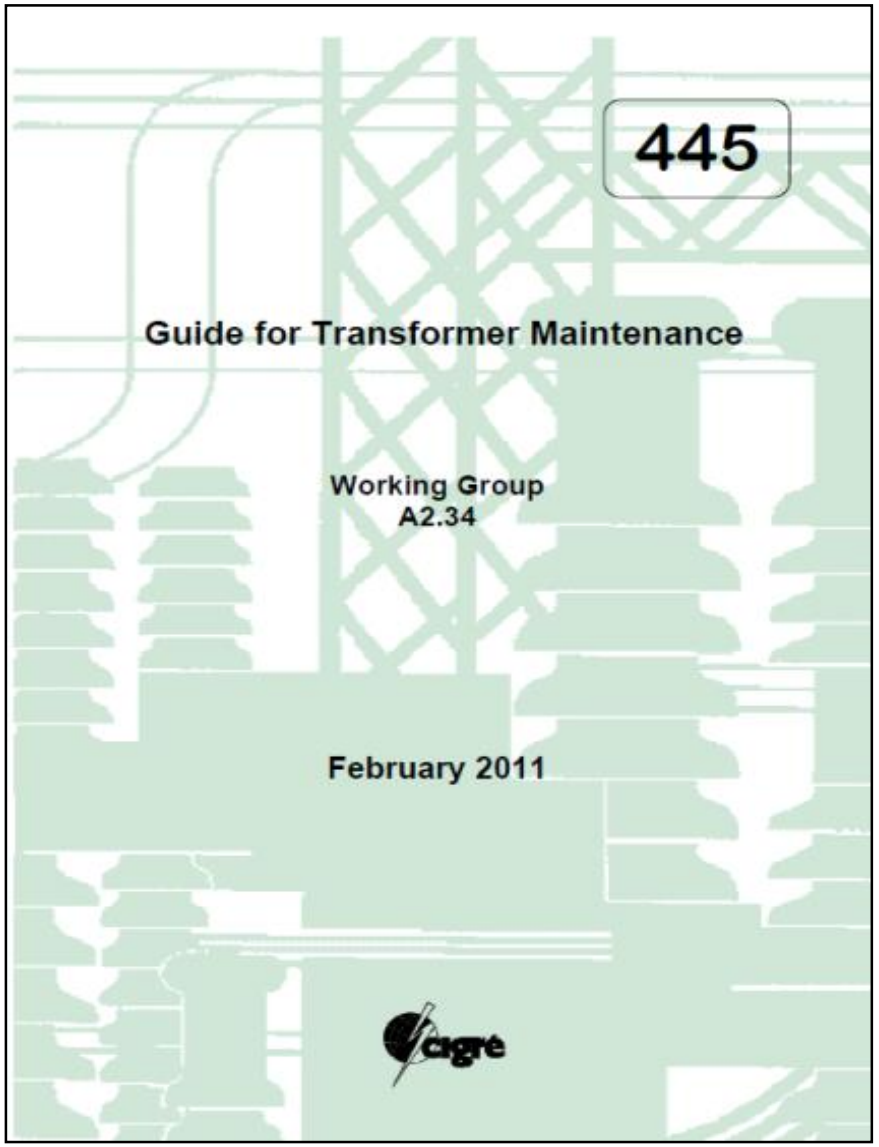
Testing and Standards for Power Transformers

- CIGRE
  - CIGRE Brochure 342 (SFRA-FRAX)
  - CIGRE Brochure 414 (DFR-IDAX)
  - CIGRE Brochure 445 (Guide for Transformer Maintenance)
- IEC, TC 14
  - IEC 60076-1, Power Transformers
  - IEC 60076-2, Temperature rise
  - IEC 60076-3, Insulation levels, dielectric tests and external clearances in air
  - IEC 60076-18, Measurement of frequency response (SFRA)
- ANSI, IEEE Transformer Committee
  - IEEE C57.152 (former IEEE 62-1995)
  - IEEE C57.12.00-2006 (under revision)
  - IEEE C57.12.90-2006 (under revision)
  - IEEE PC57.149 (SFRA)
- GOST
  - GOST 11677-85, Power Transformers



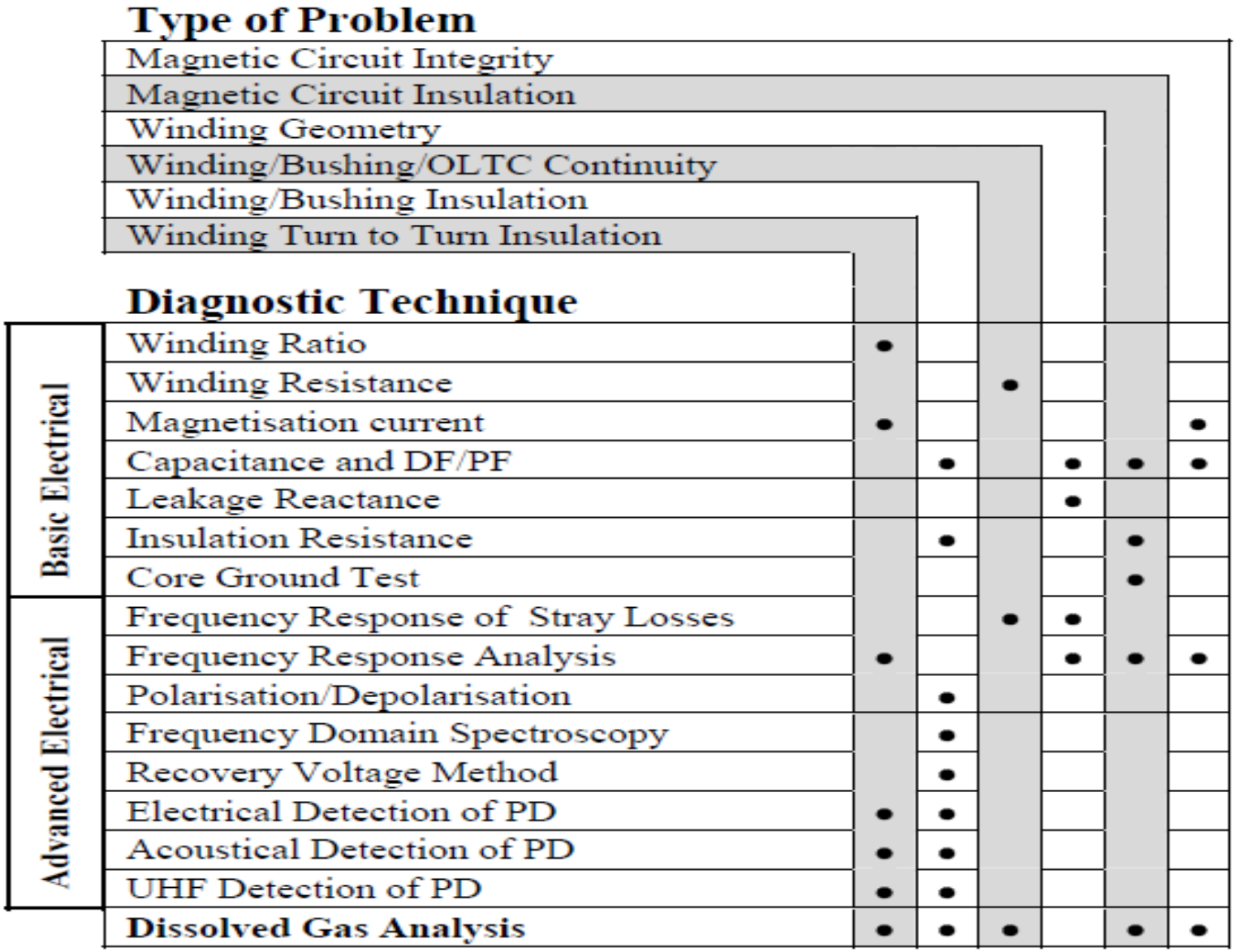
Cigré Technical Brochure 445, 2011

Guide for Transformer Maintenance



Megger

”Diagnostic” matrix CIGRE TB445



Type of Problem	Magnetic Circuit Integrity	Magnetic Circuit Insulation	Winding Geometry	Winding/Bushing/OLTC Continuity	Winding/Bushing Insulation	Winding Turn to Turn Insulation
Diagnostic Technique						
Basic Electrical	Winding Ratio	•		•			
	Winding Resistance			•			
	Magnetisation current	•					•
	Capacitance and DF/PF		•		•	•	•
	Leakage Reactance				•		
	Insulation Resistance		•			•	
	Core Ground Test					•	
Advanced Electrical	Frequency Response of Stray Losses			•	•		
	Frequency Response Analysis	•			•	•	•
	Polarisation/Depolarisation		•				
	Frequency Domain Spectroscopy		•				
	Recovery Voltage Method		•				
	Electrical Detection of PD	•	•				
	Acoustical Detection of PD	•	•				
	UHF Detection of PD	•	•				
	Dissolved Gas Analysis	•	•	•		•	•

Table 29: Electrical Tests and DGA Diagnostic Matrix

Transformer testing by Megger

STANDARD TEST TYPES			MEGGER TEST SETS										
Component		Test	Delta	IDAX	MIT	FRAX	MLR	TTR	MTO	LTC 135	MoM	TRAX	OTS	KF
Windings		Resistance							X	X		X		
		Ratio/polarity						X				X		
		Excitation current	X	X				X				X		
		Short-circuit impedance				X	X					X		
		Frequency response analysis				X								
		Insulation resistance			X									
		Capacitance	X	X								X		
		Power factor/tan delta	X	X								X		
		Dielectric frequency response		X										
Bushings		Capacitance	X	X								X		
		Power factor/tan delta	X	X								X		
		Dielectric frequency response		X										
Insulating oil		Water content												X
		Dielectric strength											X	
		Power factor/tan delta	X	X								X		
Cellulose insulation		Moisture content		X										
Tap changers	Load	Resistance							X	X		X		
		Ratio						X				X		
		Continuity (make before break)							X	X		X		
		Dynamic resistance (DRM)								X		X		
	De-energized	Resistance							X	X		X		
		Ratio						X				X		
Core/Tank		Insulation resistance		X	X									
		Frequency response analysis				X								
		Ground test									X	X		

So many tests to do?

Ambient conditions?

Or tangled cables?

Number of climbs up and down a ladder?

Cable test van

The Variant: cable fault location, cable testing and diagnosis in a modular system

History of **cable** test vans

First cable test van

1000 vans to USSR

2000 vans worldwide

Vario KMT

4000 vans worldwide

1969 1980 1985 1988 1995 1997 2006 2012

500 test vans delivered to USSR

Hitec 2000

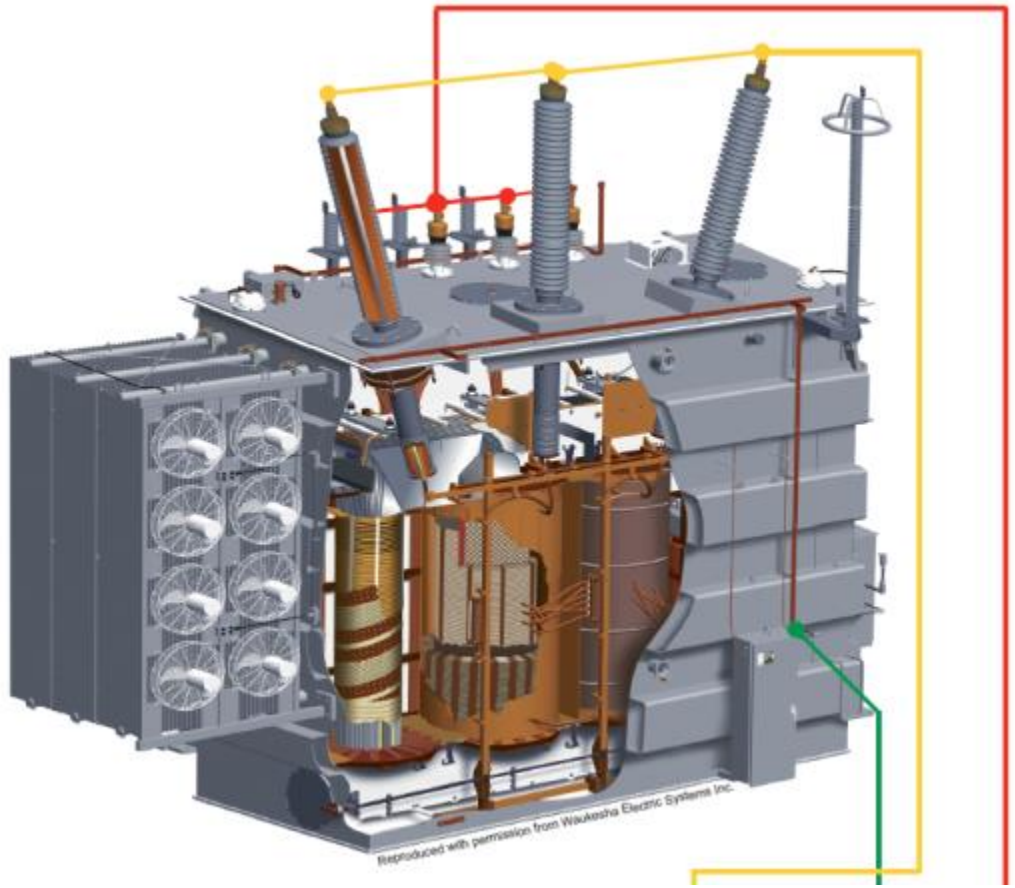
Centrix 1/3-ph

Variant

History of **transformer** test vans

Designation

- Commissioning
- Preventive maintenance
- Outage troubleshooting
- After repair check



- Issues that can be identified:
  - deterioration of electrical insulation
  - mechanical displacements/damage
  - winding-, bushing-, tap changer-, core- and oil condition
  - check for ratio, vector group, no-load& load losses

Unique features

- Routine and advanced diagnostic tests
- Centralized control and reporting
- Two sets of cable (HV & LV) shared among instruments
- Automated test circuit arrangement and switching process
- OLTC remote control
- Safe operation and user guidance through the tests

Routine and diagnostic tests onboard:

- Insulation Resistance
- DC Winding resistance / Tap Changer Test
- Capacitance and dissipation factor for transformer and bushings
- Turn ratio and vector group verification
- Moisture-in-cellulose assessment with DFR technique
- Short circuit impedance (optional)
- Power losses for no-load and short circuit conditions (optional)
- Frequency Response Analysis (optional)
- Withstand tests at elevated voltage up to 100 kV AC 50 Hz and 70 kV DC (optional)
- Oil breakdown test (optional)

Operators view (inside)

Central PC: with PowerDB

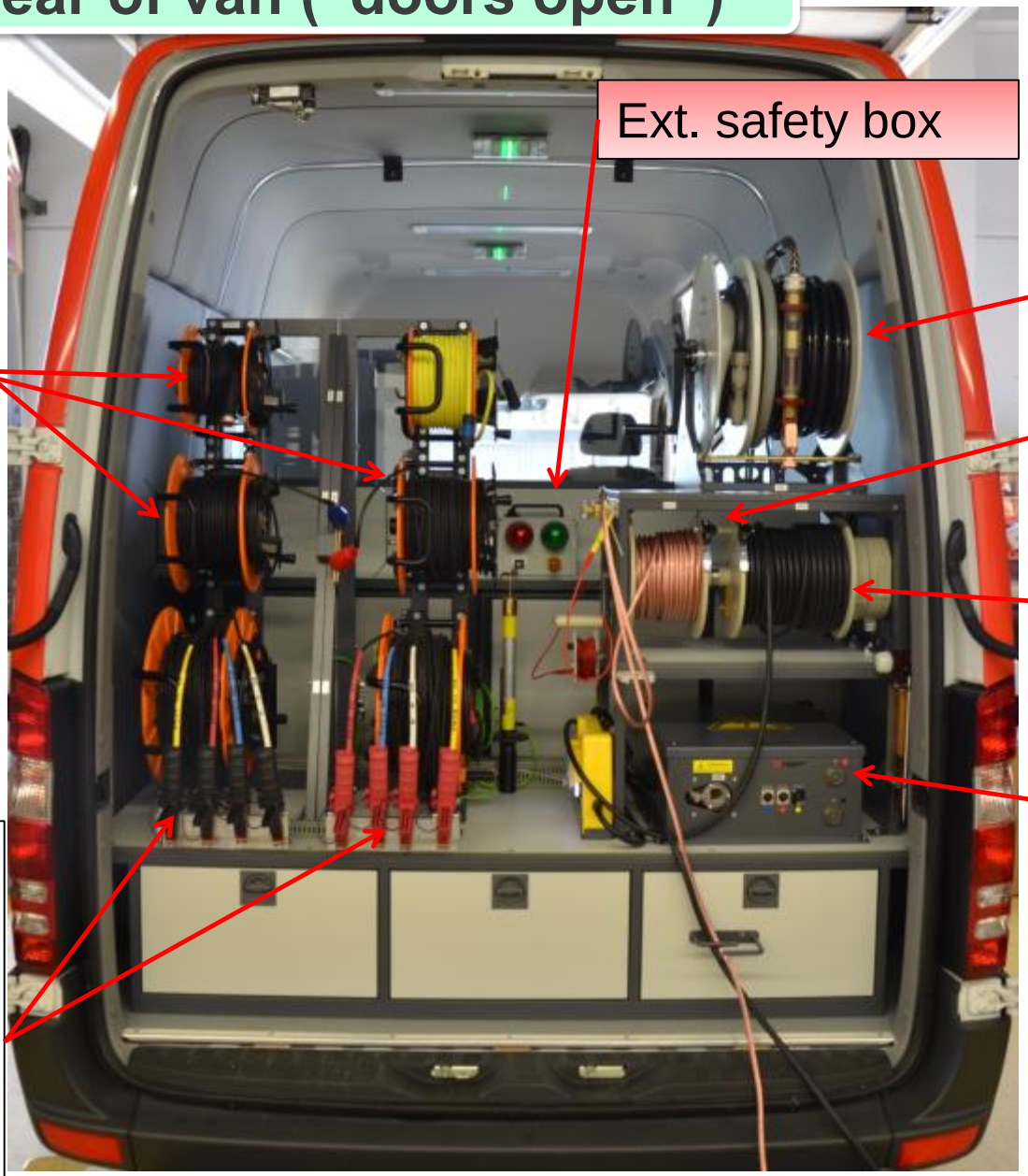
WiFi Keyboard and mouse

Power supply, control and safety unit

19” cabinets with test instruments inside

View from rear of van ("doors open")

Megger.



Ext. safety box

Drums w. 30 m cables for HV tests (IR, tanD /Capacitance)

HV cable

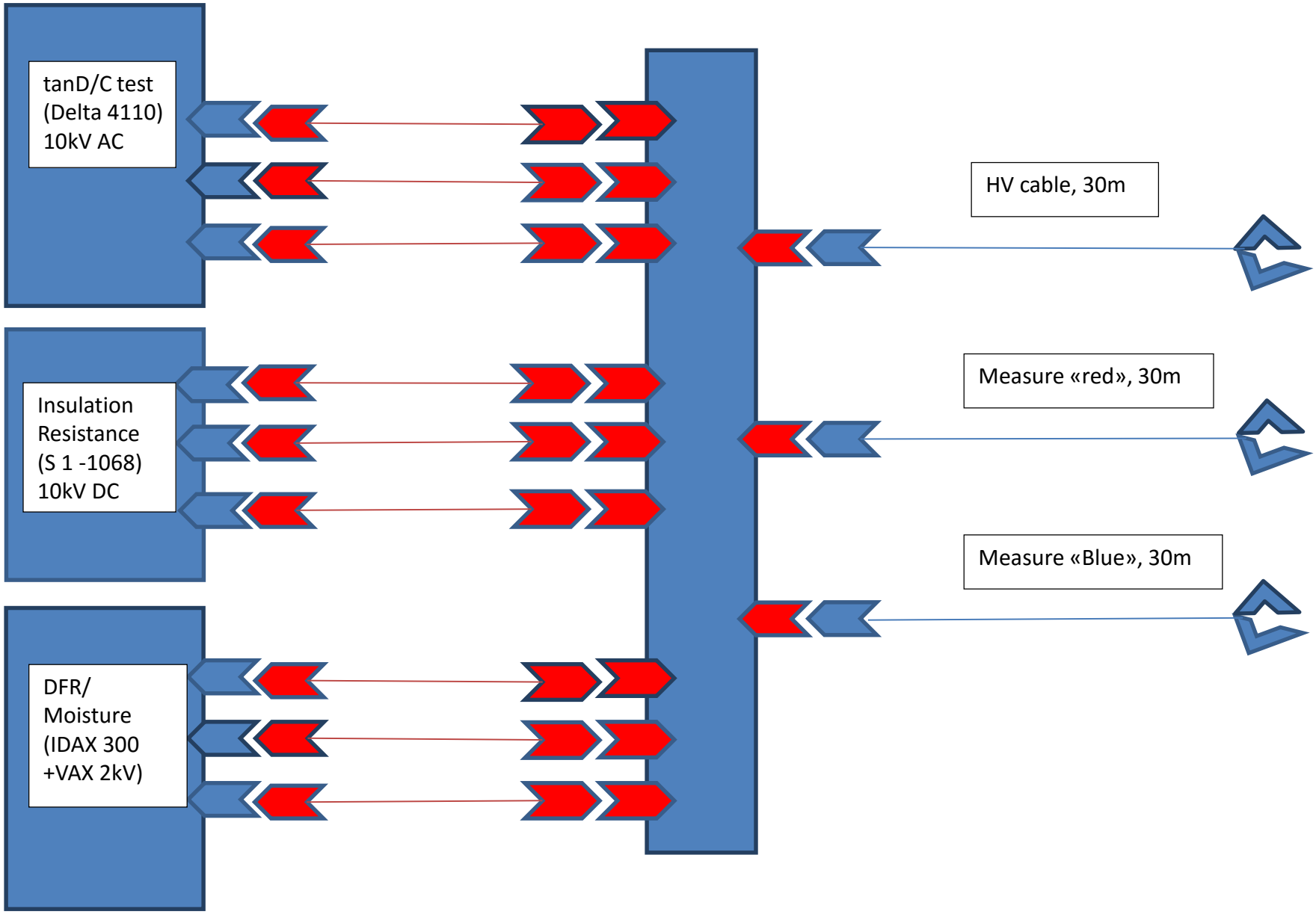
Protective earthing cable

Mains drum + fuse box

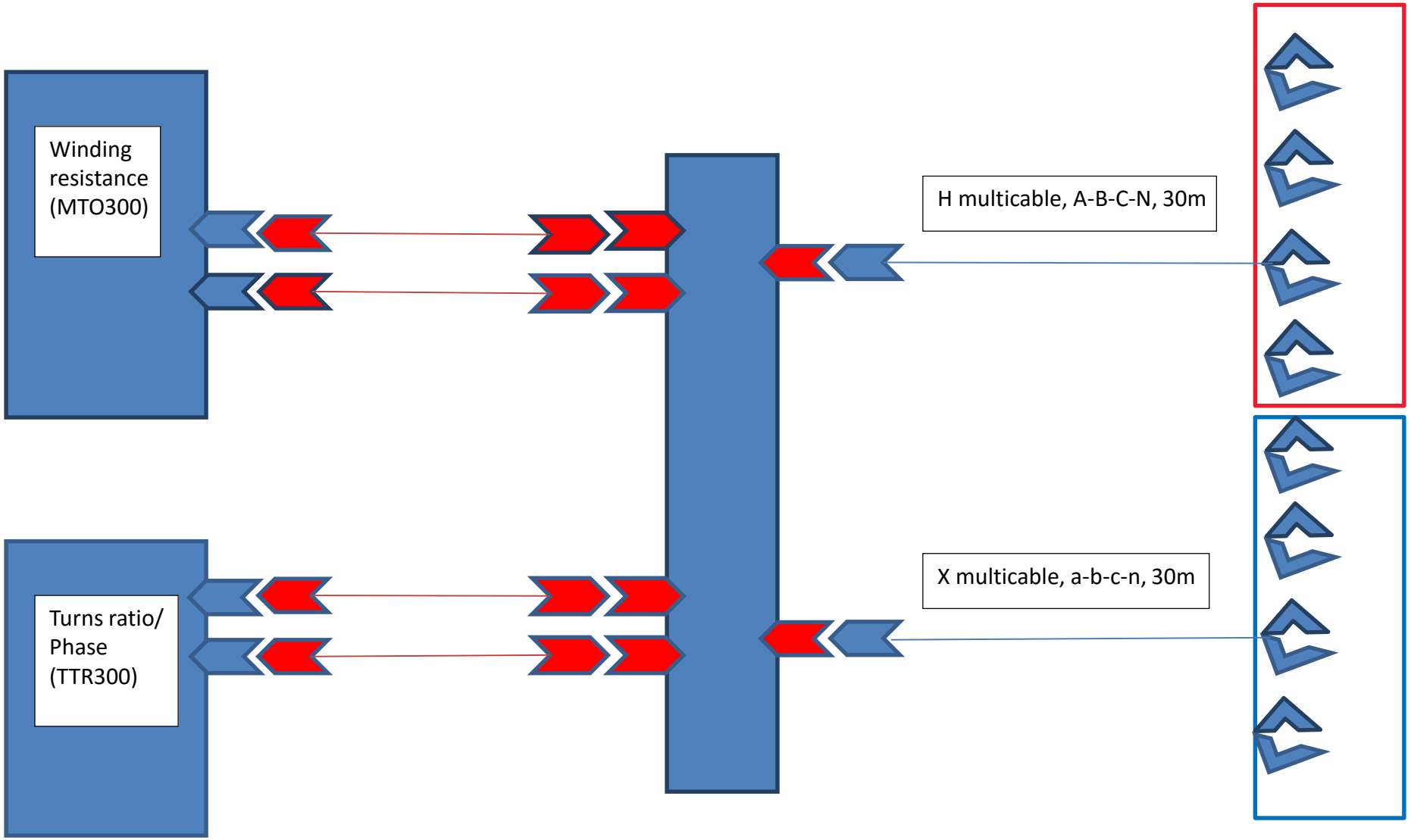
HV-LV Switch for measuring circuits

Drums 30 m cables for winding resistance / TTR tests (3ph + neutral, HV and LV side)

HV commutator

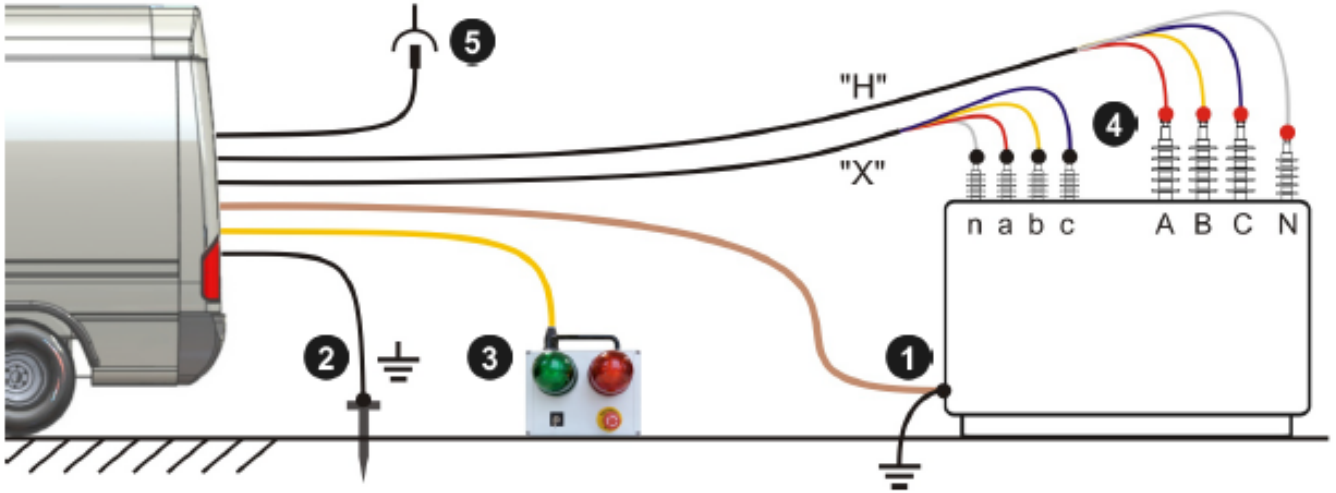


LV commutator

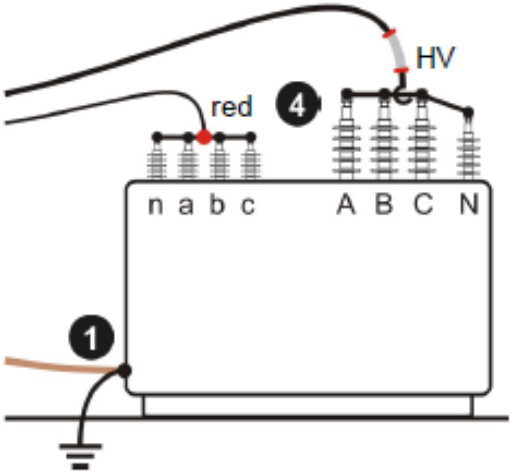


Connection diagram

LV Test Connection for MTO / TTR



HV Test Connection for DELTA / S1



Mandatory connection sequence:		Notes:
1 Protective earth	⚠	The test van should never be operated without the earth cable being connected! This applies in respect of mains operation as well as generator operation.
2 FU cable (earth spike)		The earth spike should be driven into the ground as close as possible to the vehicle.
3 External safety device		Norm-compliant signalling and Emergency Stop according to DIN EN 50191 / VDE 0104.
4 HV connection	⚠	Observe the five safety rules!
5 Power supply	📖	Connect the power cord to a mains outlet or a busbar in compliance with the requirements of the test van and of the specific country.
	⚠	If the conditions at the site make it impossible to establish the electrical connection in the way described above, it is the responsibility of the operator to ensure the safety of the connection to the test van by taking appropriate measures.

Optional: HV source on board

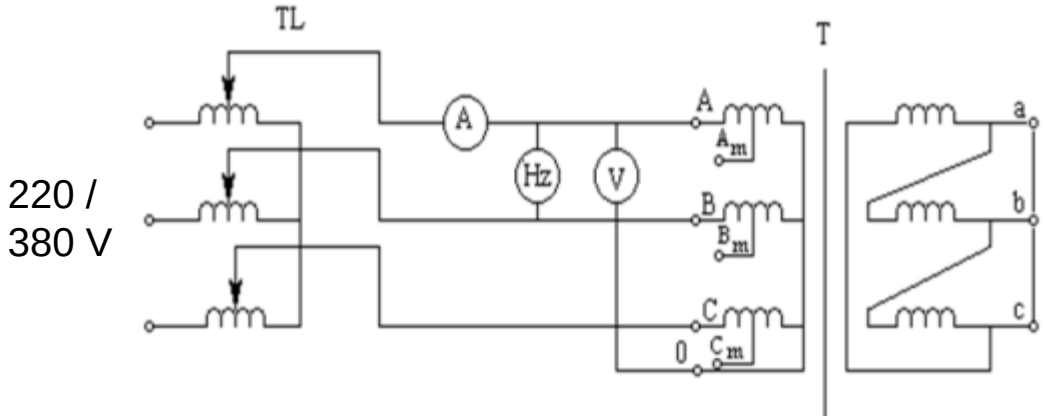
Single phase HV source

- 100 kV AC 50 Hz
- 70 kV DC

Optional: power loss measurement at reduced voltage

Loss measurement at reduced voltage of 380 / 230 V is a good compromise under on site conditions (due to limitations in power and voltage sources)

- No-load circuit
- Short circuit condition



Important to have a factory data on losses at reduced voltage as reference!

Well-known components:

Specification:

Parameter	Value
Power supply	1 or 3 phase, 230-400 V, 50-60 Hz
Test leads	30 m
Insulation testing (IR, DAR, PI, DD, SV)	
Test voltage	up to 10 kV
Range of measurement	100 kOhm…15 TOhm
Charging current	2 mA, 6 mA (short circuit)
Noise immunity	8 mA
Dissipation factor (tan δ)	
Test voltage	0-12 kV
Test current (at 12 kV)	300 mA (4 minutes), 100 mA (continuous)
Test frequency range	45-70 Hz (12 kV), 15-400 Hz (4 kV), 1-500 Hz (250 V)
Measurement range of dielectric losses tan δ and capacitance	0-100 (0-10,000%), (max. resolution 0.001%) 0 -100 µF, (max. resolution 0.01 pF)
Individual temperature correction of tan δ results	from 5°C to 50°C insulation test temperature to 20°C reference
Noise immunity	Electrostatic 15 mA, Electromagnetic 500 µT, at 50 Hz
Winding resistance and OLTC	
Core de-magnetisation	automatic
Test current	up to 10 A
Measurement range	1 µOhm – 2 kOhm
Accuracy	+/- 0,25%
Ratio and vector group	
Excitation voltage	up to 80 V
Ratio measurement range	0,8 – 45000
Phase deviation	+/-90°
Accuracy	+/-0,1%... +/- 0,3%
No-load and short-circuit loss power (optional)	
Range of measured AC voltage	0-650 V
Range of measured current	0-100 A
Range of measured power	0-100 kW
Frequency	10-1000 Hz
Voltage withstand testing (optional)	
AC 50 Hz test voltage	0…100 kV
DC test voltage	0…130 kV
Load capacitance	0,01-1,9 nF
Leakage current measurement	up to 100 mA
Max. power consumption	20 kVA
Frequency Response Analysis (optional)	
Moisture in cellulose assessment (optional)	
Control & data acquisition & reporting	PowerDB, LabTransControl
Basic operating system	WIN 7
Interface	RS 232, USB, Ethernet

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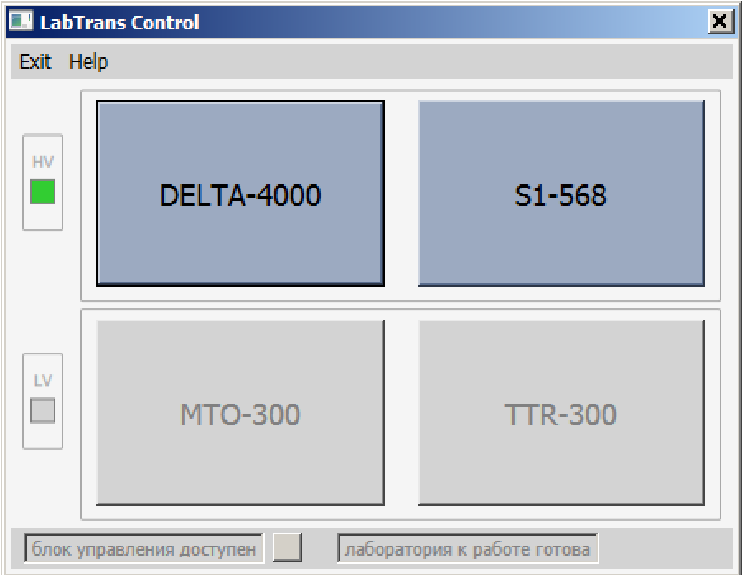
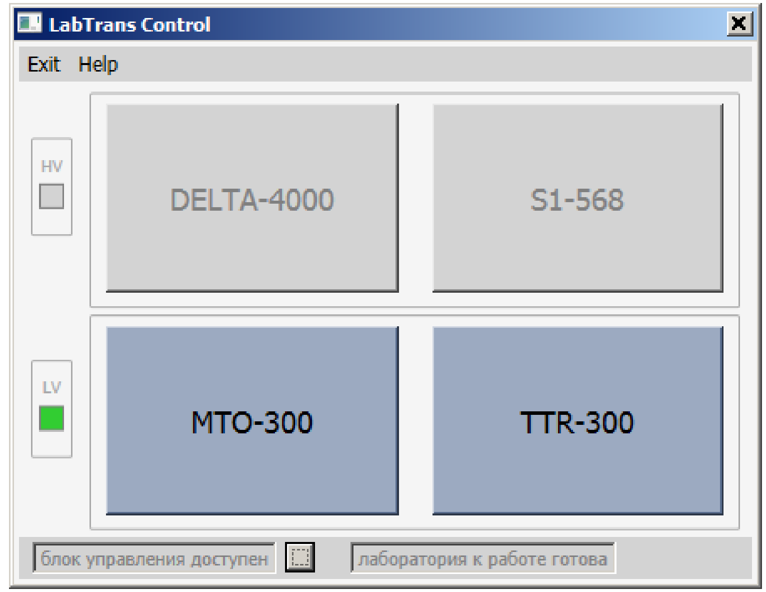
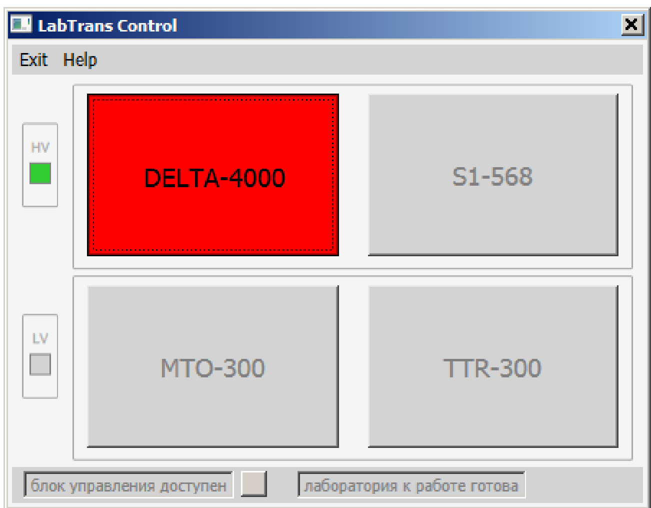
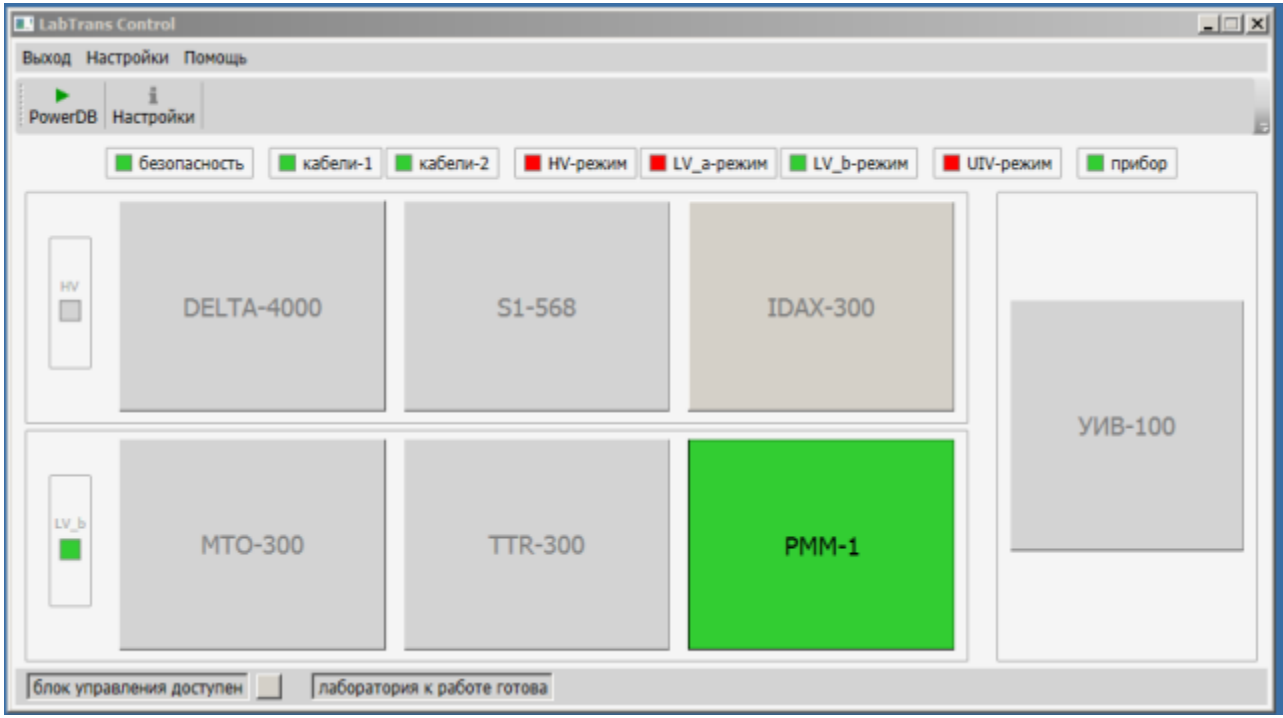
Software: Device selector

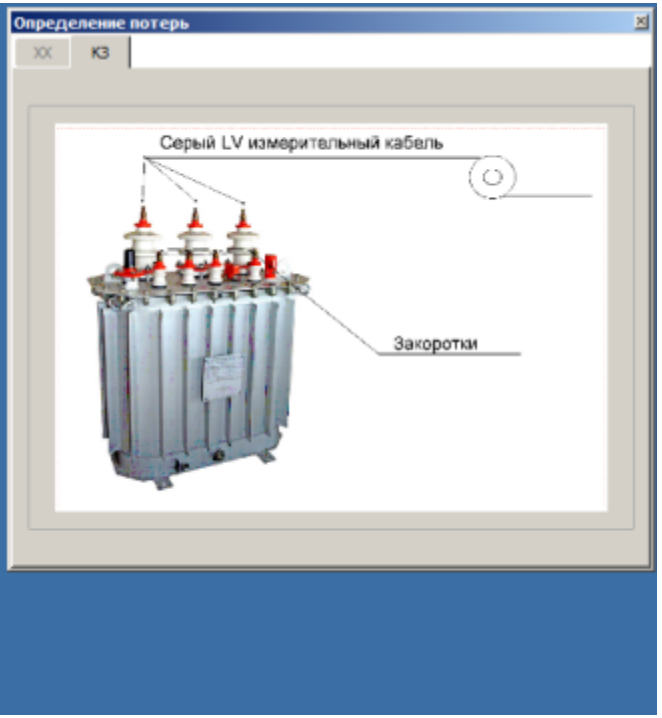






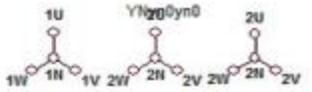
Optional: power loss measurement at reduced voltage





Complete report with PowerDB

MFR	Schorch	WEIGHT	214000 kg	OIL VOLUME	24000 kg		
SER NO		WEATHER	Sunny	OIL TEMP	25 °C		
YEAR		BIL	kV	WINDING TEMP	25 °C		
TYPE	SEALED	IMPEDANCE	13 %	CORRECT TO	85 °C		
CLASS		REASON	Routine	COOLANT	OIL		
PHASES	3	Max Wdg Diff (%):	1				



Has Tertiary ☑ Diagramm # 29 (IEC)

	VOLTAGE (kV)	kVA	RATED I	# TAPS	NOMINAL	CHANGER	TAP SETTING	WINDING MATERIAL	SHOW RESULTS
PRIMARY:	220 / 127,017	150.000	393,65	14	7	OLTC		Cu	☑
SECOND:	110 / 63,509	150.000	787,30	1				Cu	☑
TERTIAR:	10 / 5,774	50.000	2.886,75	1				Cu	☑

Form/Tap Settings | Instrument Settings | Demag | Test Wizard (F2)

Round Tap Voltages To: 1 Volt

Enable Manual Testing: ☐

First Tap 1 Voltage 255,243

Last Tap: 14 Voltage 184,757

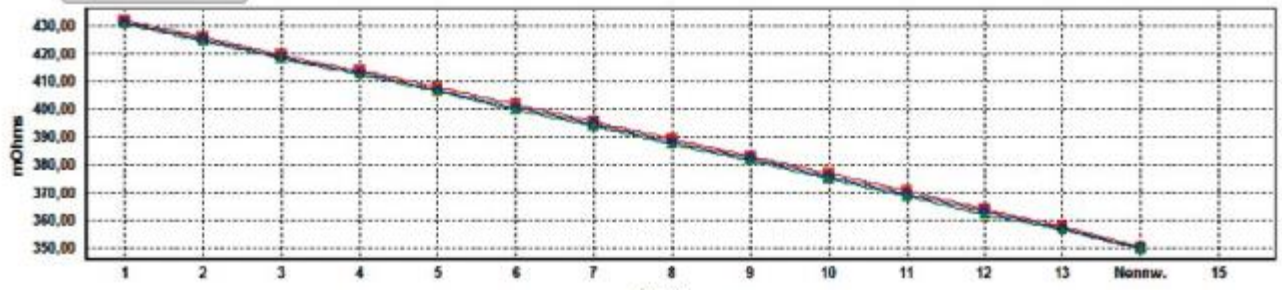
HIGH VOLTAGE WINDING RESISTANCE

Show Graph ☑

Stufenschaltercheck deaktivieren ☑ Units: mOhms

#	TAP	Current (amp)	Nameplate Voltage	Measured Resistance 1U-1N	1V-1N	1W-1N	Reading Stability %	Winding Difference %
1		8,134		432,2	431,5	430,8	99,87	0,320
2		8,128		426,3	425,4	424,7	99,89	0,361
3		8,114		419,8	419,0	418,5	99,86	0,301
4		8,115		413,8	413,0	412,2	99,91	0,396
5		8,111		407,7	406,7	406,1	99,95	0,386
6		8,092		401,5	400,2	399,5	99,91	0,491
7		8,093		395,1	394,5	393,9	99,93	0,325
8		8,191		389,0	388,1	387,1	99,90	0,503
9		8,187		382,9	382,1	381,4	99,82	0,381
10		8,185		376,7	375,7	374,9	99,93	0,477
11		8,181		370,7	369,3	368,5	99,93	0,594
12		8,175		364,1	363,2	362,2	99,92	0,541
13		8,172		357,7	357,1	356,5	99,90	0,332
14		8,165		350,5	350,0	349,5	99,83	0,269

Format Kurvenachse



Conclusions

- Transformer test van concept:
  - combines routine electric tests and advanced diagnostic techniques
  - allows a complete transformer check in field.
- Field experiences:
  - substantial testing time saving >70%
  - help prevent accidents
- Streamlined data handling:
  - reporting, database for assessing results, comparing w previous tests and eventually establishing trend of the transformer condition