بسم الله الرحمن الرحیم

All-in-one Test Solution

KAVOSH T22

EAFA GROUP

All-in-one Test Solution

KAVOSH T22

Power Transformer Diagnostics

International Standards related to PT

Standards

- IEC 60076
- IEEE C57.152
- IEC 61378-1
- IEC 60137
- IEC 60214
- IEEE C12.90
- IEEE C57.125
- IEC 60422
- IEEE C57.104

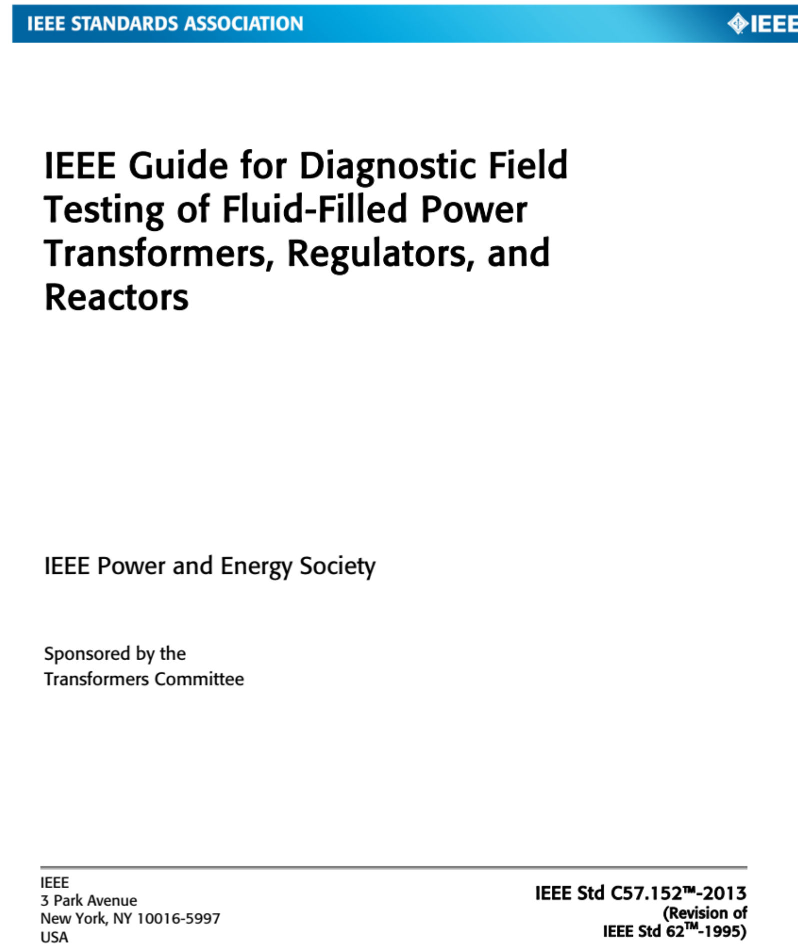
IEC 60076-1

Edition 3.0 2011-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Power transformers –
Part 1: General



IEEE STANDARDS ASSOCIATION

IEEE

IEEE Guide for Diagnostic Field Testing of Fluid-Filled Power Transformers, Regulators, and Reactors

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C57.152™-2013
(Revision of
IEEE Std 62™-1995)

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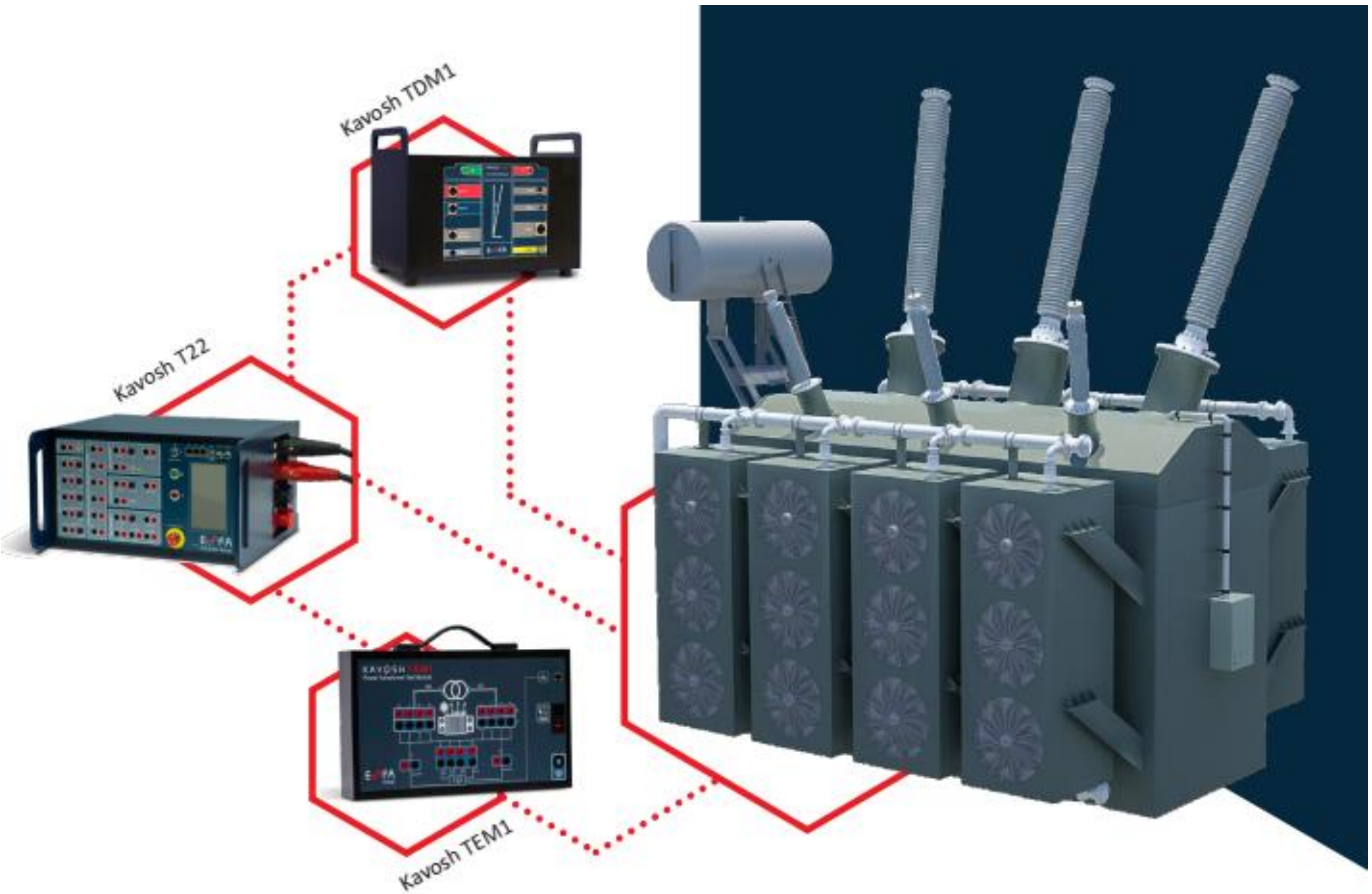
On-site Tests of the PT

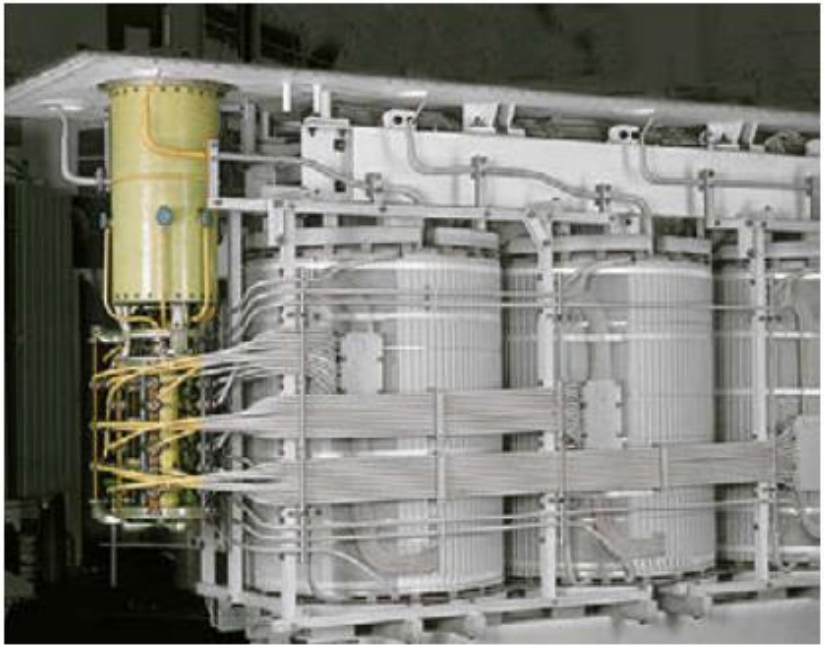
- Winding Resistance
- Dynamic Resistance of On Load Tap Changers (OLTCs)
- Demagnetization
- Turn Ratio (TTR)
- Excitation Current (No-Load Current)
- Magnetic Balance
- Vector Group
- Short Circuit Impedance
- Zero Sequence Impedance
- Capacitance and Dissipation Factor
- Insulation Resistance

On-site Tests of the PT



On-site Tests of the PT

Dynamic resistance of On Load Tap changers (OLTCs)



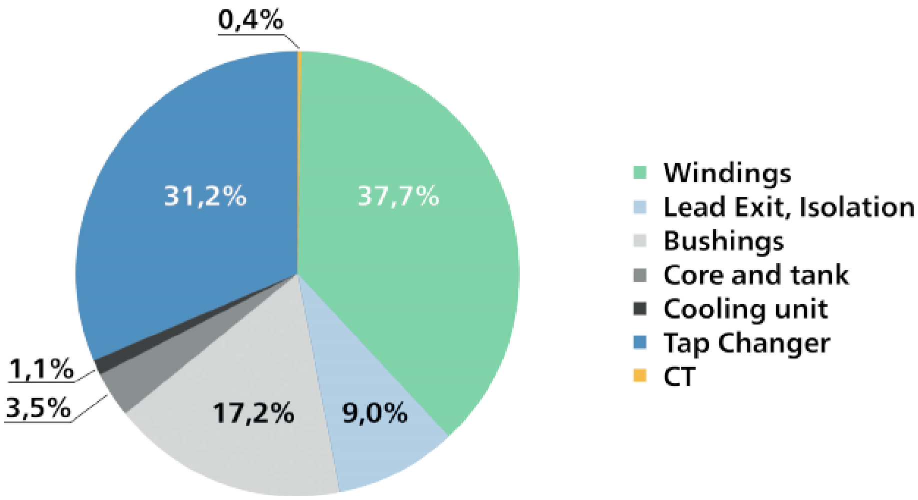
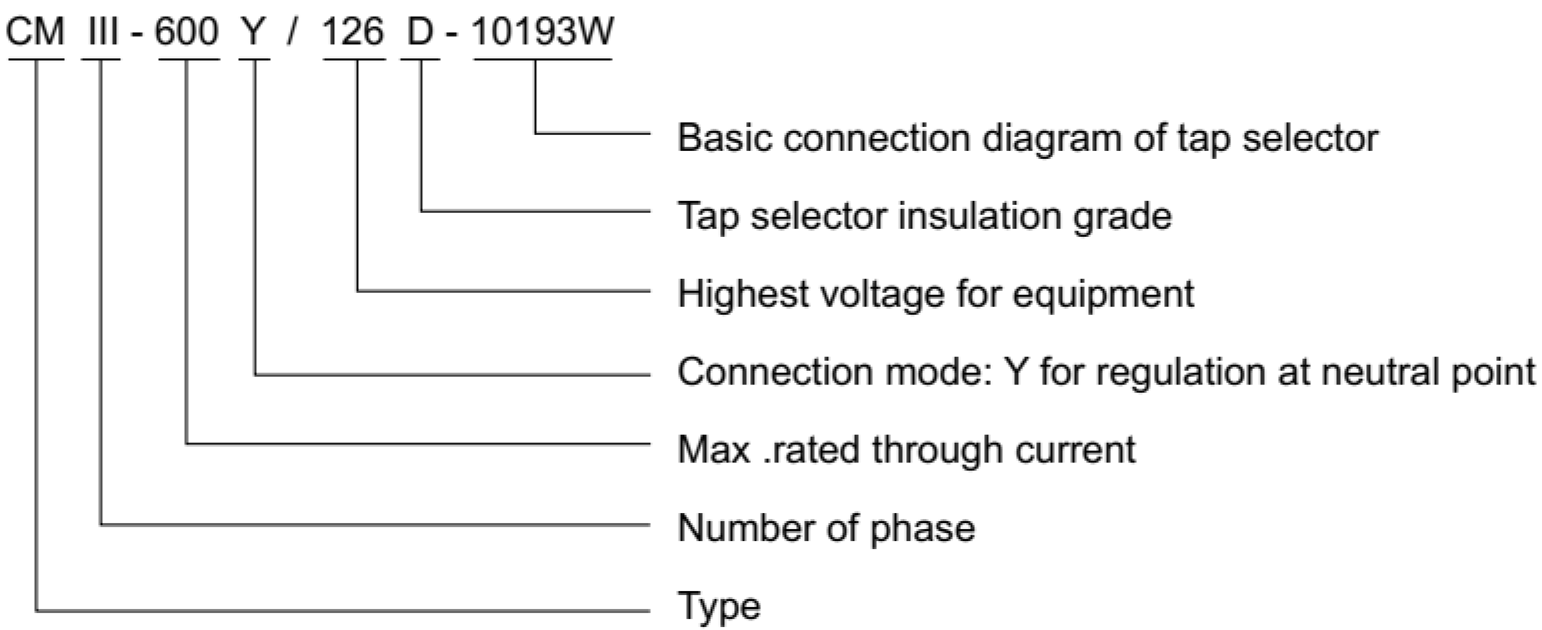


Figure 1. Failure location of substation transformers based on 536 failures [1]

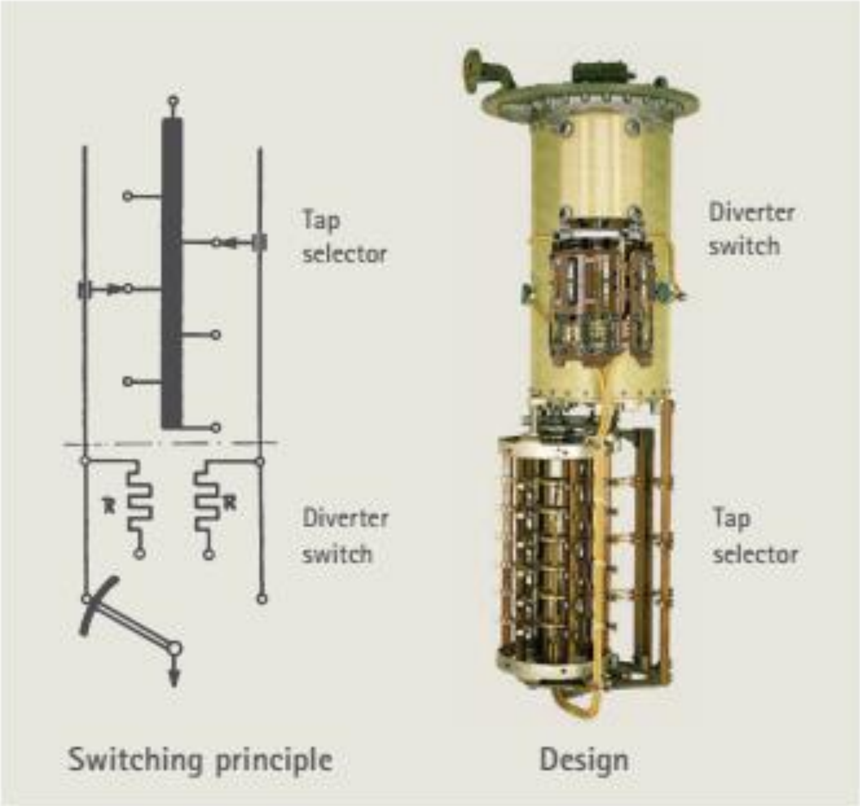
On-site Tests of the PT

Dynamic resistance of On Load Tap changers (OLTCs)



On-site Tests of the PT

Resistive Oil Type OLTC



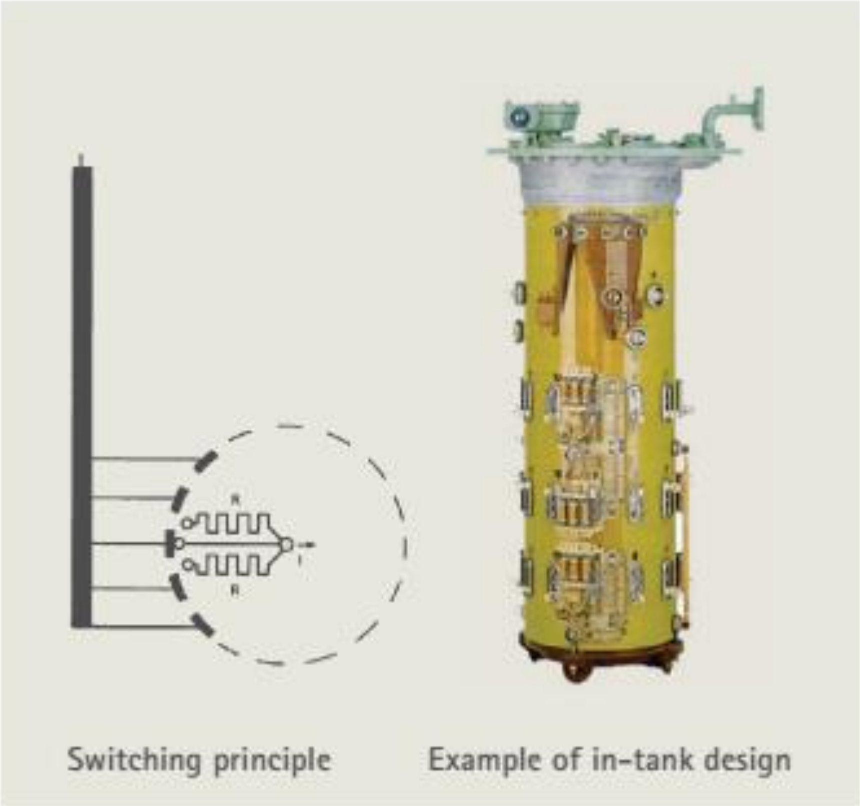


Fig. 11: Design principle – diverter switch (arcing switch) with tap selector OILTAP® M®

Fig. 13: Design principle – selector switch (arcing tap switch) OILTAP® V®

On-site Tests of the PT

Resistive Oil Type OLTC

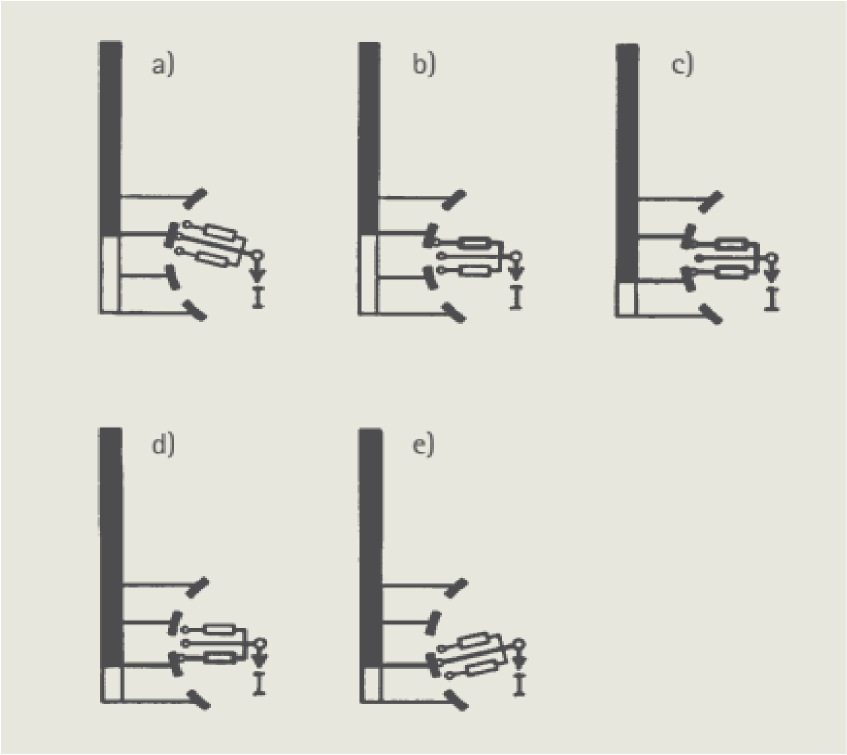


Fig. 14: Switching sequence of selector switch (arcing tap switch) OILTAP® V®

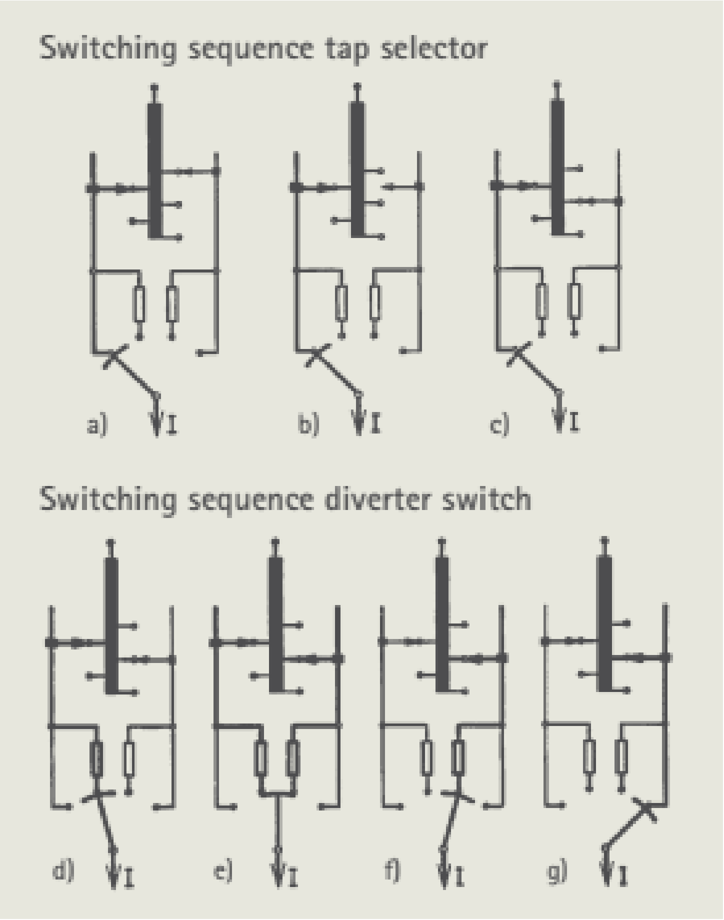


Fig. 12: Switching sequence of tap selector – diverter switch (arcing switch)

On-site Tests of the PT

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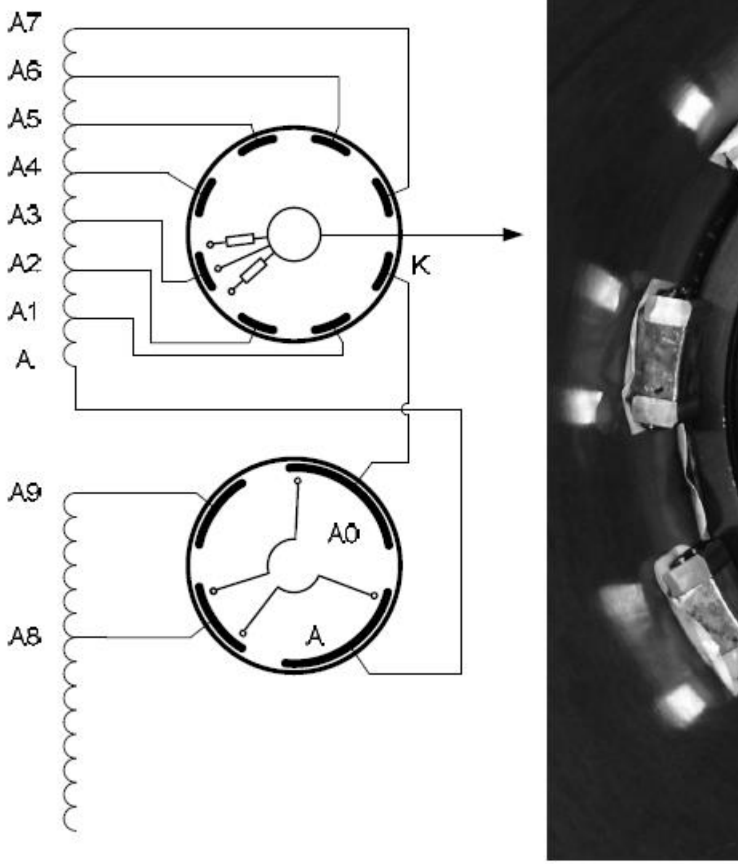


Figure 2.1 Selector switch type OLTC with
of the stator contacts of a selector switch wh

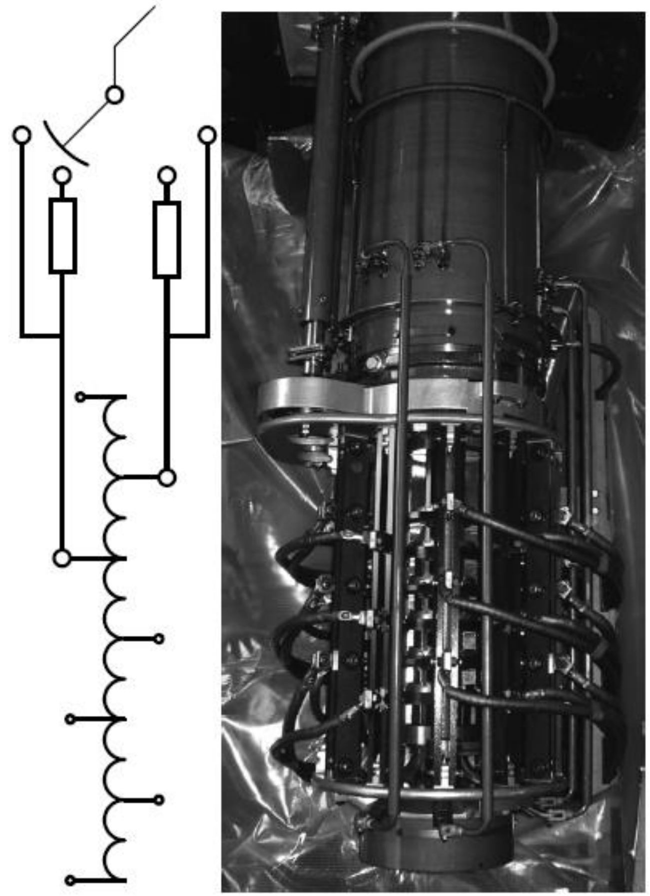


Figure 2.2 Diverter switch with transition resistors (top) and a tap selector (bottom).

picture
l.

On-site Tests of

Resistive Oil Type OLTC

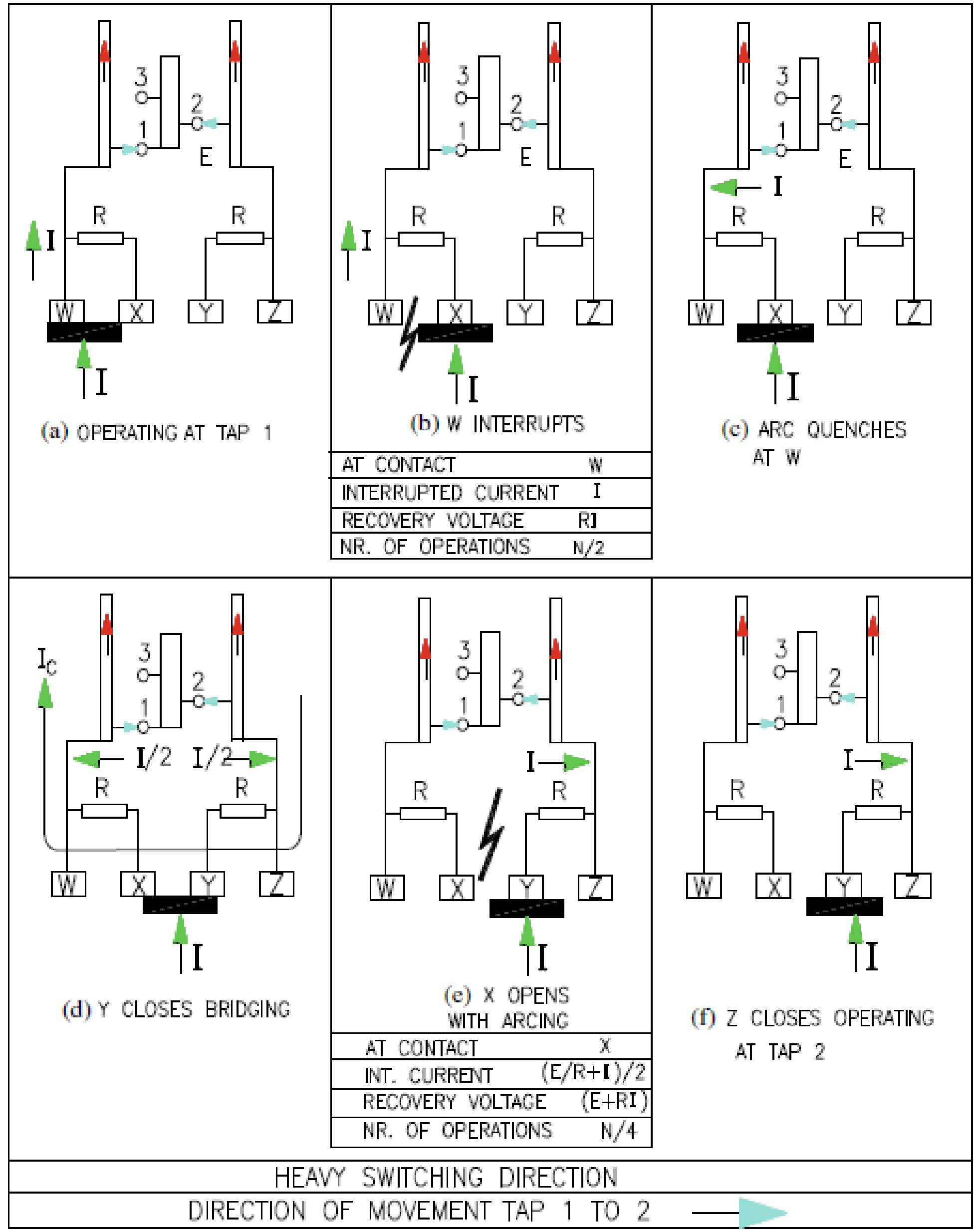
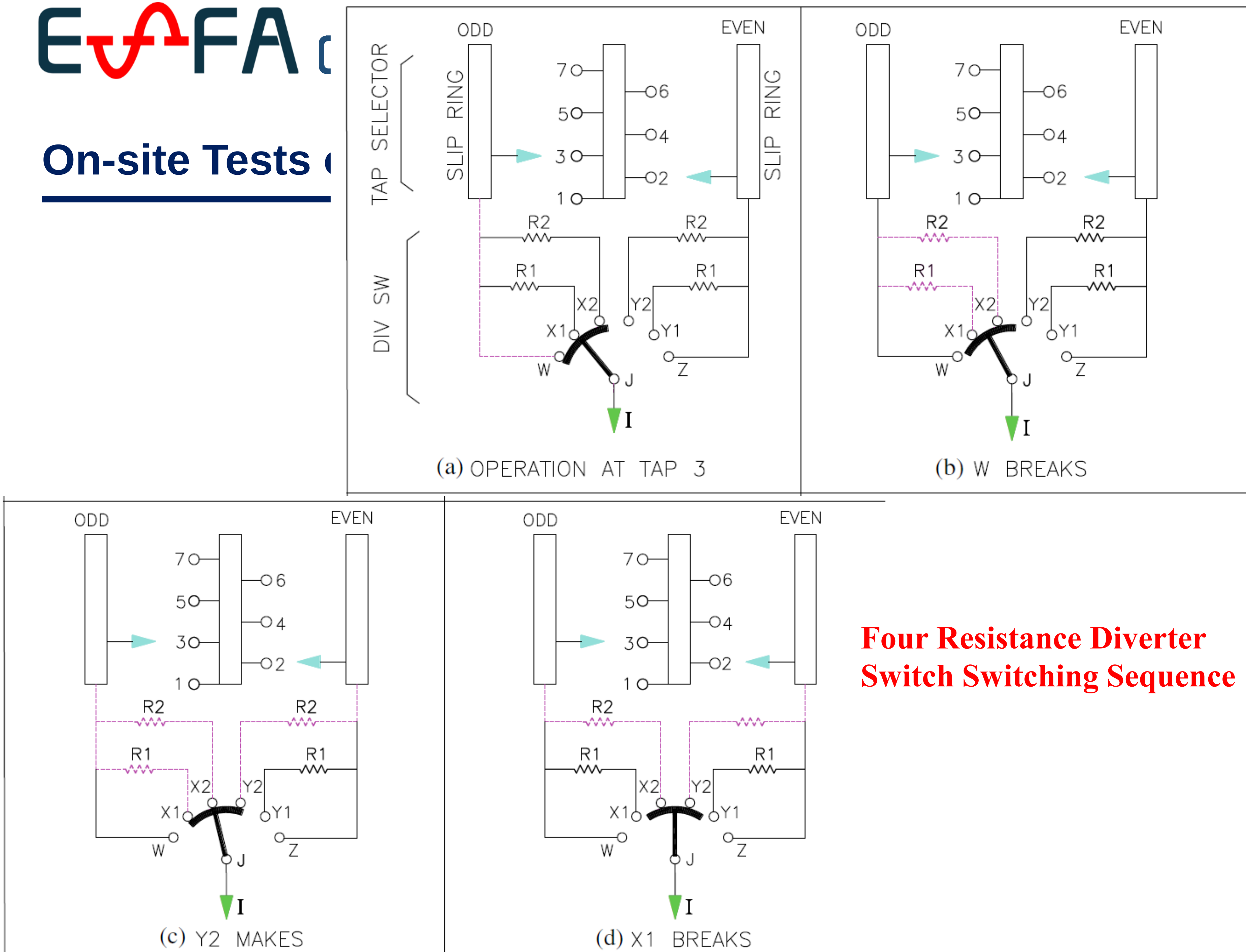


Fig. 3.8 a–f Page 1: Interruption duties of diverter switch. g–n Page 2: Interruption duties of diverter switch. o–u Page 3: Interruption duties of diverter switch. v–ac Page 4: Interruption duties of diverter switch

On-site Tests



Four Resistance Diverter Switch Switching Sequence

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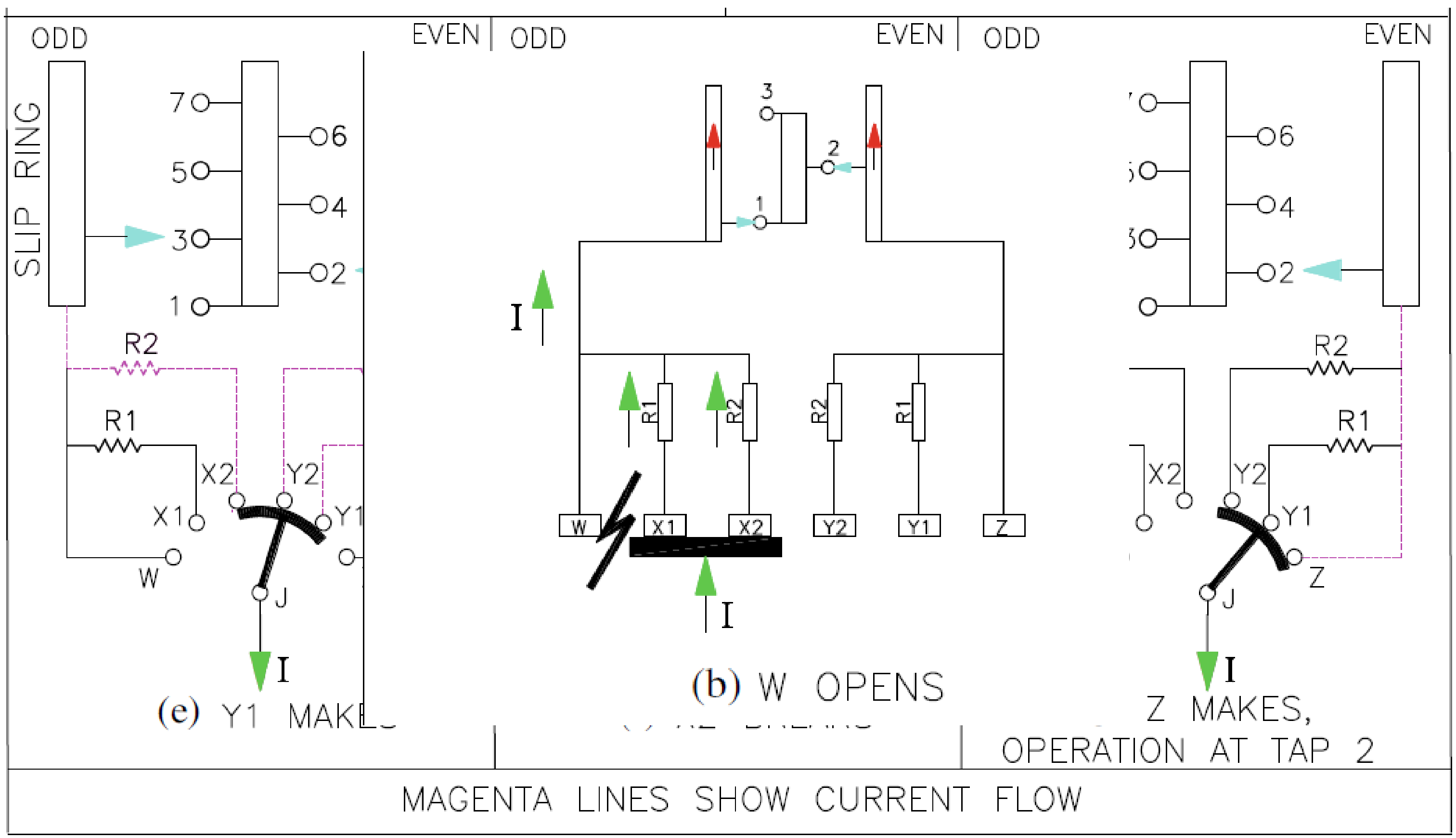
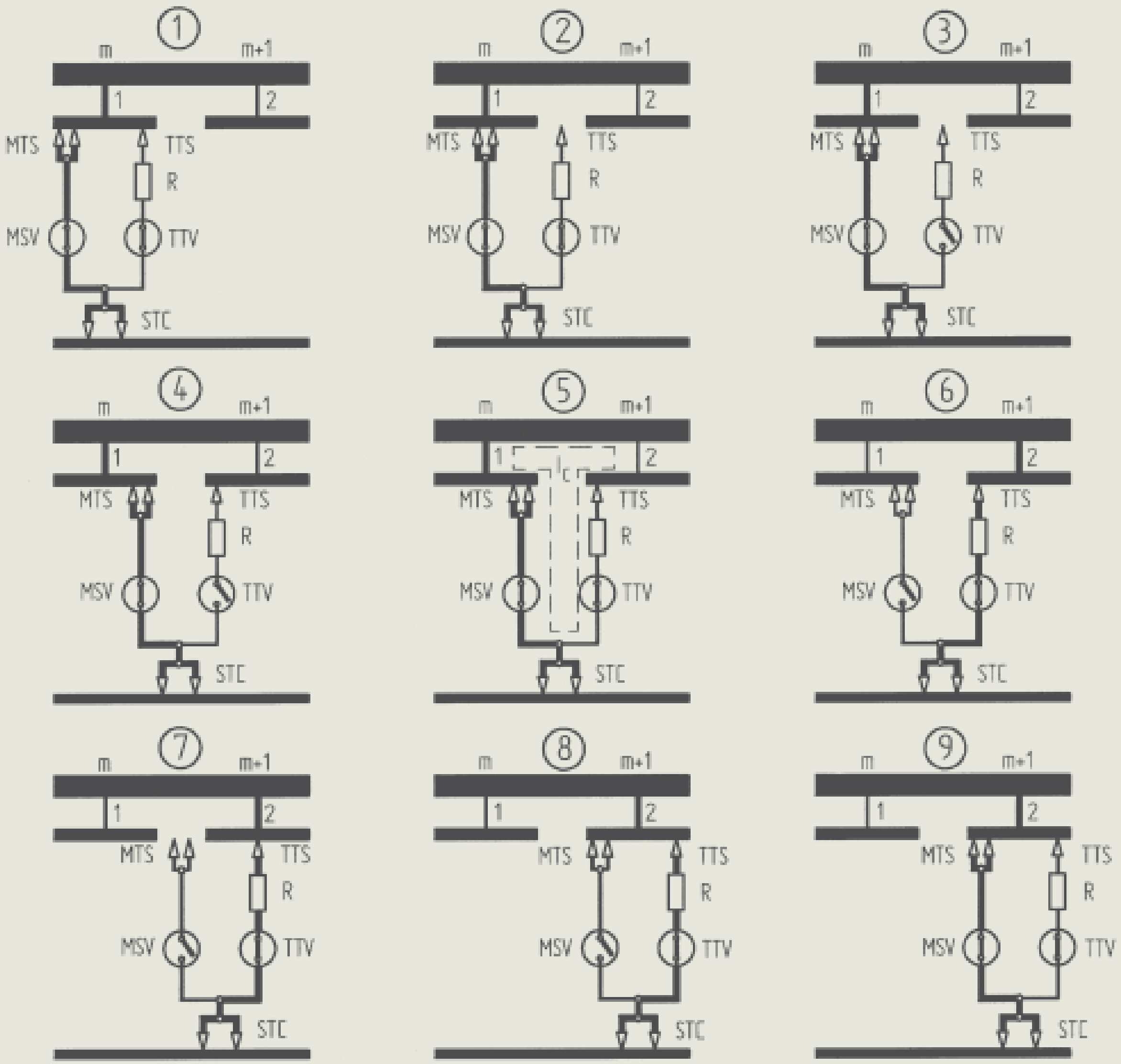
On-site Tests of the PT

Four Resistance Diverter Switch Switching Sequence

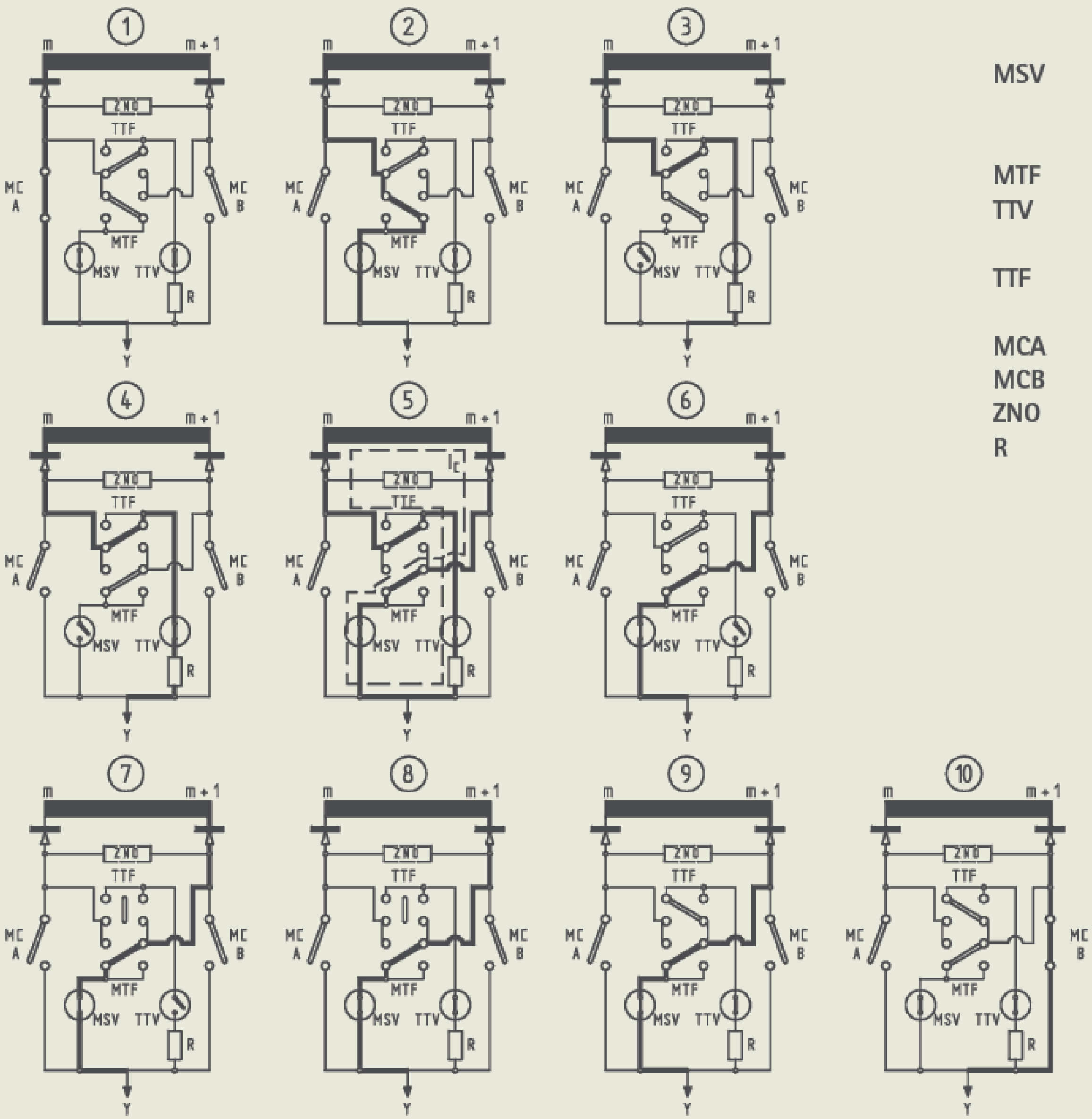


ig. 3.13 Operating sequence of four resistance diverter switch



MTS	Tap selector contacts, main path
MSV	Main switching contacts (vacuum interrupter), main path
TTS	Tap selector contacts, transition path
TTV	Transition contacts (vacuum interrupter), transition path
STC	Sliding take-off contacts
R	Transition resistor
IC	Circulating current
m, m+1	Tap m, tap m+1

Fig. 28: Switching sequence of resistor type OLTC with the same vacuum interrupters for the closing and opening side of the diverter switch – VACUTAP® VV®

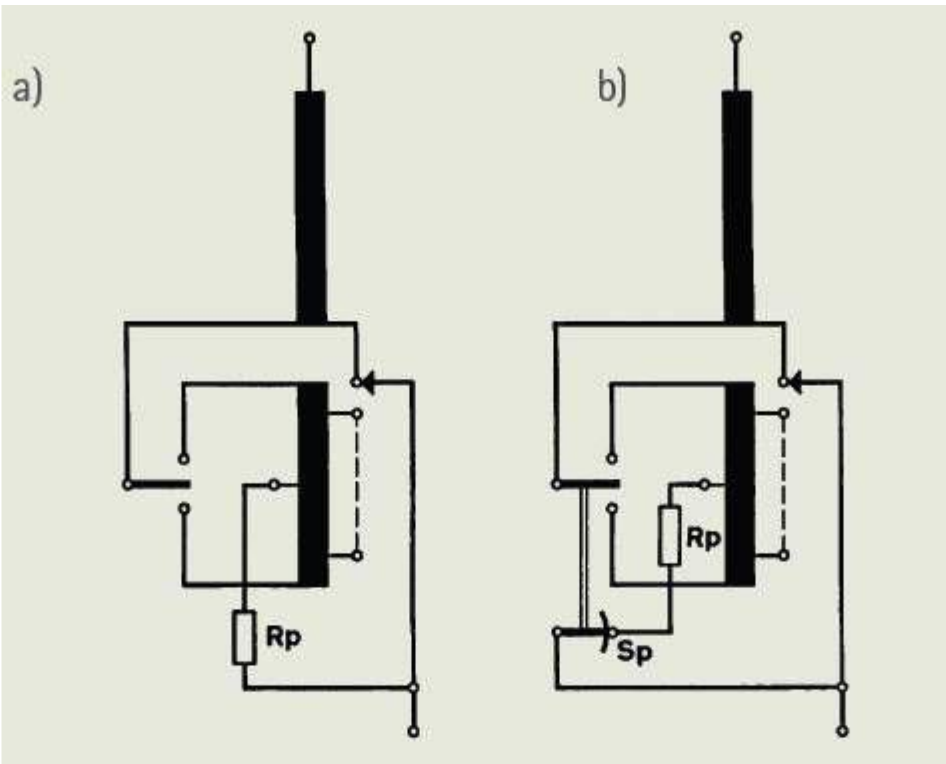


MSV	Main switching contacts (vacuum interrupter), main path
MTF	Transfer switch, main path
TTV	Transition contacts (vacuum interrupter), transition path
TTF	Transfer switch, transition path
MCA	Main contacts side A
MCB	Main contacts side B
ZNO	ZNO arrester
R	Transition resistor

Fig. 29: Switching sequence of resistor type OLTC VACUTAP® VR®

On-site Tests of the PT

Tie-in Resistor



Tie-in resistor

On-site Tests of the PT

Dynamic resistance vs static resistance

- **Static winding resistance measurement:**

Investigation of resistance-oriented issues of winding, bushing connection and contact, and tap changer connection and contacts

- **Dynamic resistance measurement (DRM) of OLTC:**

Investigation of transient contacts, transition resistor/reactor, and OLTC mechanism during tap switching intervals (between 40 to 70 ms)

On-site Tests of the PT

Measurement methods:

- Discontinuity detection
- Dynamic current (resistance) measurement

On-site Tests of the PT

Measurement methods:

- **Discontinuity detection:**
  - ✓ **Detecting undesired break before make condition by monitoring current change**
  - ✓ **Simultaneous winding resistance measurement**

This test starts after severe core saturation. This results in more current level change and longer duration.

On-site Tests of the PT

Measurement methods:

- **Dynamic Current Measurement:**
  - ✓ Describes conditions during operation and provide contact timing
  - ✓ Detect discontinuity with current change detection
  - ✓ Presented as a percentage ripple, slope, and current-time diagram

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On-site Tests of the PT

Measurement principle

- Discontinuity detection:
  - ✓ Detecting undesired break before make condition by monitoring current change
  - ✓ Simultaneous winding resistance measurement

This test starts after severe core saturation. This results in more current level change and longer duration.

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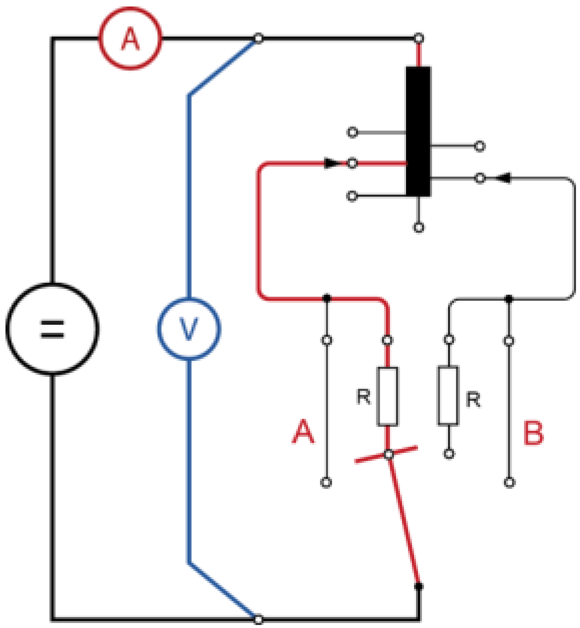
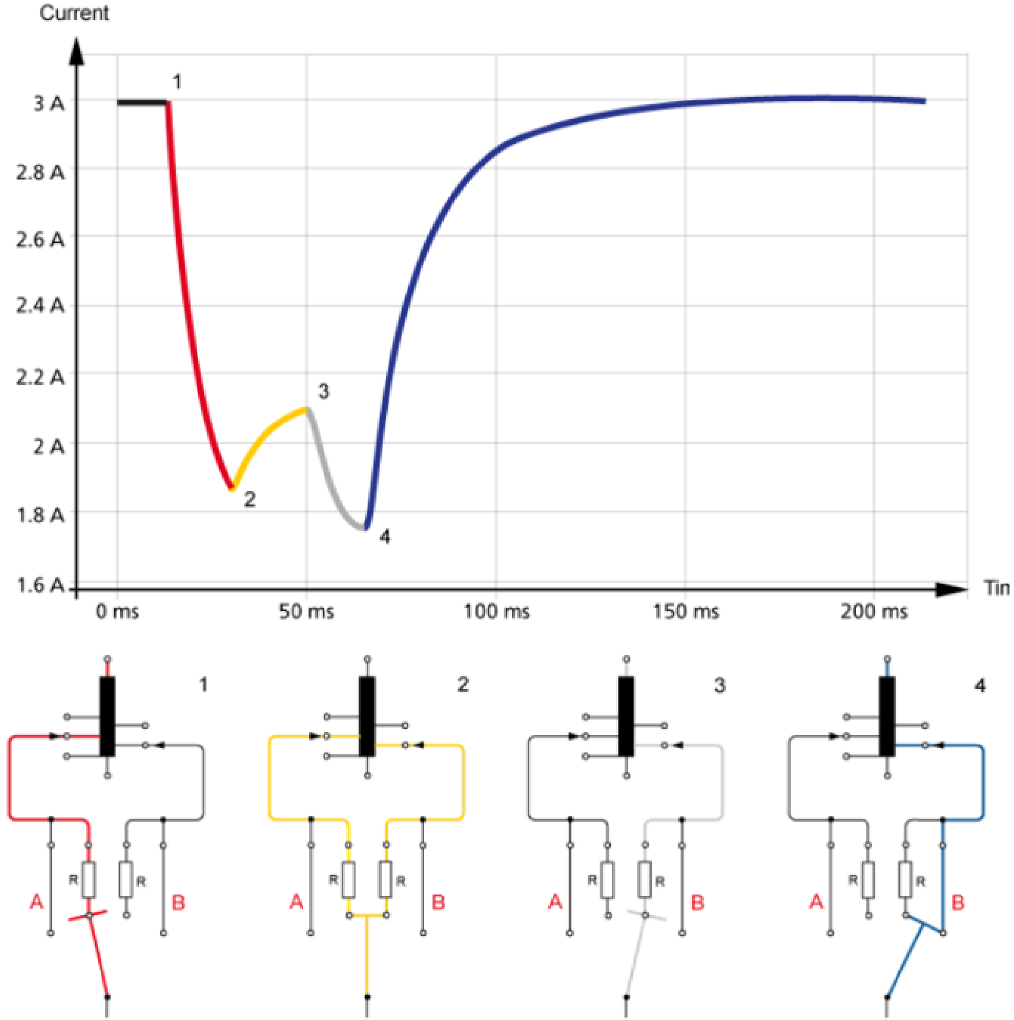
On-site Tests of the PT

Measurement principle





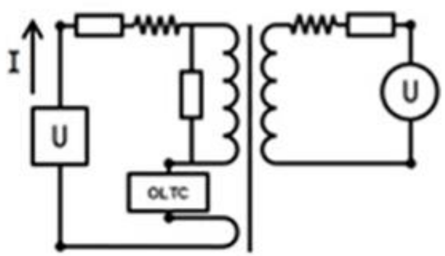
On-site Tests of the PT

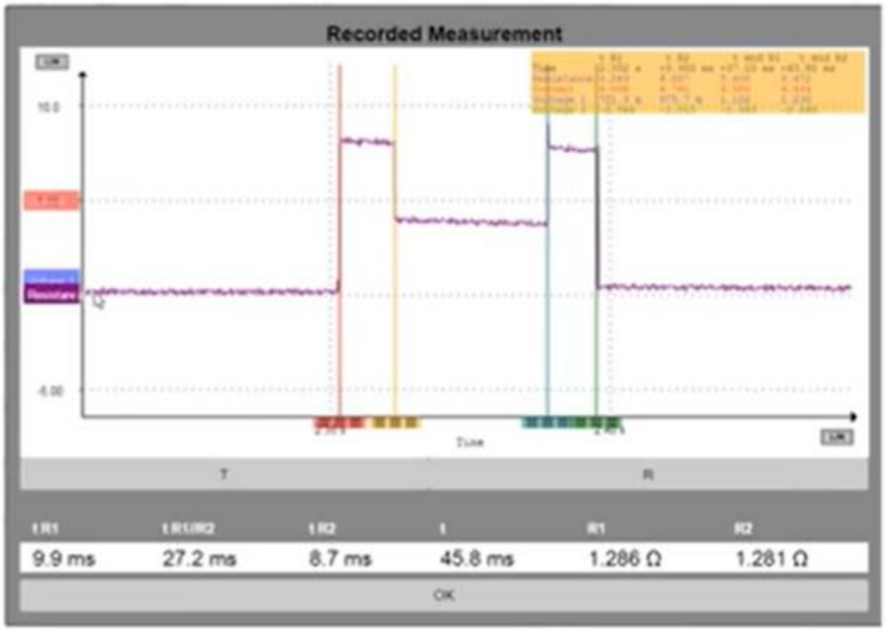
Measurement principle

- Not measured directly, calculated from measured voltage and current

$$U = RW \times I + \left(\frac{n_1}{n_2}\right) \times U_2 + U_{OLTC}$$

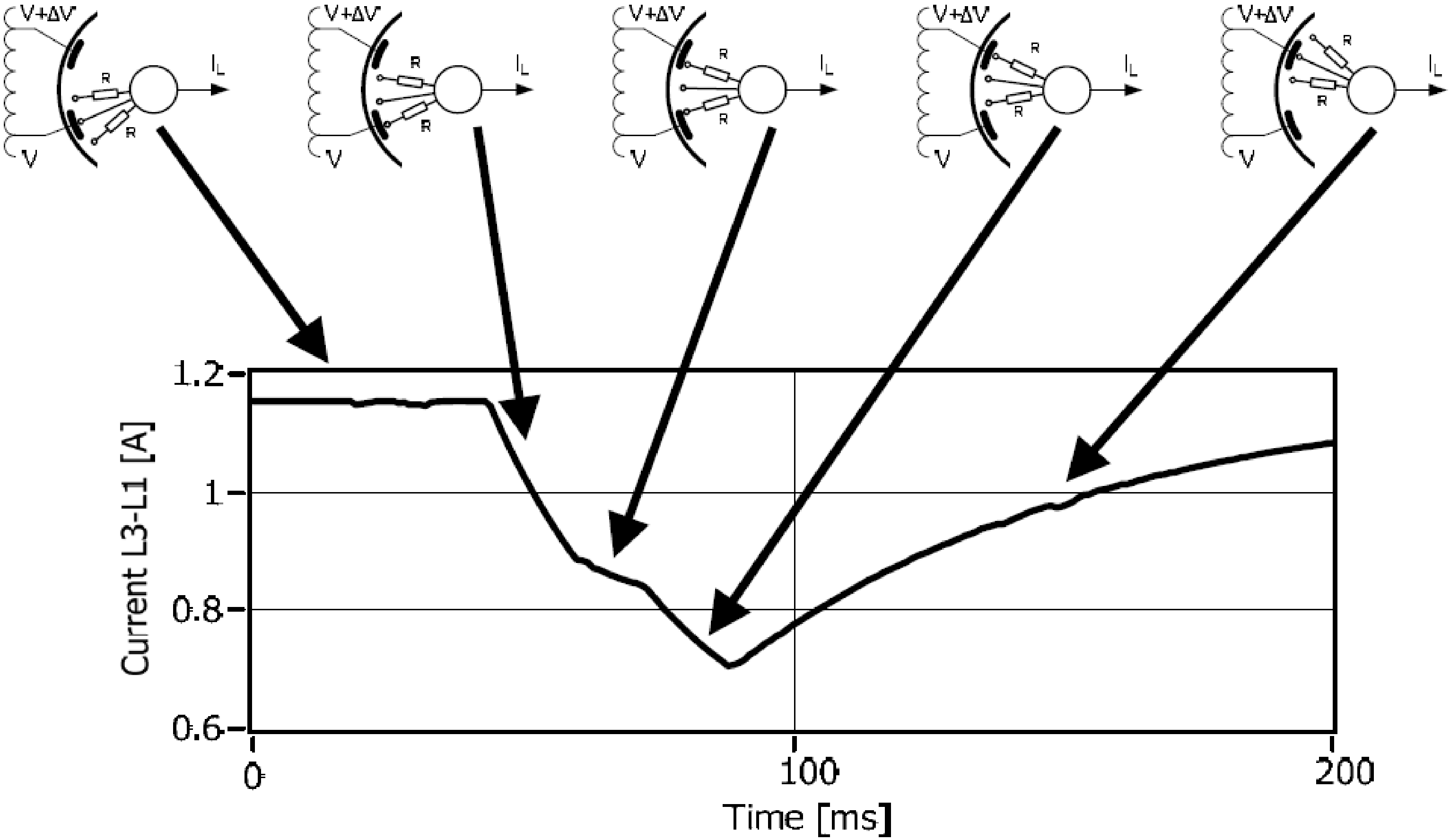
$$R_{OLTC} = \frac{U_{OLTC}}{I}$$





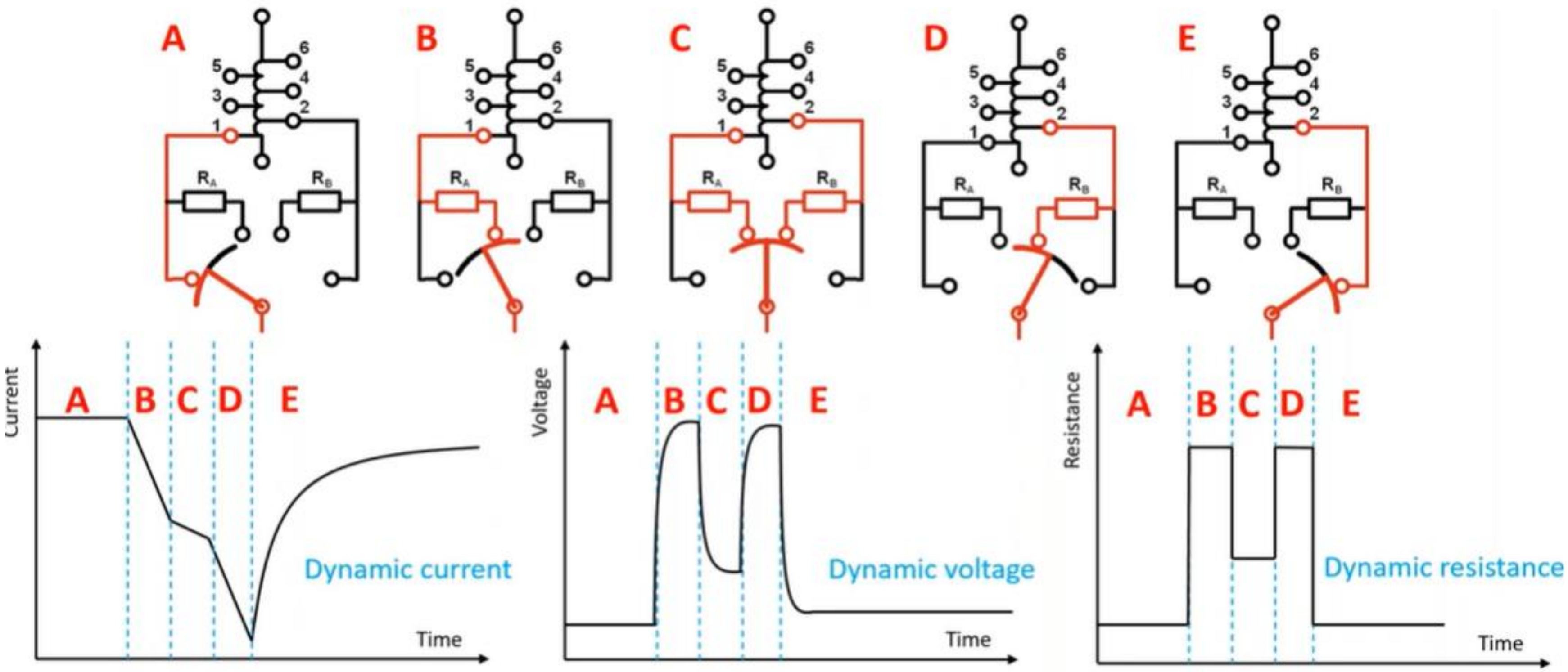
On-site Tests of the PT

Measurement principle



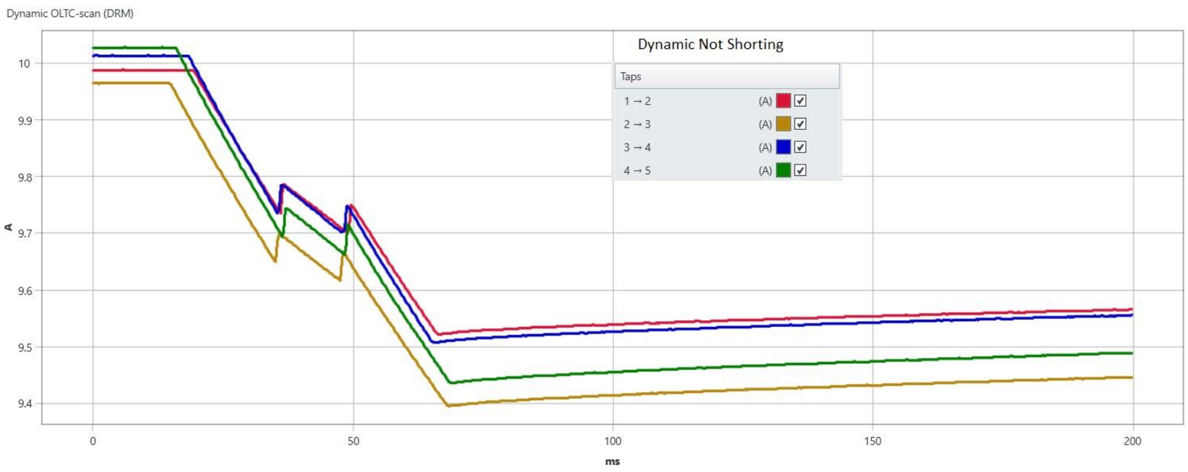
On-site Tests of the PT

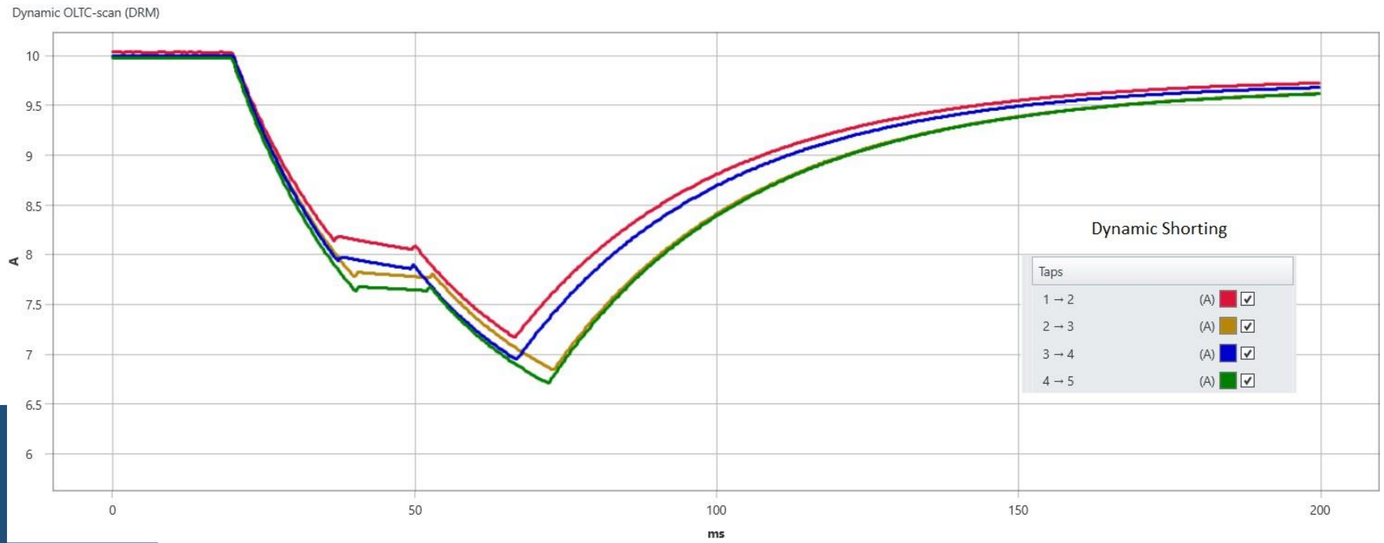
Measurement principle



On-site Tests of the PT

Secondary Short Circuit:

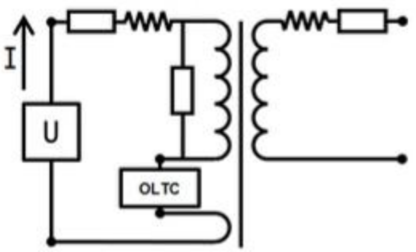


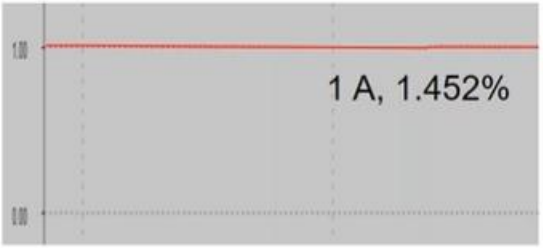


On-site Tests of the PT

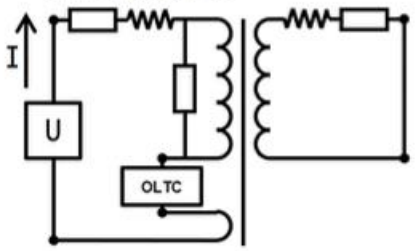
Secondary Short Circuit:

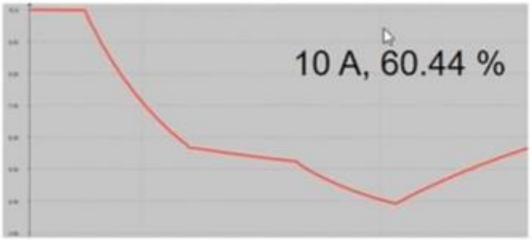
- Open LV

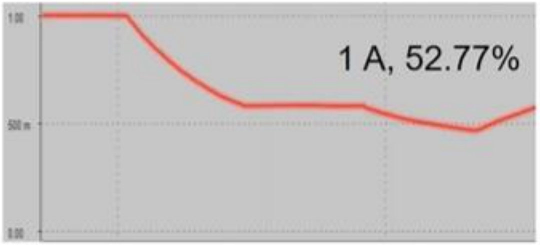




- Shorted LV







On-site Tests of the PT

I Test ?

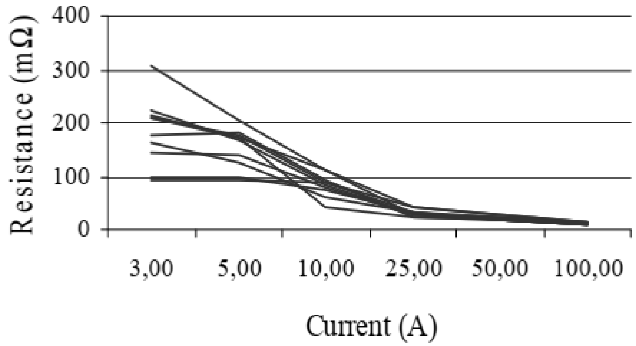


Figure 4.8 Static resistance measurements of service-aged OLTC contacts. The measurement current was increased to 100 A. A strong dependency of the contact resistance on the measurement current is revealed.

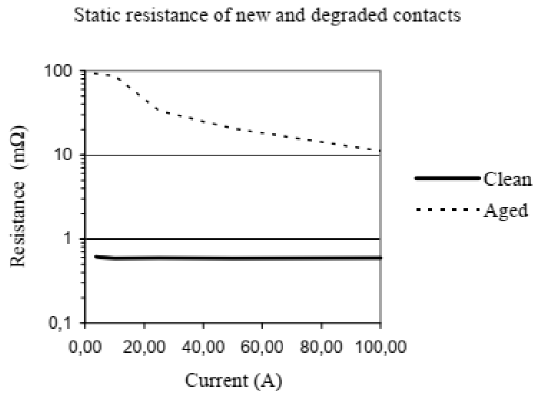
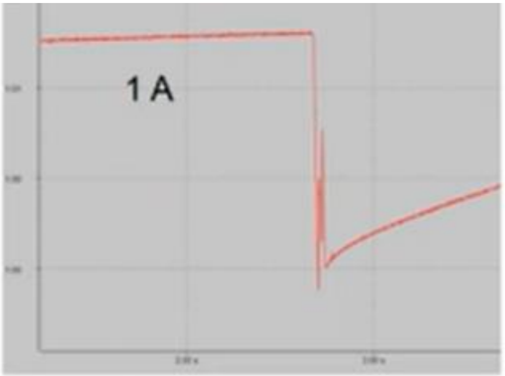


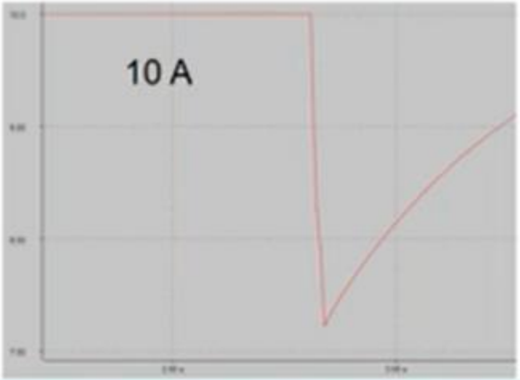
Figure 4.9 The contact resistance of clean and degraded contacts when the current is increased from 2.5 A to 100 A. Degraded contacts show high resistances at low currents, while the difference between clean and degraded contacts becomes smaller at higher currents.

On-site Tests of the PT

I Test ?

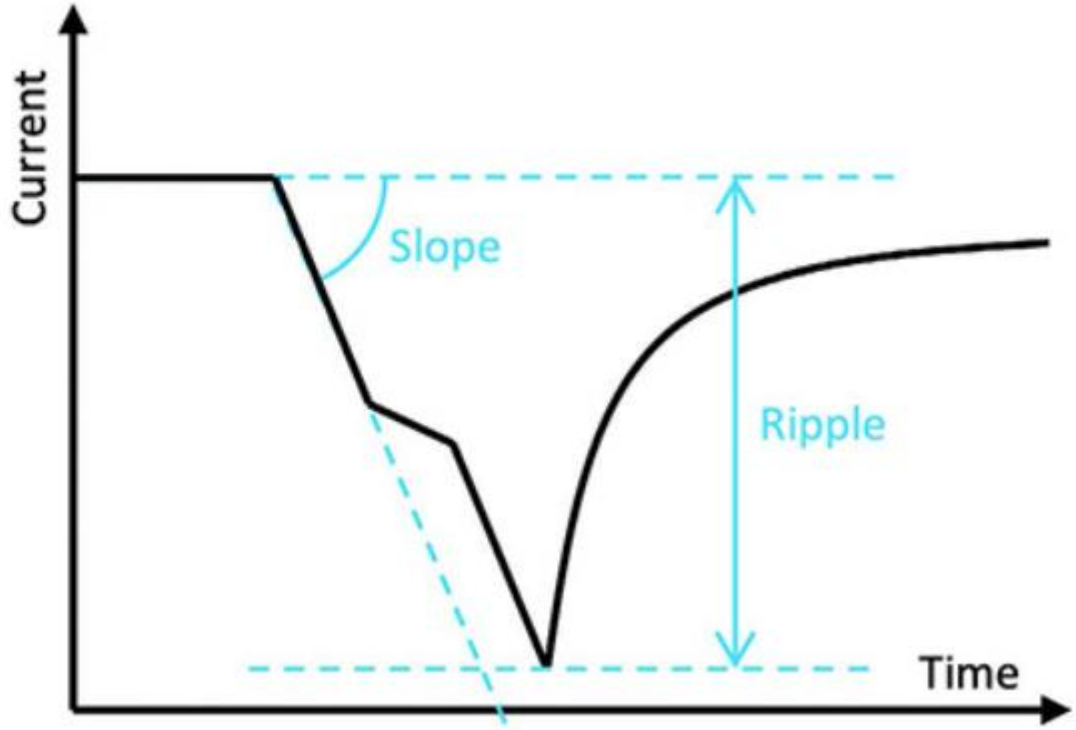
- Same transition time for both currents
- Lower current more sensitive to contact bouncing
- Oil coating – Can cause false interruption
- Max 15 % of rated current.





On-site Tests of the PT

Ripple and Slope:



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On-site Tests of the PT

Ripple and Slope:

Slope:

- reflects the resistivity of the current carrying transition components.
- If current decays more rapidly than expected, this indicates that the transition path has become more resistive than normal.

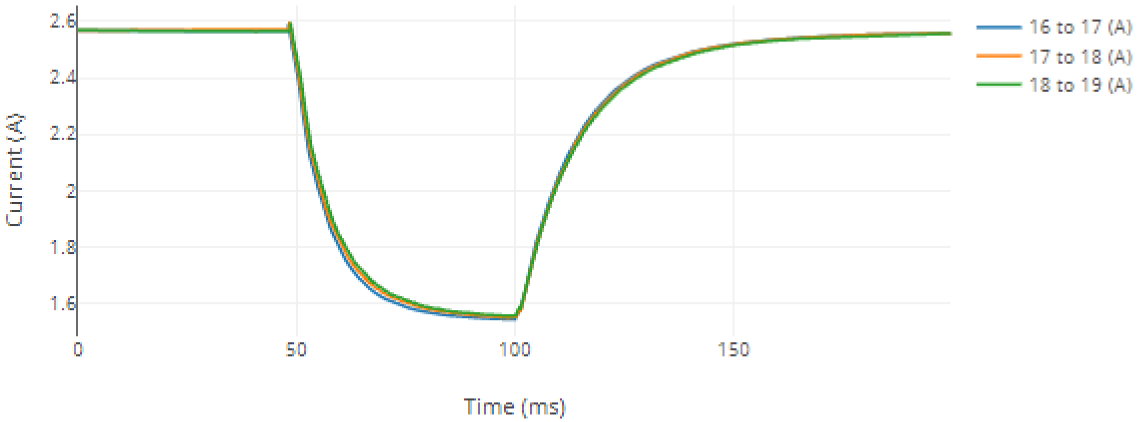
Ripple:

- If the ripple is uncharacteristically large, this indicates an increase in the resistance of the transition path *and/or* that the tap change operation is slower than it should be.

On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

30MVA, 63/20kV, MR- VV,

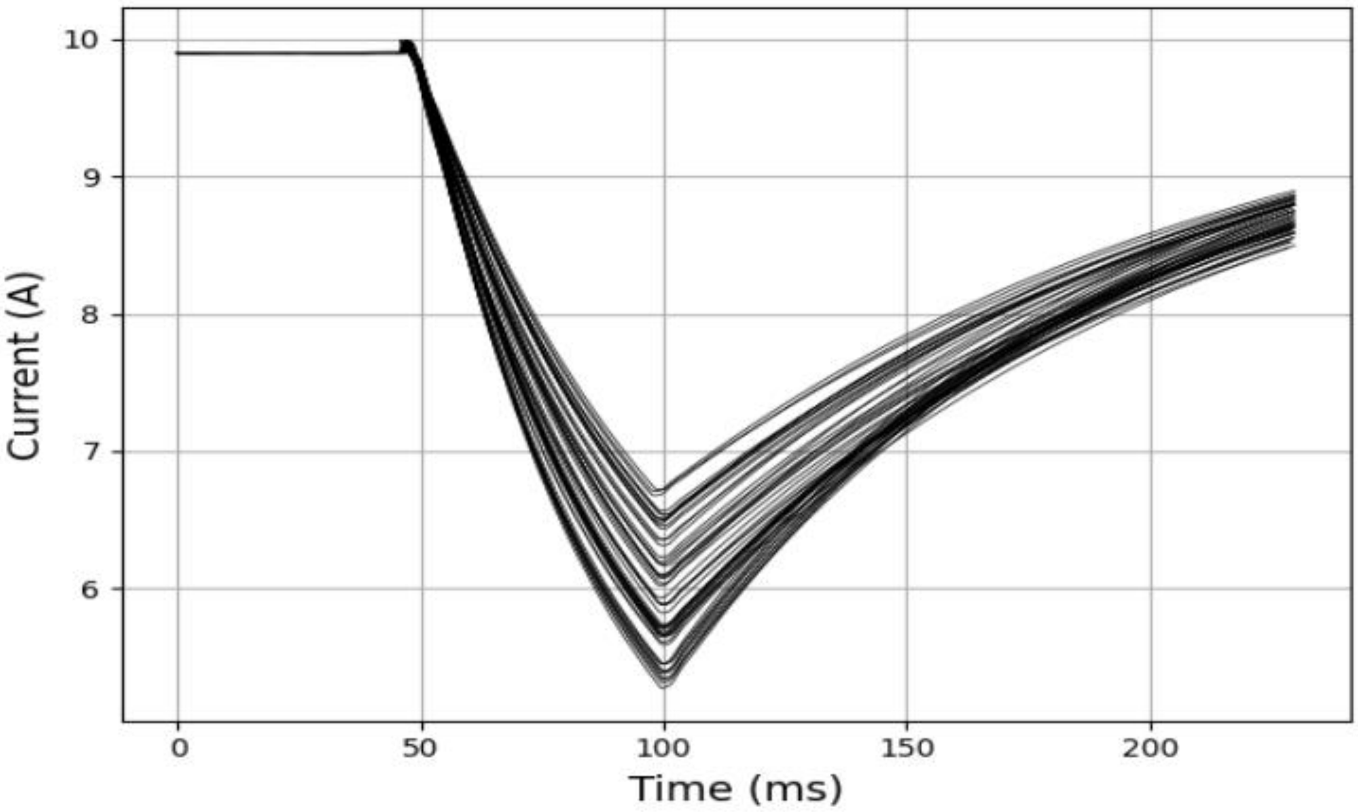


■	⇅	Phase	Tap	Ripple	Slope
☐	↓	A	17 to 16	40.65 %	87.42 A/s
☐	↓	A	18 to 17	40.49 %	84.77 A/s
☐	↓	A	19 to 18	40.50 %	81.72 A/s
☐	↑	A	16 to 17	39.83 %	83.35 A/s
☐	↑	A	17 to 18	39.58 %	80.61 A/s
☐	↑	A	18 to 19	39.34 %	77.19 A/s

On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

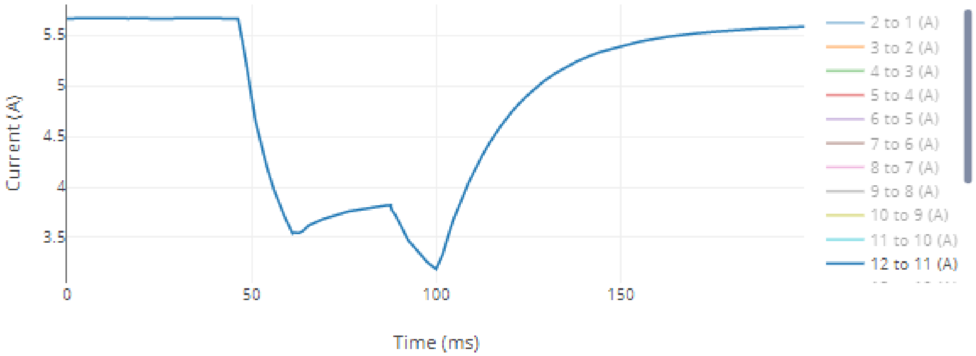
50MVA, 132/34 kV, Dyn1, MR- VV,



On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

22.5MVA, 63/20kV, ABB-UBB,

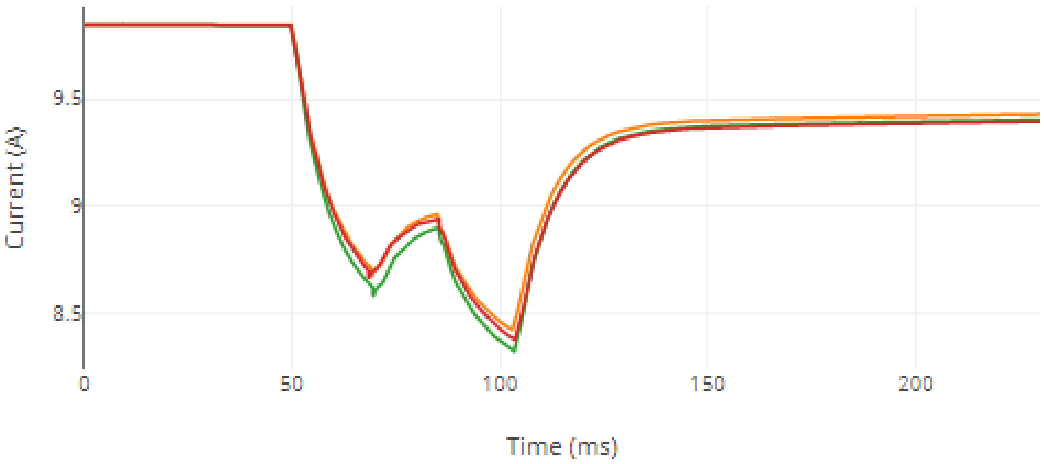


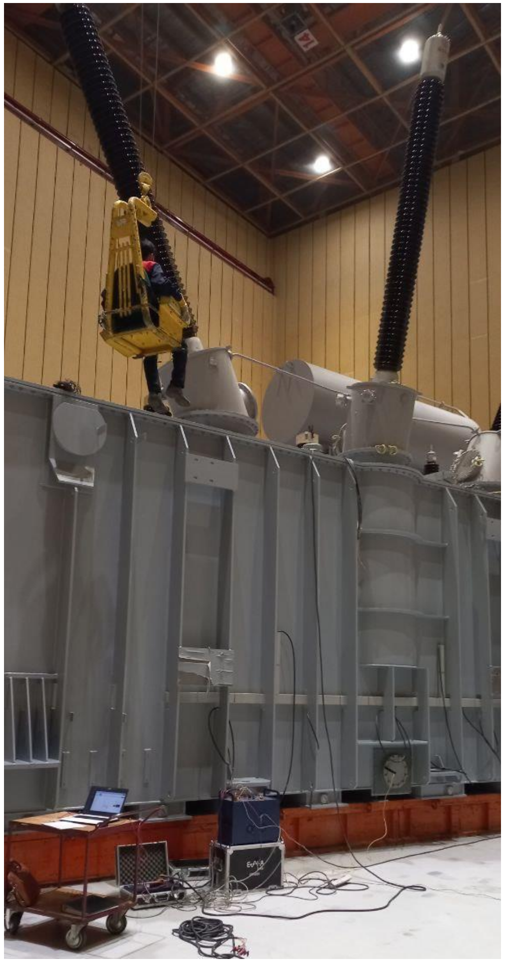
■	⇅	Phase	Tap	Ripple	Slope
☐	↓	A	2 to 1	41.08 %	159.76 A/s
☐	↓	A	3 to 2	42.45 %	188.82 A/s
☐	↓	A	4 to 3	37.24 %	124.56 A/s
☐	↓	A	5 to 4	41.42 %	165.69 A/s
☐	↓	A	6 to 5	40.11 %	148.4 A/s
☐	↓	A	7 to 6	36.44 %	114.05 A/s
☐	↓	A	8 to 7	41.96 %	179.27 A/s
☐	↓	A	9 to 8	43.13 %	192.82 A/s
☐	↓	A	10 to 9	38.59 %	132.9 A/s
☐	↓	A	11 to 10	37.81 %	127.14 A/s
☐	↓	A	12 to 11	43.80 %	188.96 A/s
☐	↓	A	13 to 12	42.23 %	171.87 A/s
☐	↓	A	14 to 13	40.37 %	143.91 A/s
☐	↓	A	15 to 14	34.99 %	108.82 A/s
☐	↓	A	16 to 15	39.35 %	140.1 A/s
☐	↓	A	17 to 16	40.87 %	153.04 A/s
☐	↓	A	18 to 17	36.70 %	116.86 A/s
☐	↓	A	19 to 18	37.56 %	122.33 A/s

On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

410MVA, 420/20kV, MR VMIII,

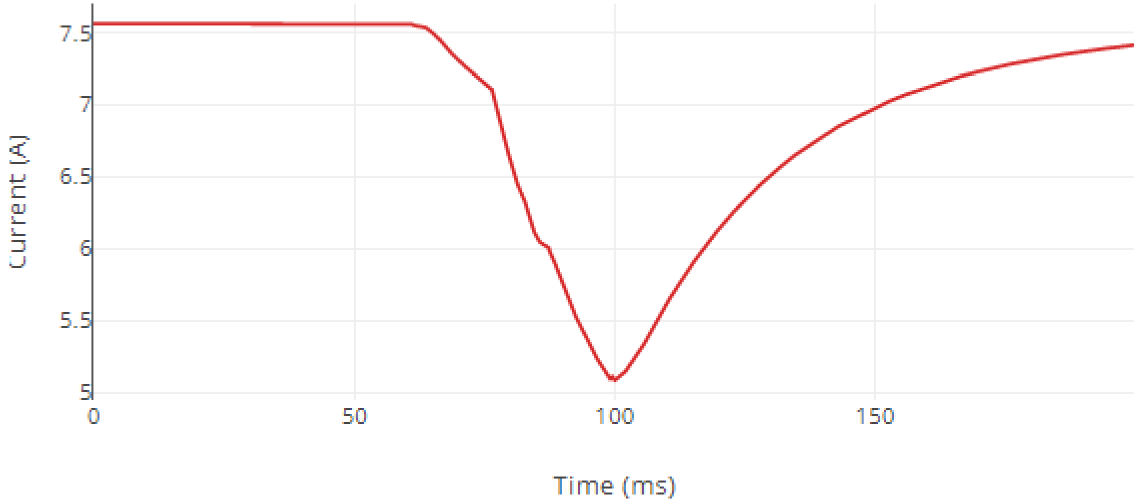




On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

312.5MVA, 230/19 kV, Mitsubishi, MR (Mofatteh, Hamedan)



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On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

On load reactor type tap changer

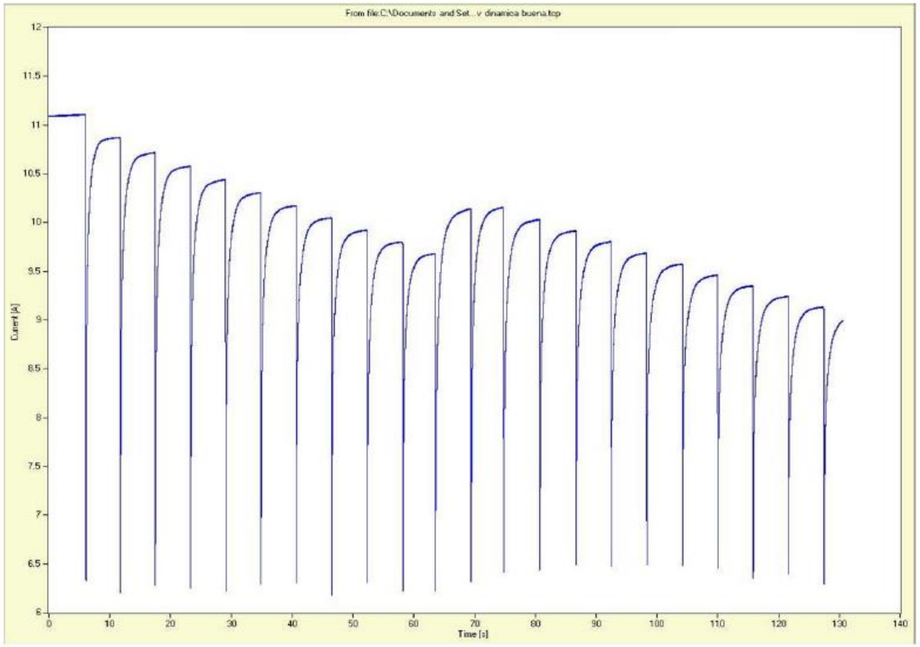


Figure 1.
Dynamic graph of a resistor tap changer
fine-coarse regulation

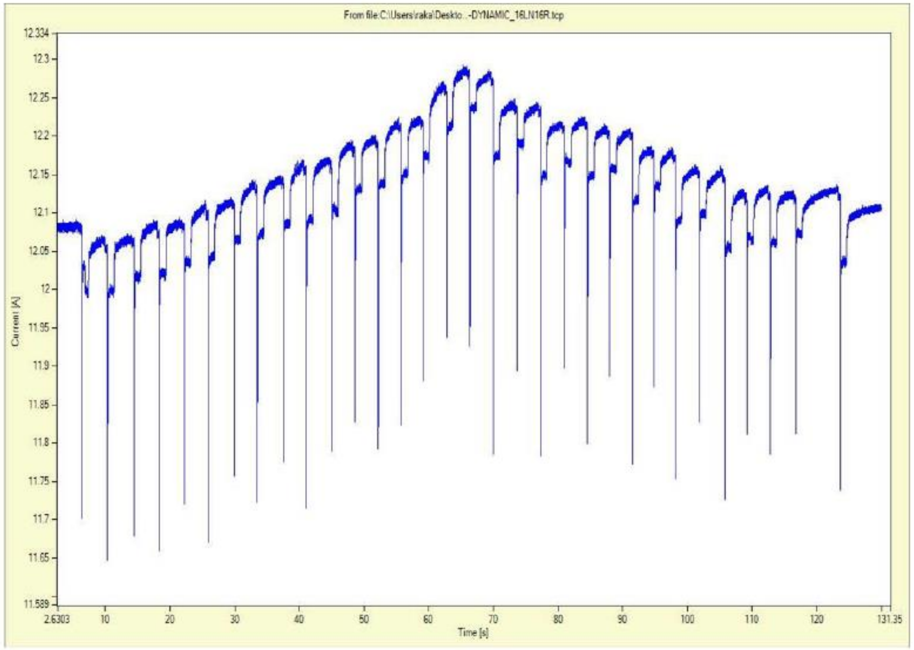
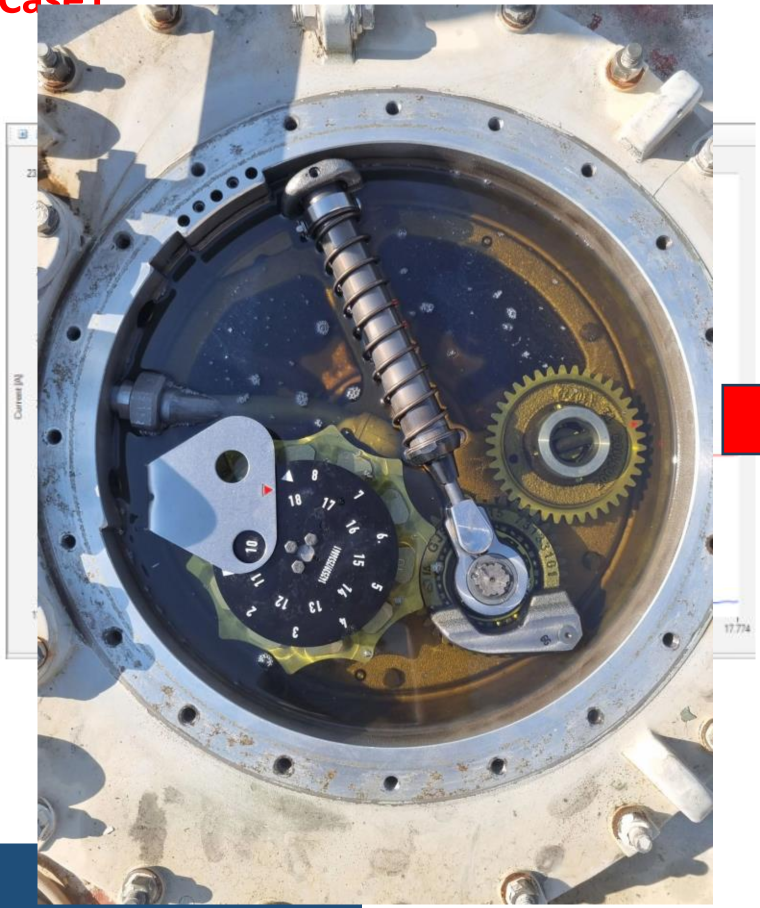


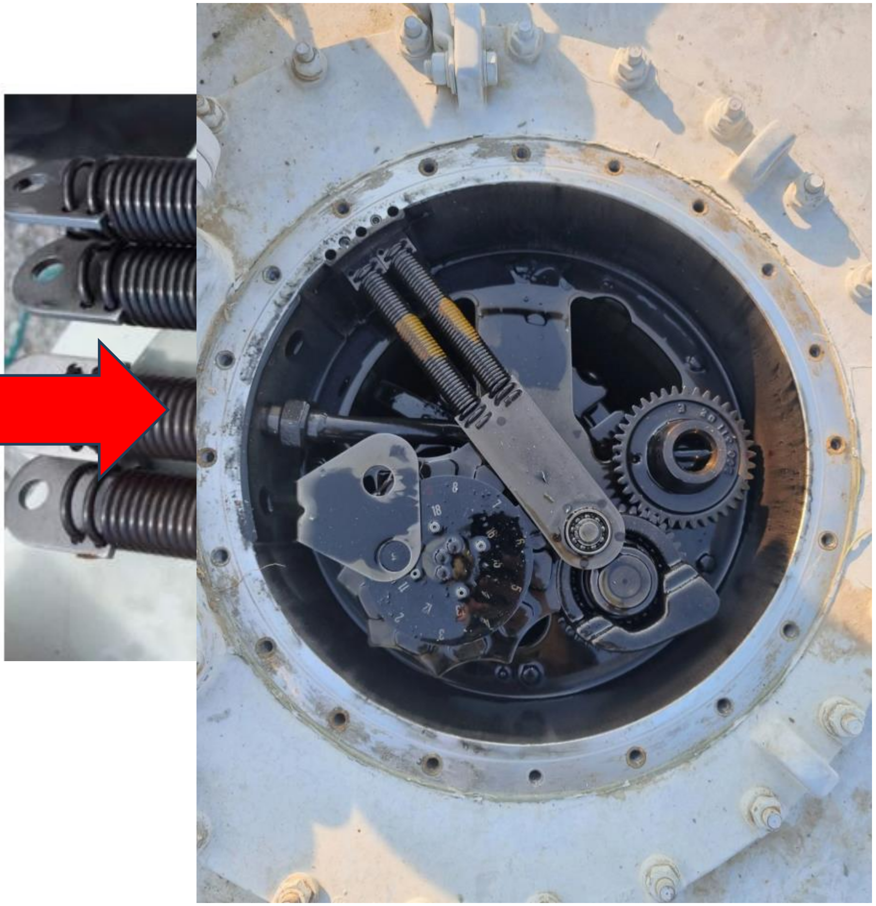
Figure 2.
Dynamic graph of a reactor tap changer
plus-minus regulation

On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

Case1:





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On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

Case7:

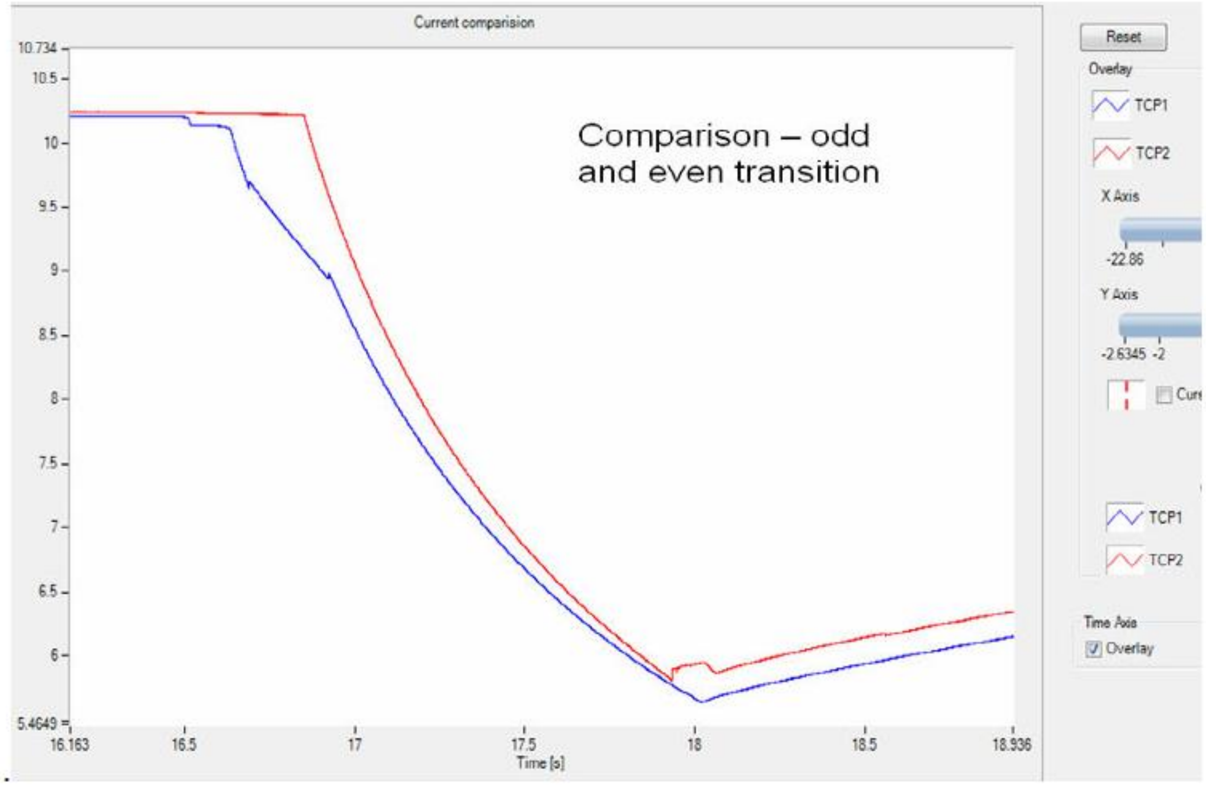

Figure 8.
Transition Time in Excess of 1 Second

On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

Case8:

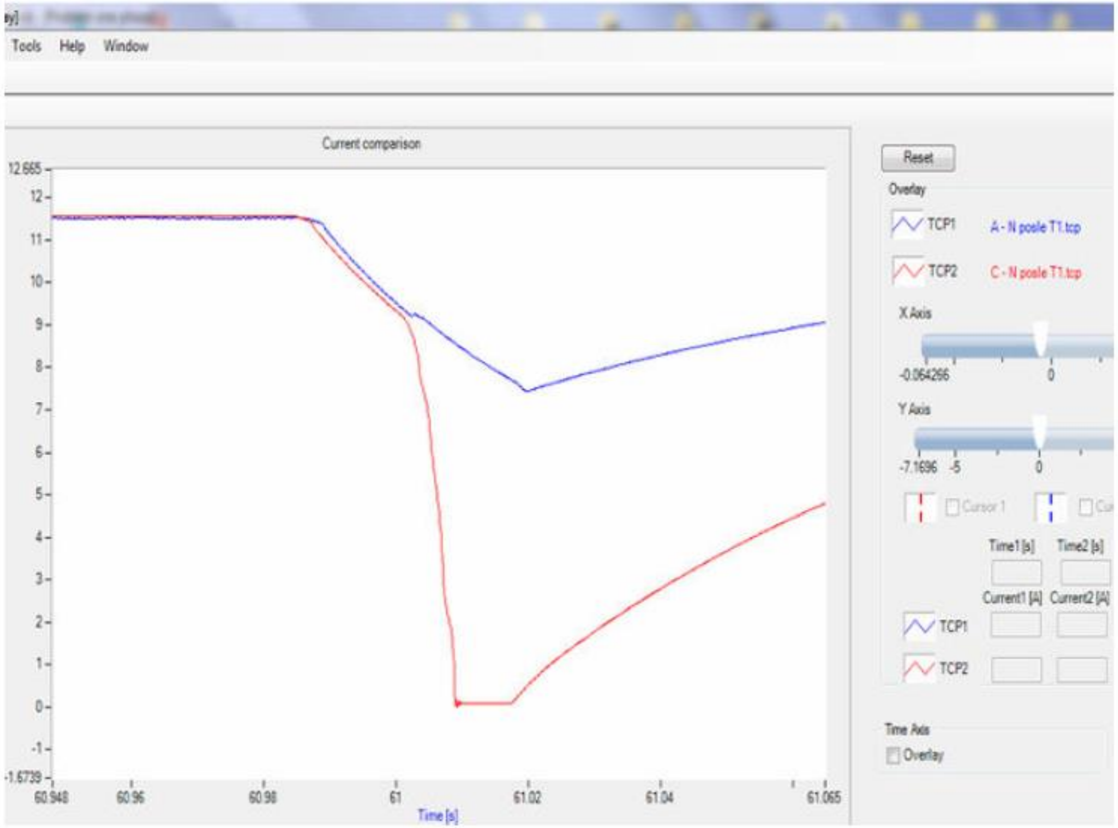

Figure 9.
The Second Resistor Does Not Make, Creating an Open Circuit

On-site Tests of the PT

OLTC DRM (Dynamic Resistance Measurement)

Case9:

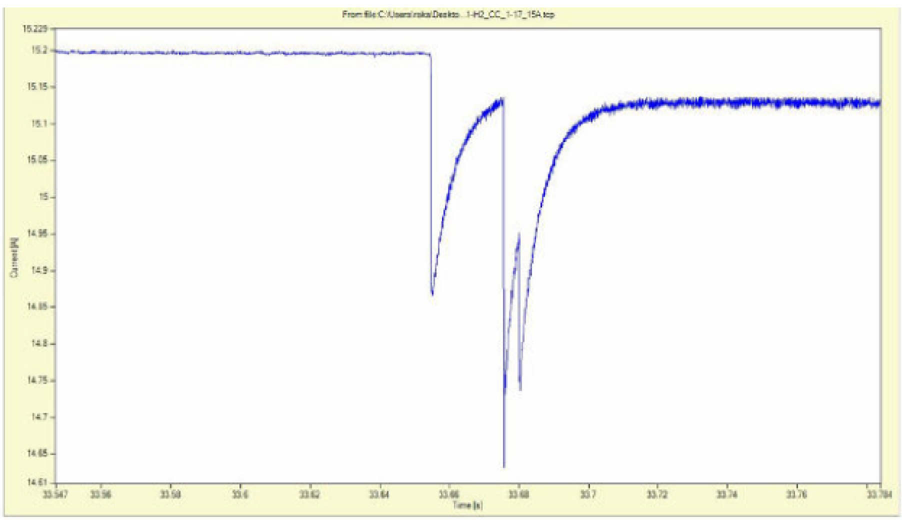

Figure 23.
Abnormal Transition Showing Incorrect Bypass Switch Operation

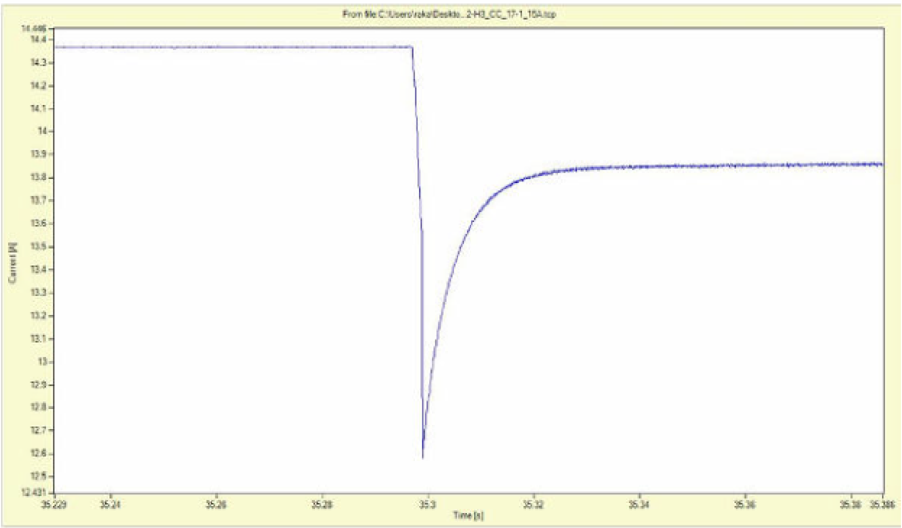

Figure 24.
Normal Transition of This Type of Tap Changer

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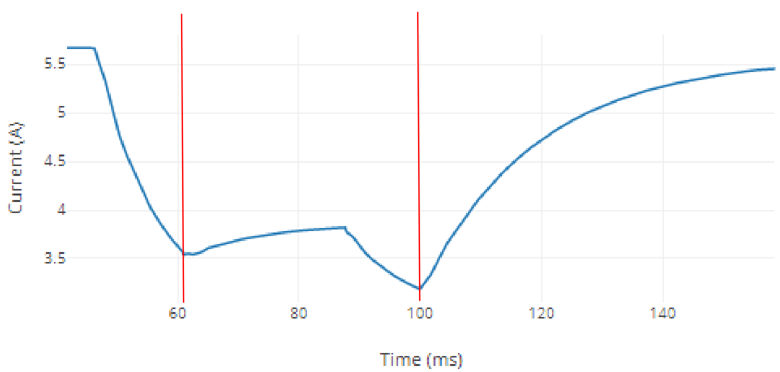
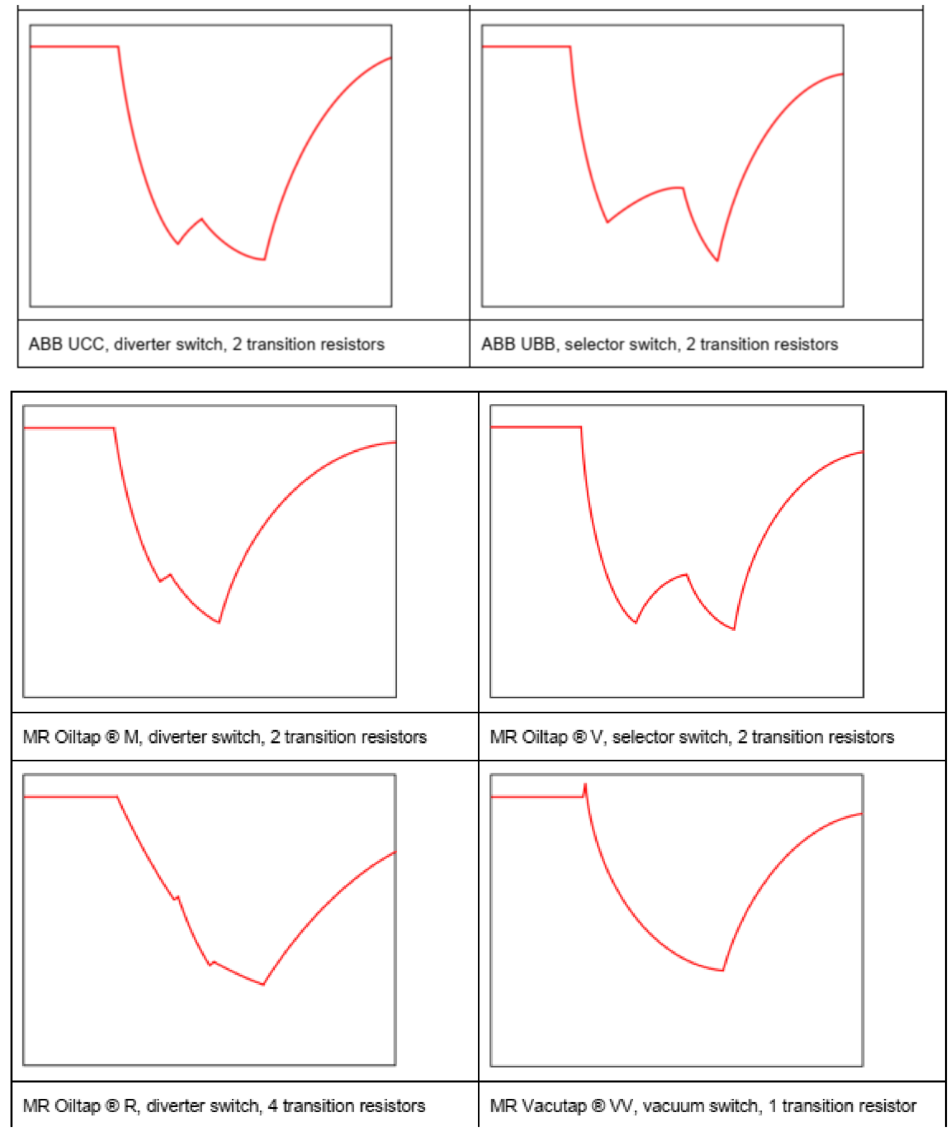
On-site Tests of the PT

DRM Analysis

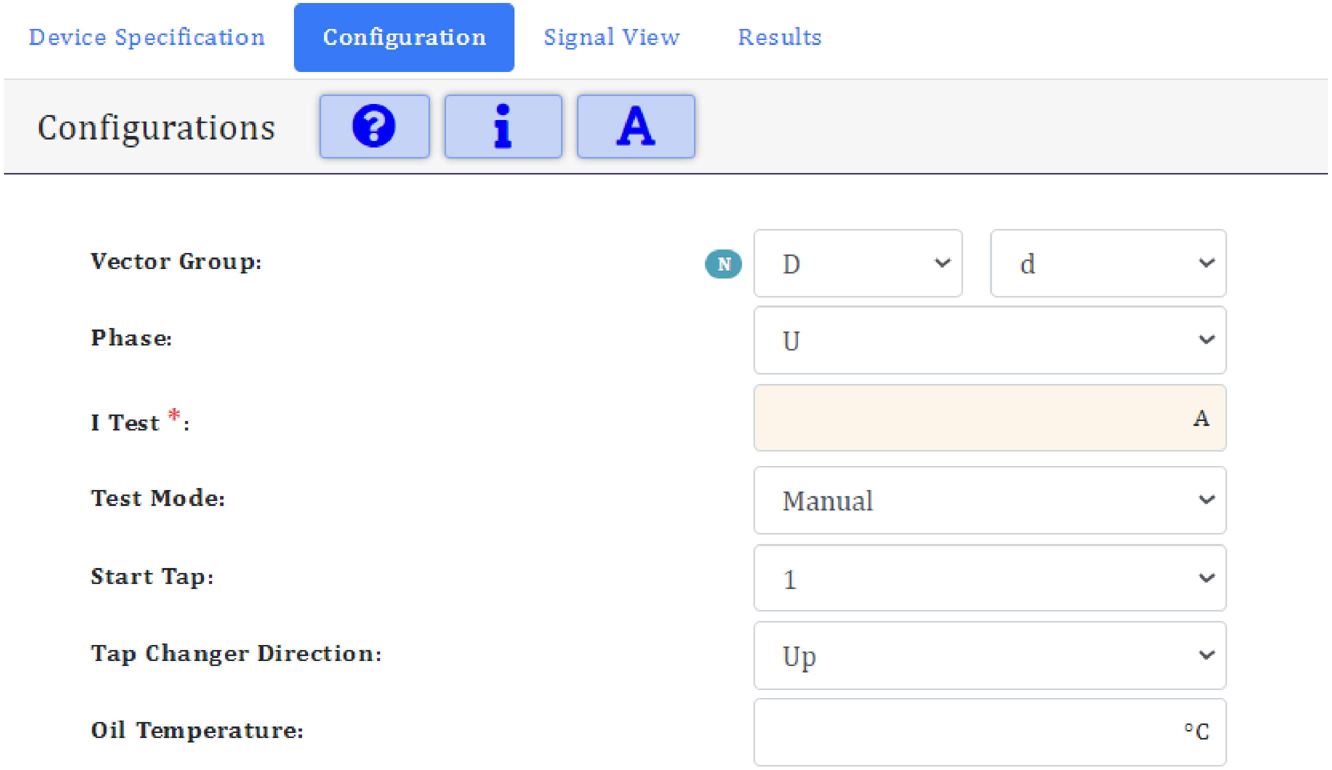
- ✓ Comparing to a finger print measurement
- ✓ Phase-to-phase comparison
- ✓ Switching time and interruptions





On-site Tests of the PT

DRM: KAVOSH T22



On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

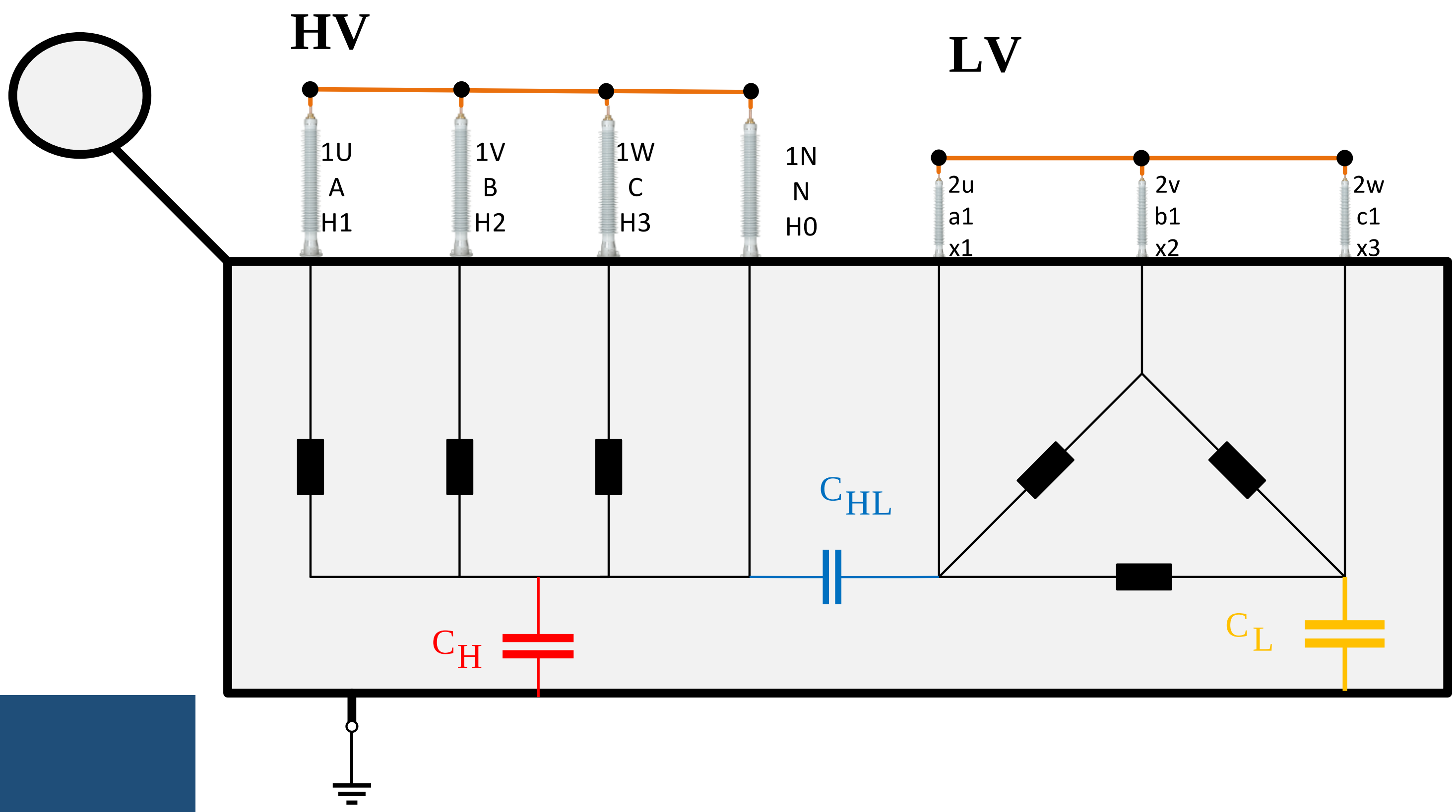
- De-energize and isolate transformer.
- Transformer tank and bushing flange should be grounded properly.
- All terminals with neutral for the same winding must be connected together.

On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

2-winding transformer



On-site Tests of the PT

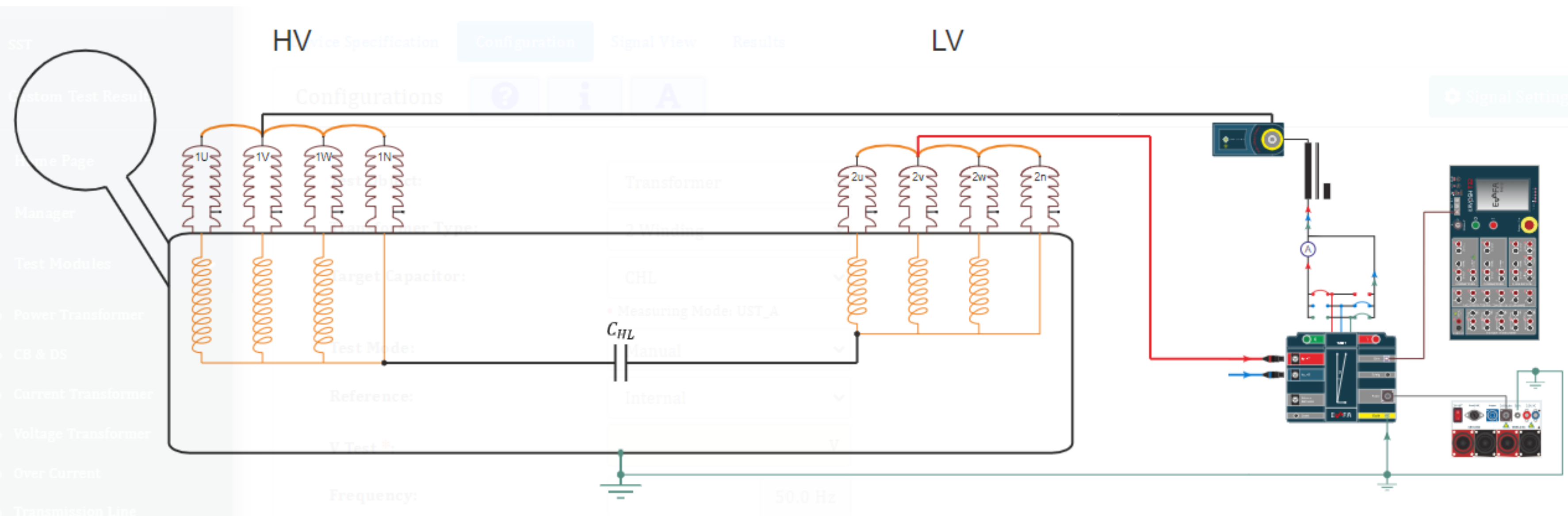
Capacitance and Dissipation Factor Measurement (TDM1)

How?

2-winding transformer

Test Object:	Transformer
Transformer Type:	2 Winding
Target Capacitor:	CHL

* Measuring Mode: UST_A



On-site Tests of the PT

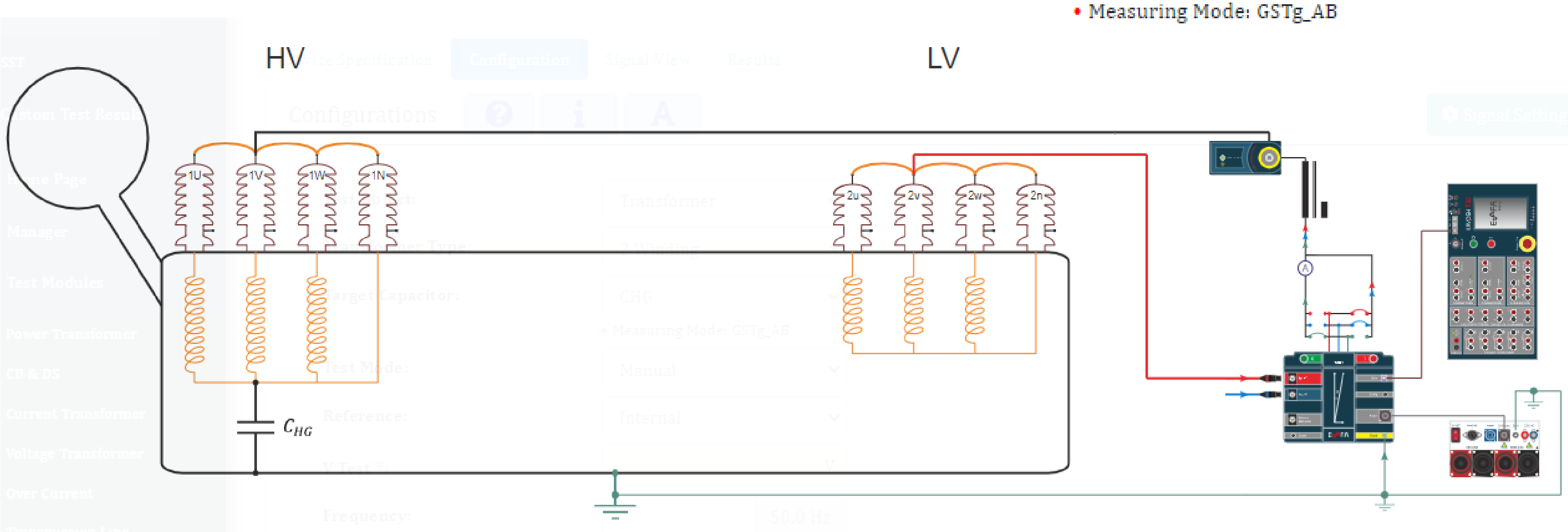
Capacitance and Dissipation Factor Measurement (TDM1)

How?

2-winding transformer

Test Object:	Transformer
Transformer Type:	2 Winding
Target Capacitor:	CHG

• Measuring Mode: GSTg_AB



On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

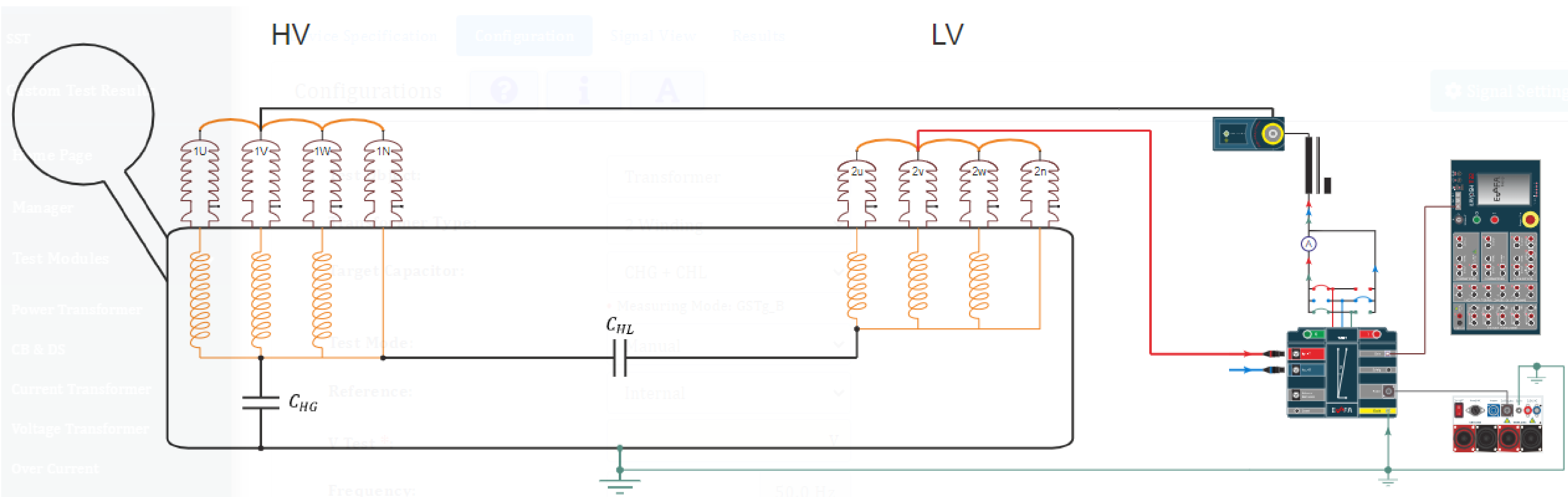
2-winding transformer

Test Object: Transformer

Transformer Type: 2 Winding

Target Capacitor: CHG + CHL

- Measuring Mode: GSTg_B



On-site Tests of the PT

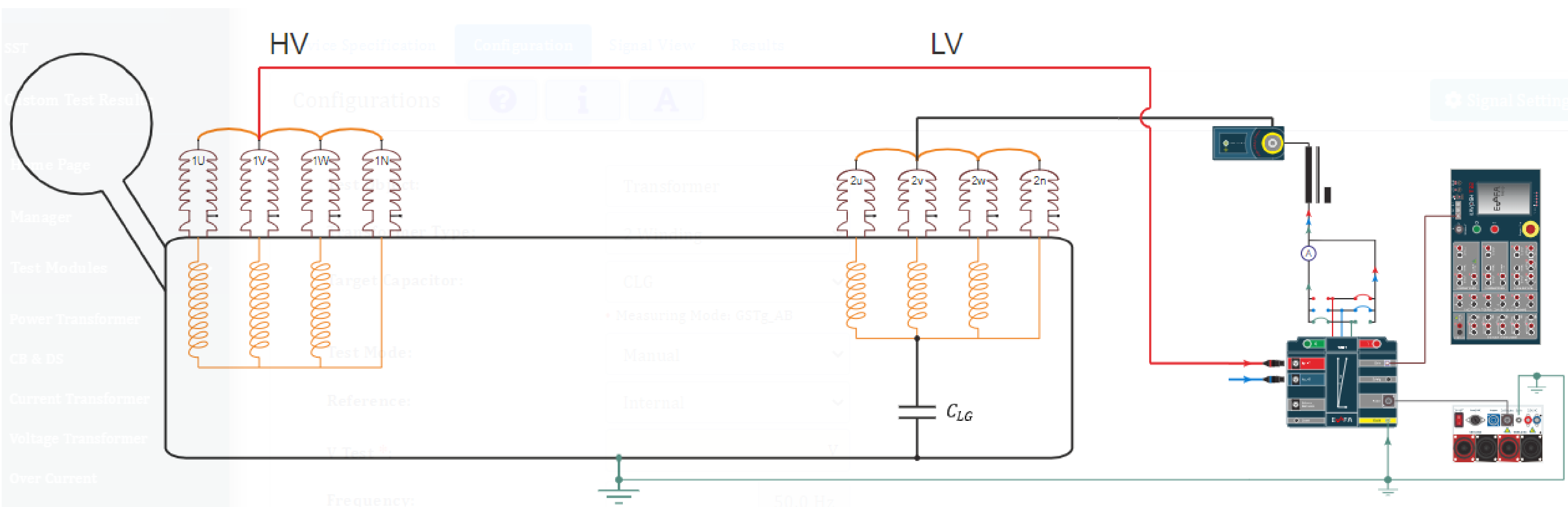
Capacitance and Dissipation Factor Measurement (TDM1)

How?

2-winding transformer

Test Object:	Transformer
Transformer Type:	2 Winding
Target Capacitor:	CLG

- Measuring Mode: GSTg_AB



On-site Tests of the PT

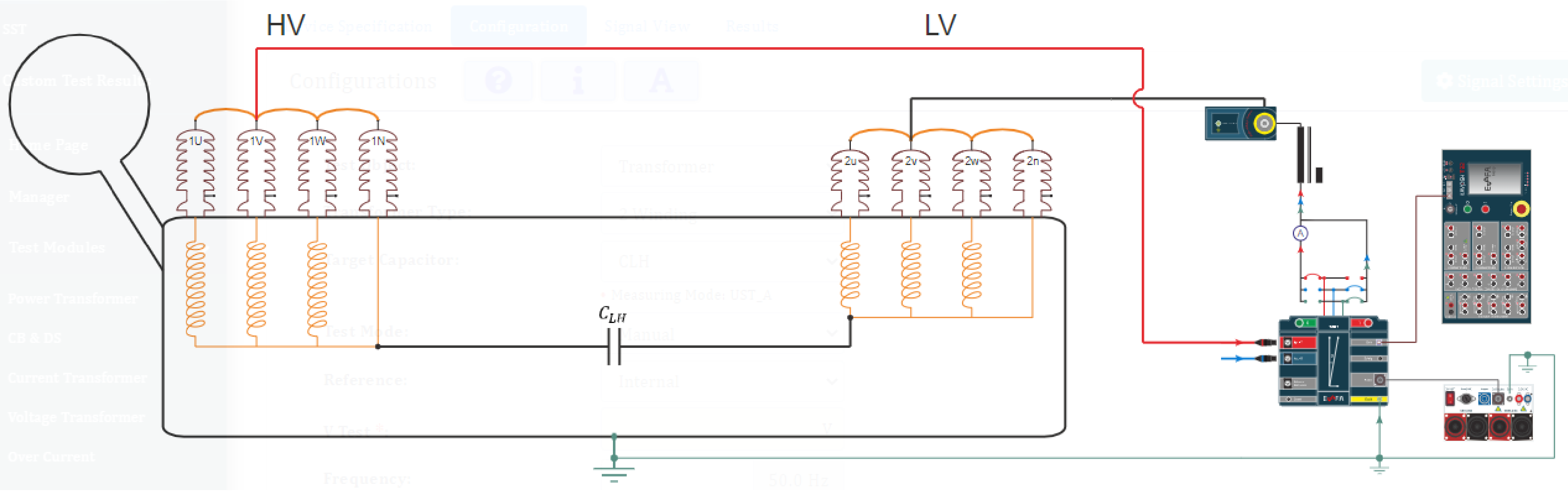
Capacitance and Dissipation Factor Measurement (TDM1)

How?

2-winding transformer

Test Object:	Transformer
Transformer Type:	2 Winding
Target Capacitor:	CLH

• Measuring Mode: UST_A



On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

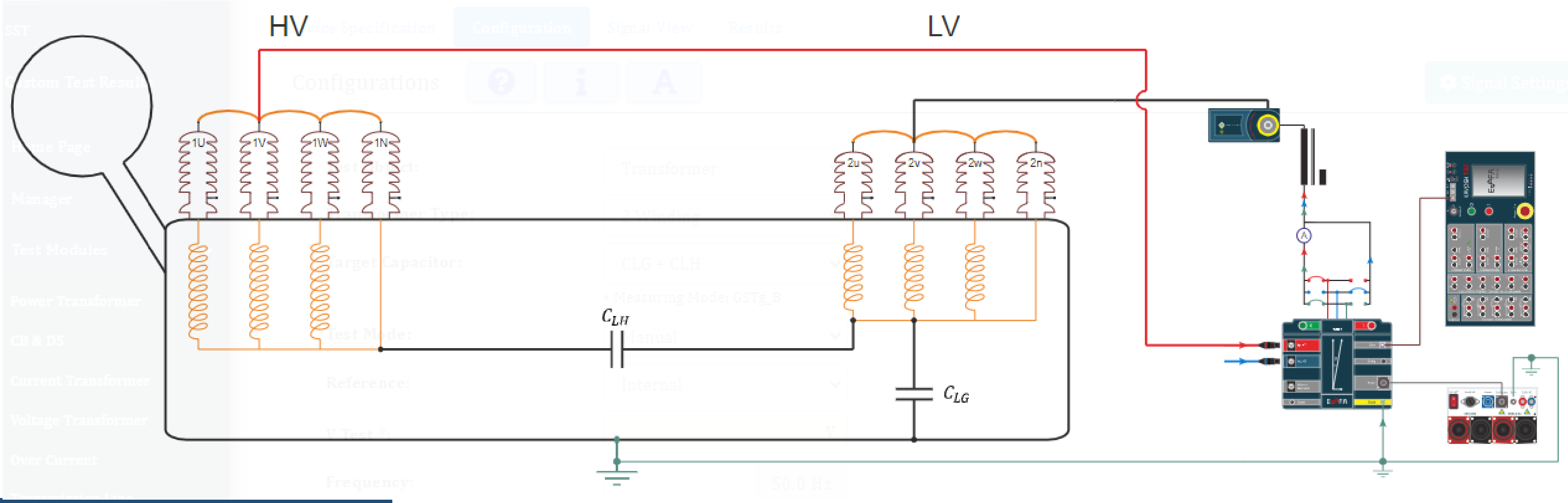
2-winding transformer

Test Object: Transformer

Transformer Type: 2 Winding

Target Capacitor: CLG + CLH

- Measuring Mode: GSTg_B

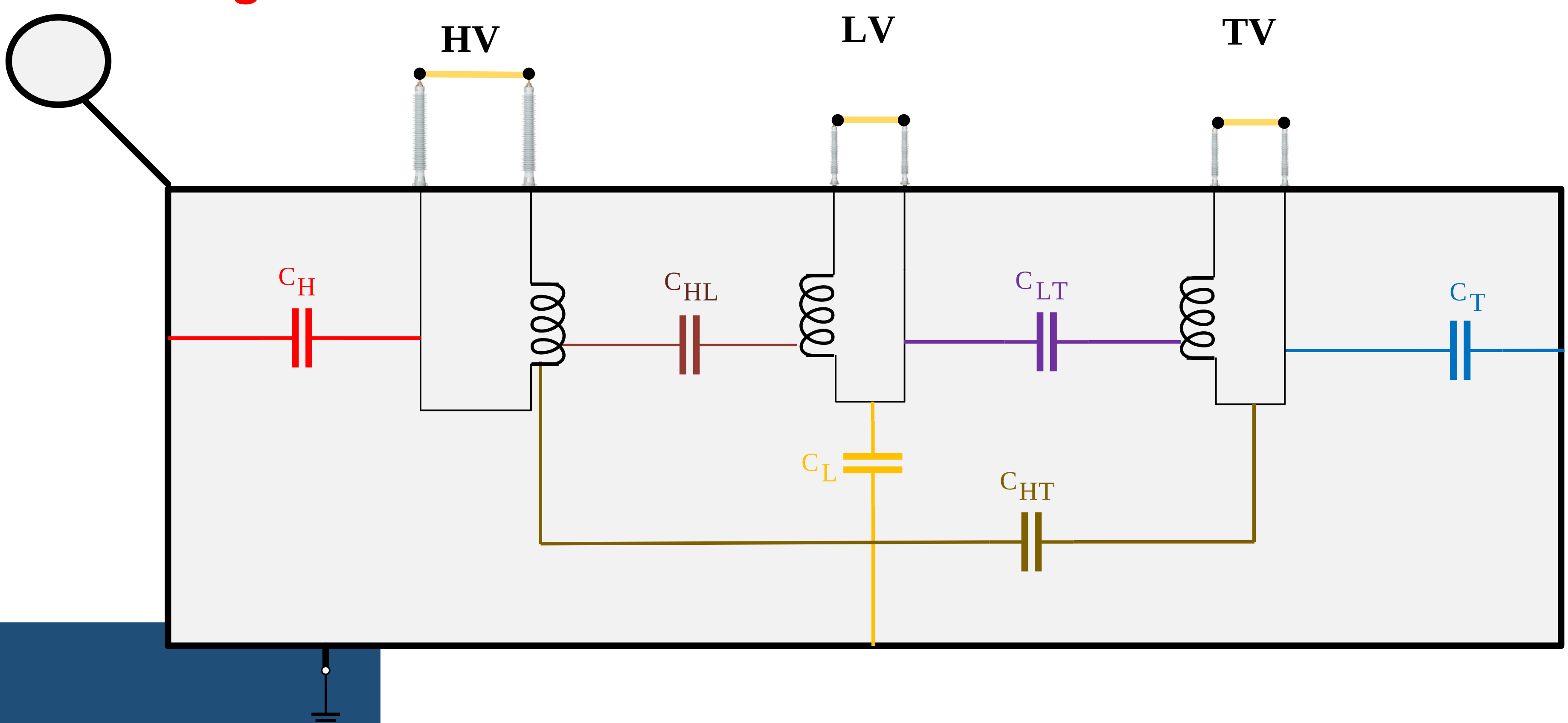


On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

3-winding transformer



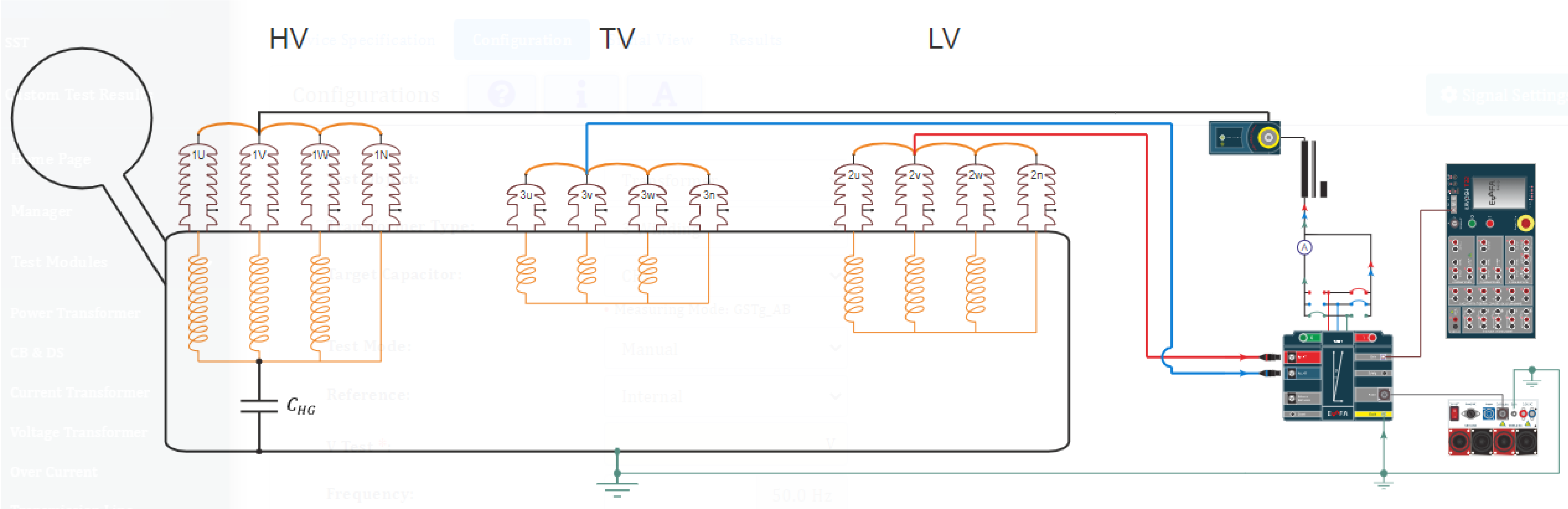
On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

3-winding transformer

Test Object:	Transformer
Transformer Type:	3 Winding
Target Capacitor:	CHG

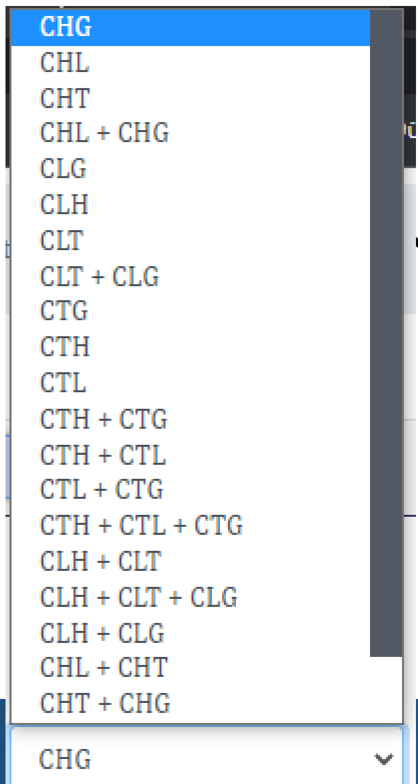


On-site Tests of the PT

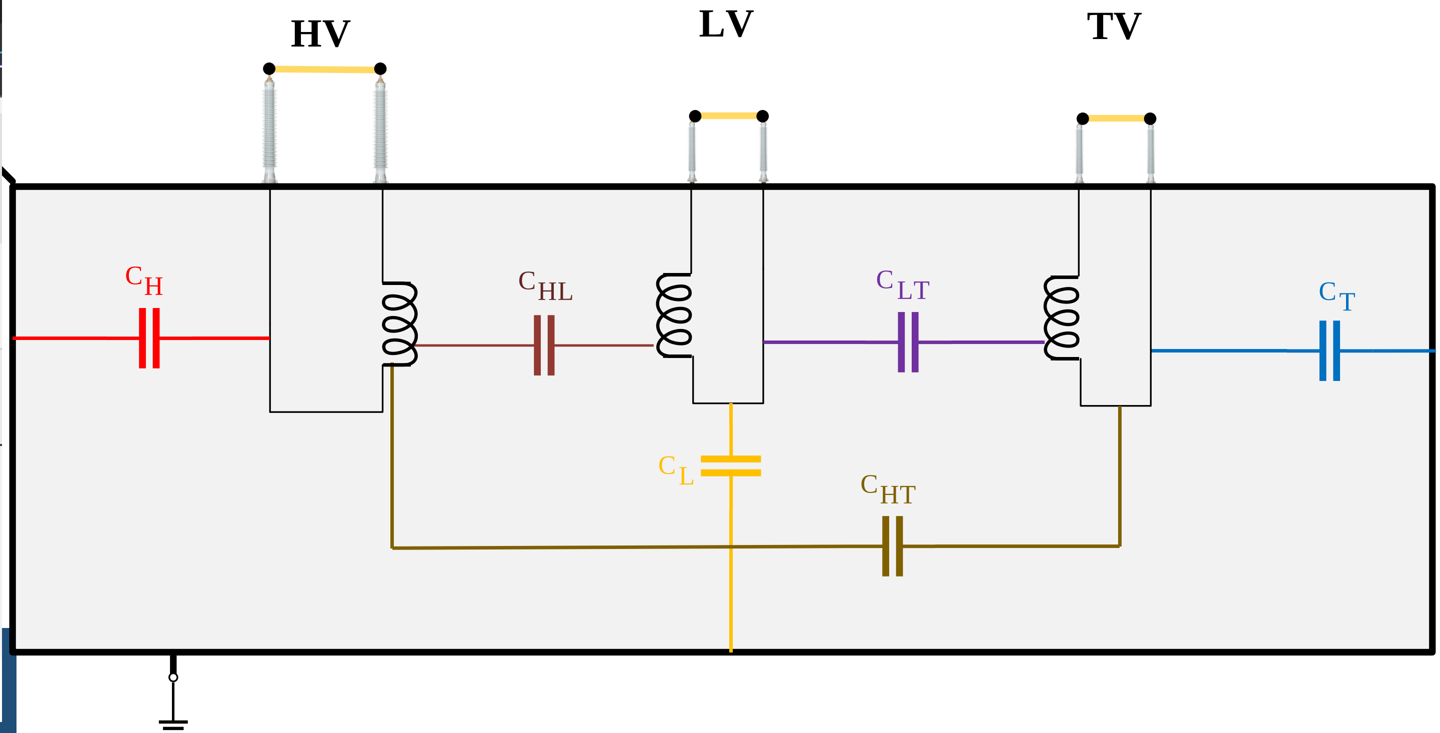
Capacitance and Dissipation Factor Measurement (TDM1)

How?

3-winding transformer



More wirings available on: kavosh.online

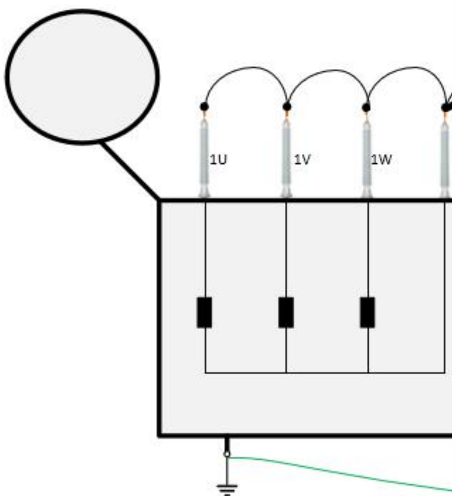


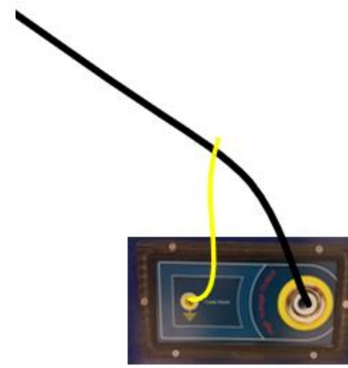
On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

Autotransforme)





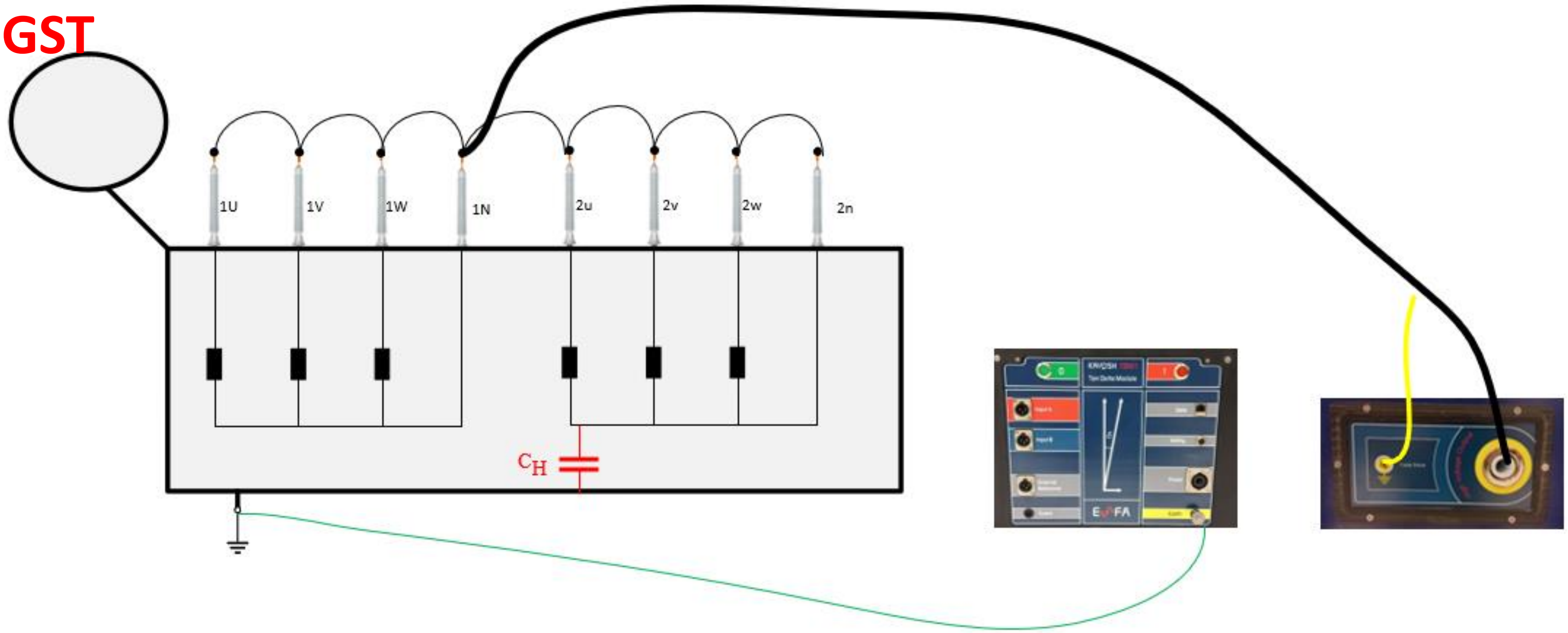
On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

Autotransformer without tertiary winding (inaccessible)

GST



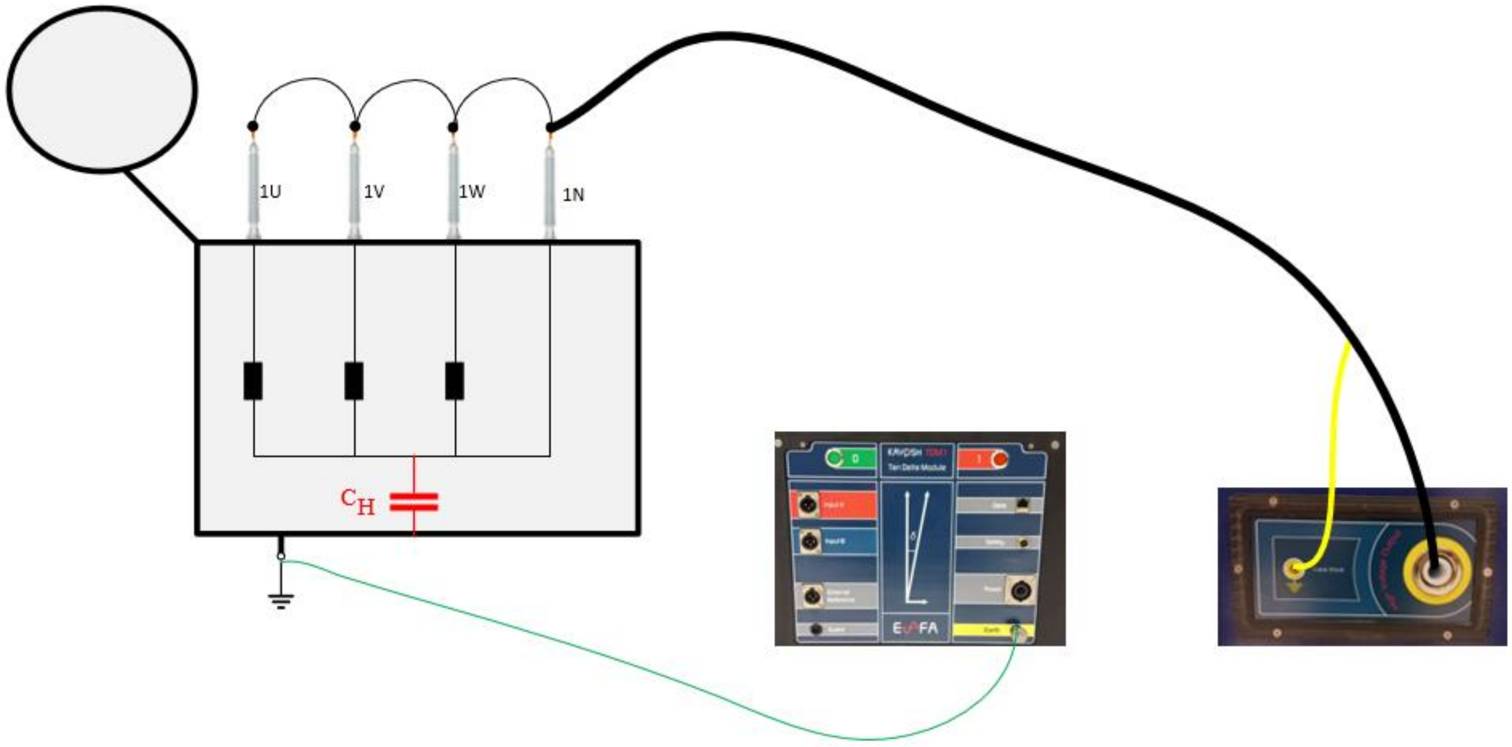
On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

How?

Reactor

GST



On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

230kV/14.4kV, 160MVA

Point	Mode	Frequency	V out	I out	Cap	DF	T Oil
CL+CLH	GST	55 Hz	1.9988 kV	27.913 mA	40.369 nF	0.641	10 °C
CL	GSTg_A	55 Hz	1.9984 kV	21.064 mA	30.491 nF	0.667	10 °C
CLH	UST_A	55 Hz	9.9958 kV	34.196 mA	9899.6 pF	0.586	10 °C
CLH	UST_A	55 Hz	1.998 kV	6.8421 mA	9909.4 pF	0.615	10 °C
CH+CHL	GST	55 Hz	9.991 kV	66.974 mA	19.452 nF	0.597	10 °C
CH+CHL	GST	55 Hz	1.9992 kV	13.421 mA	19.42 nF	0.603	10 °C
CH	GSTg_A	55 Hz	9.9956 kV	32.85 mA	9503.3 pF	0.616	10 °C
CH	GSTg_A	55 Hz	2.0012 kV	6.5785 mA	9515 pF	0.618	10 °C
CHL	UST_A	55 Hz	9.9986 kV	34.171 mA	9894.7 pF	0.611	10 °C
CHL	UST_A	55 Hz	1.9979 kV	6.8486 mA	9909.8 pF	0.616	10 °C
CL+CLH	GST	55 Hz	9.9999 kV	139.81 mA	40.385 nF	0.648	10 °C
CL	GSTg_A	55 Hz	10.001 kV	105.67 mA	30.513 nF	0.670	10 °C

On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

Assessment:

✓ IEEE C57.152

Limits for DF @ 20℃

Insulation	Voltage Level	Maximum DF for new PT	Maximum DF for old PT
Mineral Oil	< 230 kV	0.5 %	1 %
Mineral Oil	>= 230kV	0.4 %	1 %
Natural Ester	All	1 %	1 %

Limits for C

ΔC	Voltage Level
< 5 %	Acceptable
< 5 % ΔC < 10 %	Should be investigated
> 10 %	Critical

On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

Assessment:

- Tan delta rate of change is an important index indicating ageing rate or main insulation damage
- Analysis can be done by comparing results of various bushings, comparing results with similar assets and previous tests, and rate of change
- Complementary tests may be required to verify the quality of the insulation fluid (oil dielectric tests and dissolved gas analysis)
- Shorter test interval may be required for higher tan delta rate of change

On-site Tests of the PT

Capacitance and Dissipation Factor Measurement (TDM1)

Acceptance Criteria

- ✓ Measuring of bushing and transformer tan delta on an equalized temperature (oil and winding) and preferably at the same temperature of previous tests
- ✓ Comparing the absolute value of tan delta with the acceptable one (between 2 times of the initial value and 1%)
- ✓ Comparing the rate of change of tan delta with the acceptable value
  - ✓ One year : 0.05%
  - ✓ Two years: 0.07%
  - ✓ Three years: 0.09%
  - ✓ Four years: 0.11%

On-site Tests of the PT

DF: KAVOSH T22

Device Specification | **Configuration** | Signal View | Results

Configurations

Test Object:	Transformer
Transformer Type:	2 Winding
Target Capacitor:	CHL • Measuring Mode: UST_A
Test Mode:	Manual
Reference Capacitor:	Internal
V Test *:	V
Frequency:	52.5 Hz
No. of Avg. Points:	5
T Oil:	20 °C • Correction Factor: 1

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