HAEFELY HIPOTRONICS

2293
Automatic Transformer Winding analyzer

New Features

Designed by Tettex INSTRUMENTS

precision. swiss made.

HUBBELL HIGH VOLTAGE TEST SOLUTIONS

HAEFELY HIPOTRONICS

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3. Resistance measurement
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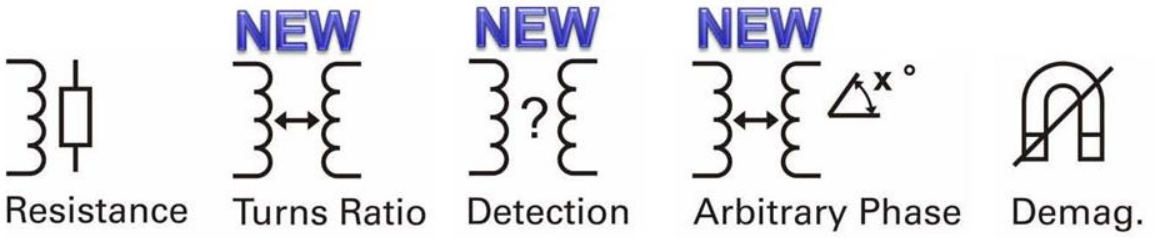
9. Applications, unique selling points and sales tools

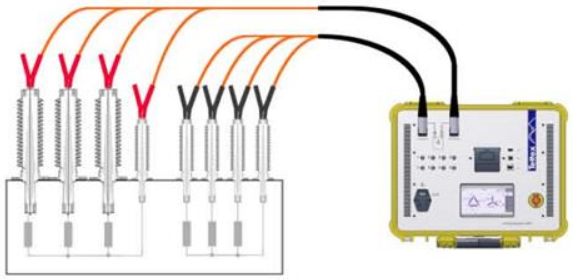
2293 Automatic Transformer Winding Analyzer

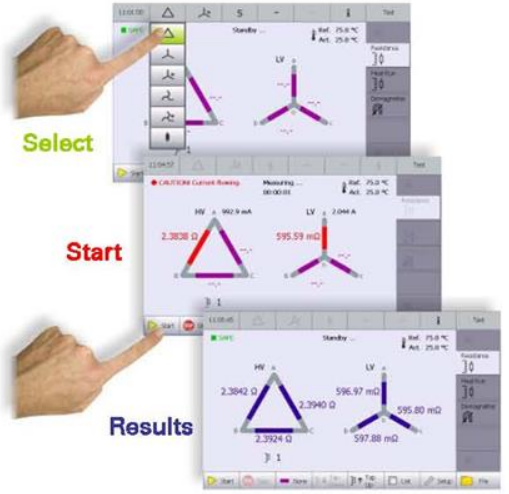
The 2293 is an automatic winding analyser, optimized to perform routine and maintenance tests on three phases power and distribution transformers



2293 Main Features

- Multipurpose winding analyzer: **transformer winding resistance, turns ratio, type detection, arbitrary phase ratio measurement, demagnetisation, magnetic balance** and **heat run test** (heat rise and cooling curve) in one instrument and without reconnection.
- **Easy operation** on touch screen interface with **full graphical test visualization.**
- **Advance test procedures** for winding resistance (SWM) and for Turns ratio
- Heat run test – Heat rise and cooling curve
- **Tap changer control** signal.





2293 Standard scope of supply

Winding resistance, Demagnetization and Cooling curve measuring unit with cable set (10m), carrying bag, test certificate, user manual.

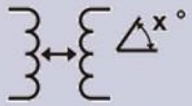
- ☑ Resistance
- ☑ Demag.
- ☑ Cooling Curve

Versions

PORTABLE VERSION

RACK VERSION

2293 Software Keys (Optional)

	2293/SKTTR	3-phase transformer turns ratio and detection measurement add on application for 2293
	2293/SKAP	Arbitrary phase shift add on application for the 2293, (2293/SKTTR needed)
	2293/SKTR	Heat rise add on application for the 2293
	2293/SKMB	Magnetic balance add on application for the 2293

2293 Accessories

	2293/TAP	Tap changer control
	2293/TEMP1	Temperature probe for liquids
	2293/TEMP2	Magnetic temperature probe
	2293/10HV 2293/10LV	Extension cable 10m High voltage side Extension cable 10m low voltage side Extension cables can be plugged for longer distances
	2293/TEMPEXT	Temperature extension box to connect up to 8 additional temperature sensors. Up to three extension boxes (24 temperature inputs) can be connected to a single 2293.
	2293/ITLOCK	Safety interlock plug to stop test from an external switch

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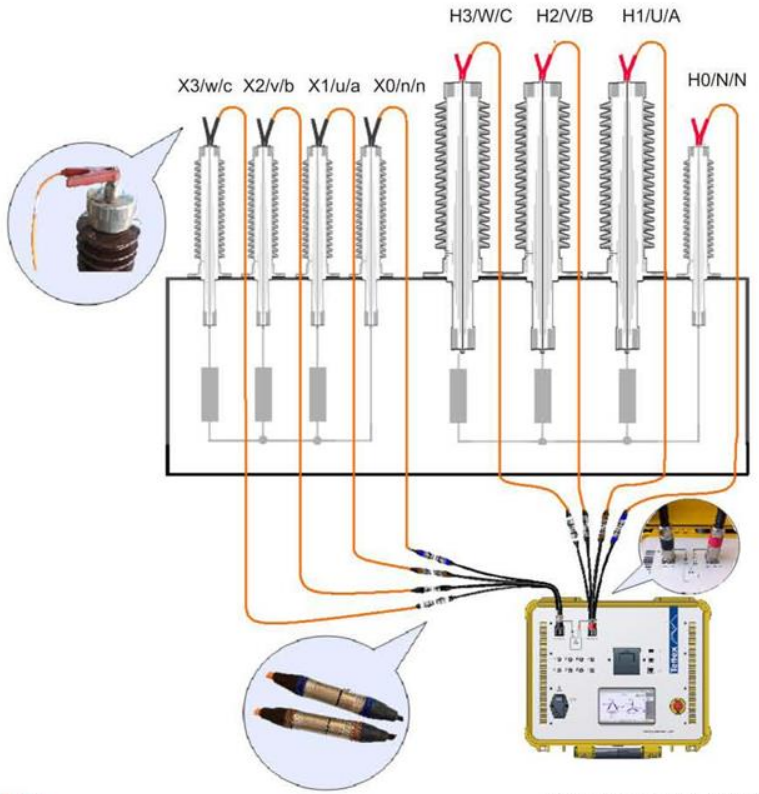
7. Cooling curve measurement
8. Applications, key customers and unique selling points
9. Sales tools

Connecting the instrument

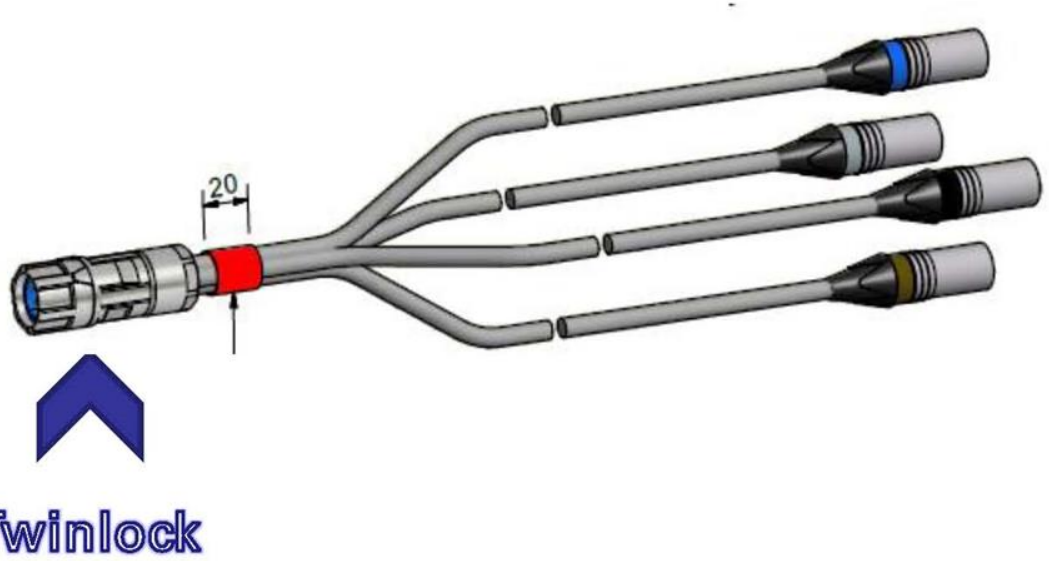
- ✓ Once time connection system, once connected will test all phases and windings.
- ✓ Extension cables (10m) as option.

Optimized design by using kelvin method in a single clamp (only one clamp per bushing

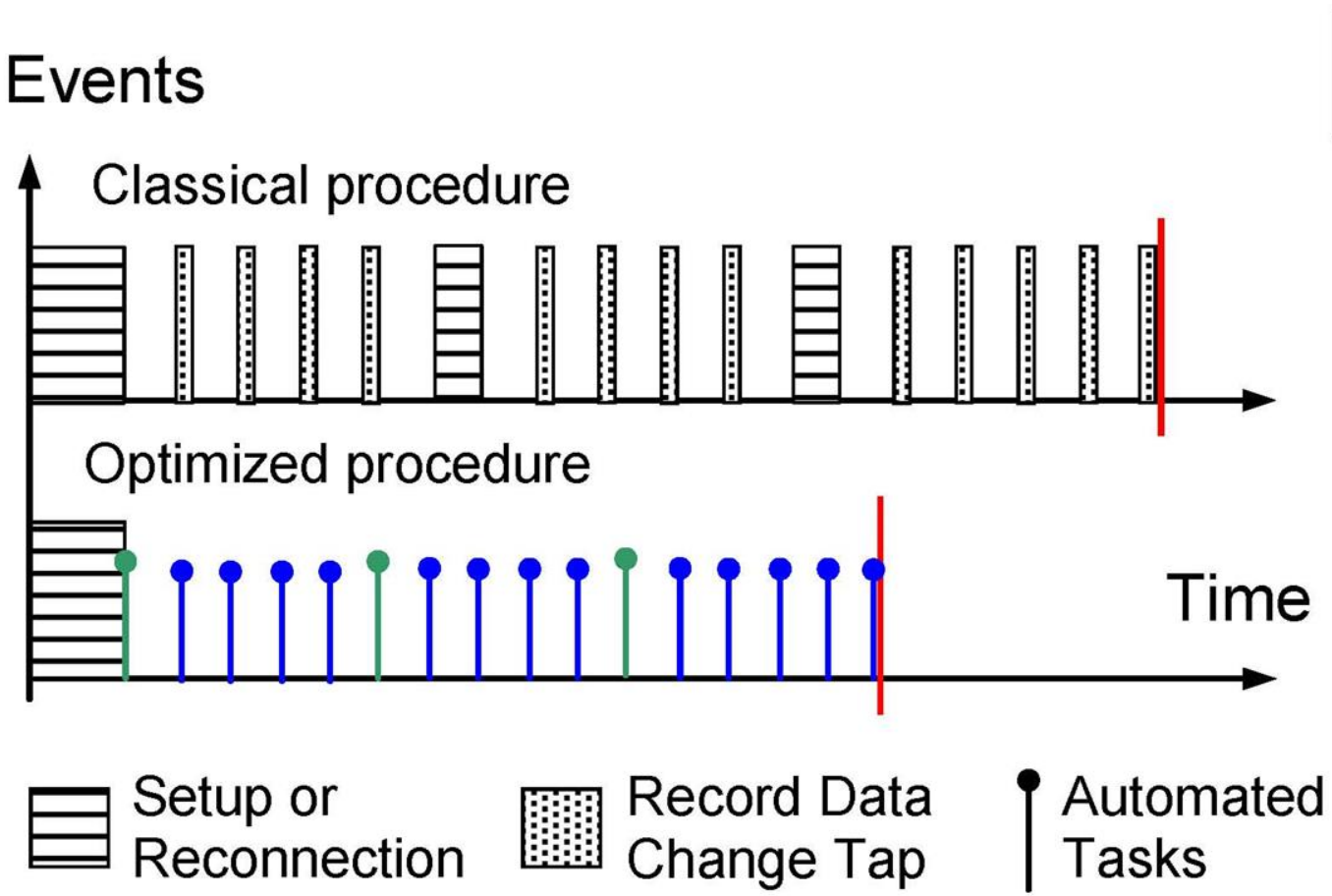


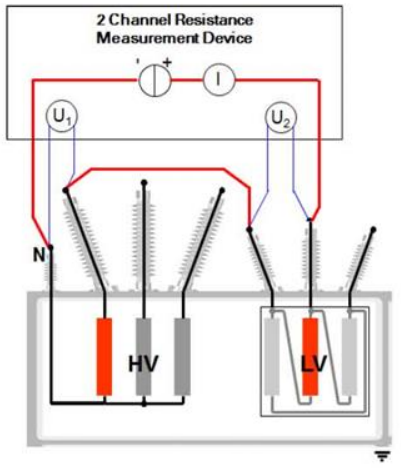
Connecting the instrument - improvements

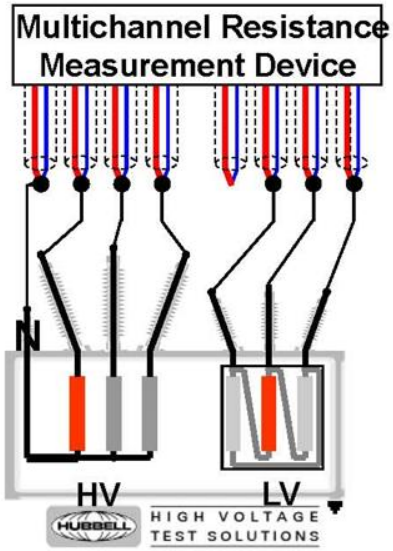
- ✓ Special fast (plug and play) connection instead screwed.
- ✓ Extended “octopus” cable (1,5m) to avoid damaging the instrument screen.



Overall Measuring time using the Tettex 2293 against classic method







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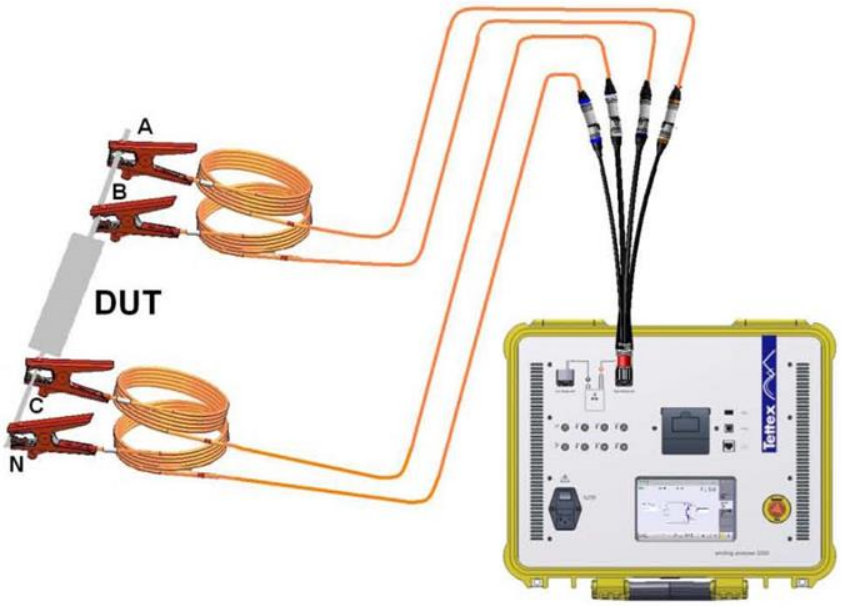
Connection Cables

	Cable set for the Low Voltage side (black clamps)". Cables are equipped with special Kelvin clamps.
	Cable set for the High Voltage side (red clamps)". Cables are equipped with special Kelvin clamps.

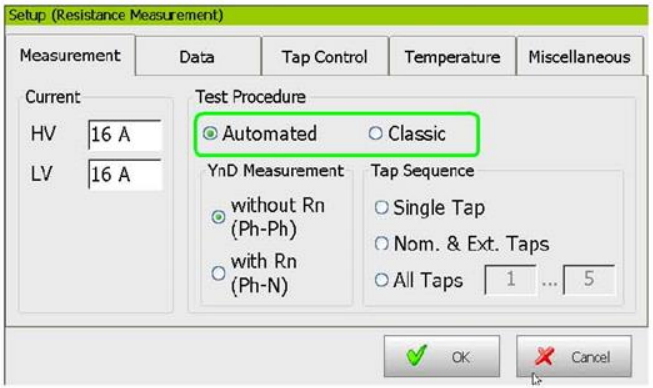
	Adaptor for the low volt side (black ring in the connector)
	Adaptor for the high volt side (red ring in the connector)

	Extension cables, same color code is used, several extension cables can Be connected together 

Classic mode



- Unit can be used on classic mode as a “normal” kelvin type low resistance measuring unit,



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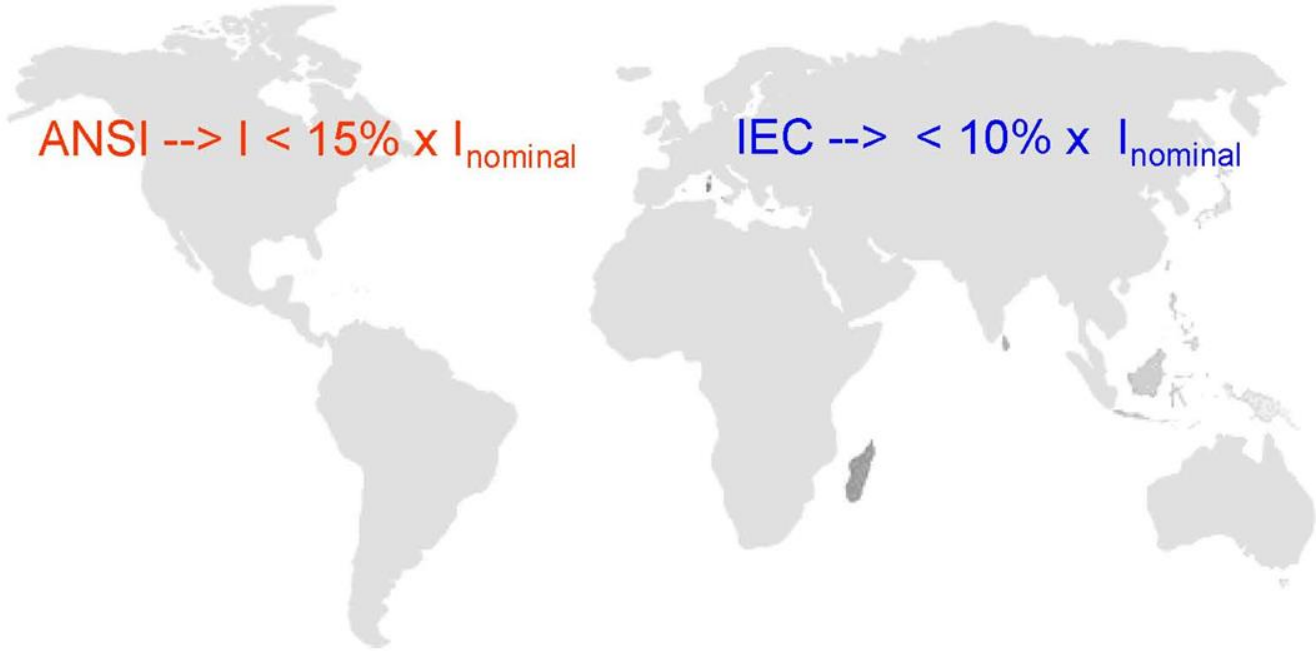
Standards requirements



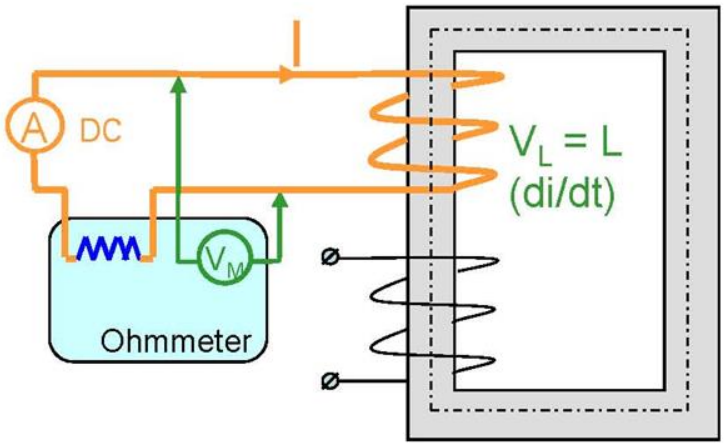
ANSI --> I < 15% x $I_{nominal}$

IEC --> < 10% x $I_{nominal}$

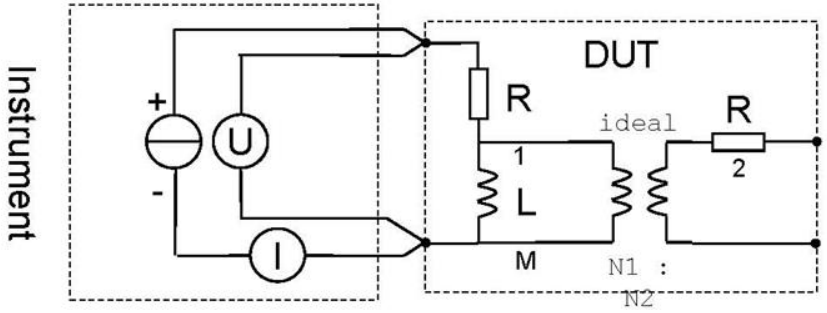
Current must be enough to saturate the core, but not so high that heat up the windings !!!

Winding Resistance Measurement principle

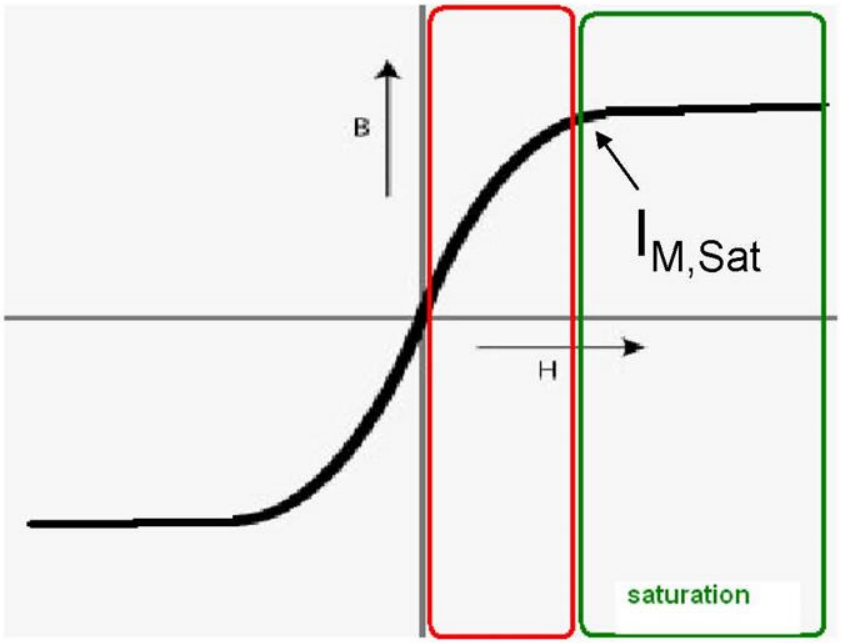
- Low resistances are normally measured according the kelvin method (4 wires).
- On large inductive objects (like transformers) , complete core magnetization is requested to get a stable value



$$R = \frac{U}{I} = \frac{U_R + U_{LM}}{I} = \frac{U_R}{I} + L_M \cdot \frac{dI}{dt}$$

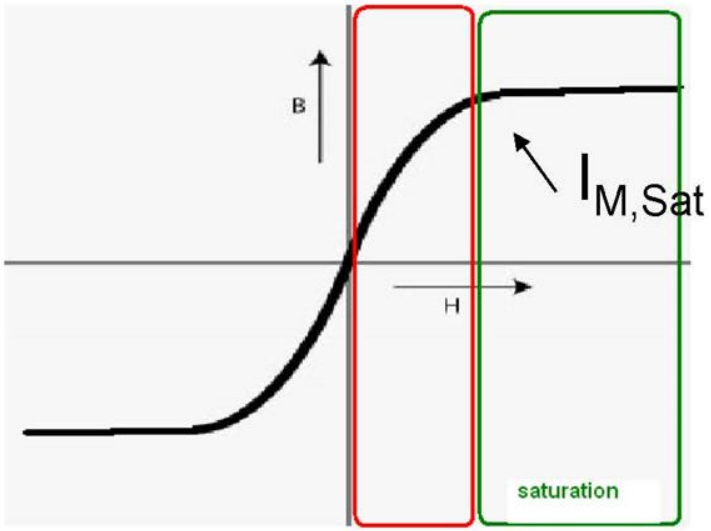


Difficulties when measurement transformers



- Inductance of the transformer is not linear, once saturation is reached the inductance drop drastically (> 100 times).
- to get stable values, target measuement current should be above the $I_{M,Sat}$.
- This saturation current ($I_{M,Sat)}$ is normally not so high (approx 150% of the no load losses current), therefore not so high currents are necesary.

Higher voltages speed up the measurement

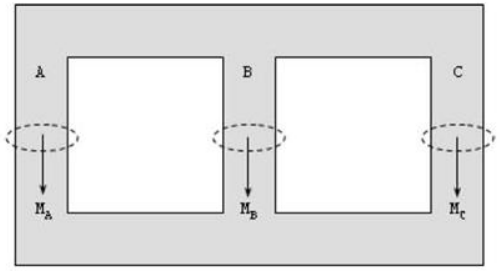


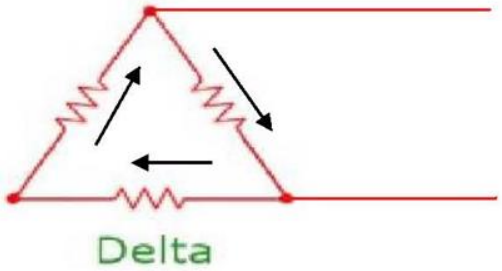
50 V charging	
10 A = 20 s	20 A = 30 s
100 V charging	
10 A = 10 s	20 A = 15 s

- Charging time (time to reach stable current) is shown in the red area
- Time to reach the green area (stable current value) depends on the inductance of the test object and the voltage and power applied.
- Higher voltages with same power speed up the magnetization (contrary what is worldwide acepted, that higher current is the key)

Delta winding problem

- The measured resistance depends on the current distribution on the two delta paths. The measured resistance is only correct, after the current has balanced to its final value.
- Using the high voltage winding to saturate the core, helps to balance the current faster, and therefore reduced the measuring time drastically

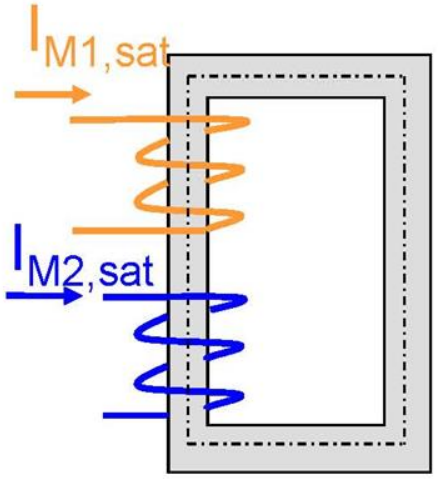




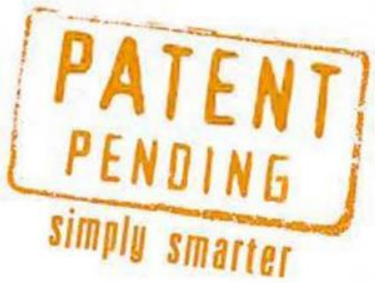
Simultaneous winding magnetization (SWM)

- Always keep in mind, that the measuring object is a transformer

$$I_{M2,Sat} = I_{M1,Sat} \cdot N_{Ratio}$$

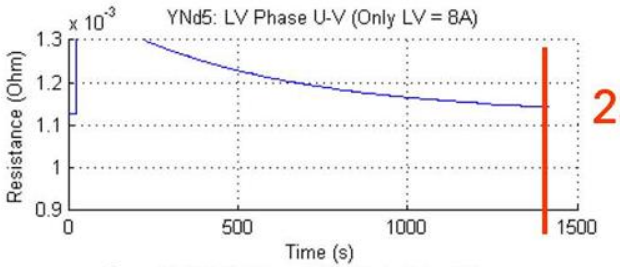


- Applying current in both transformers windings simultaneously speed up the measuring time

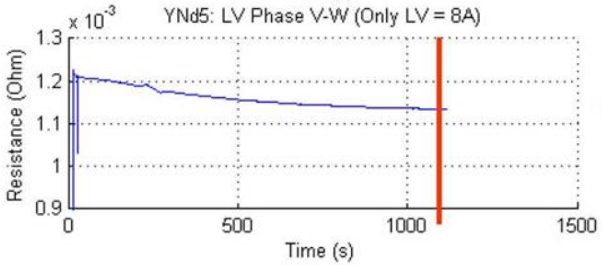


SWM – Example (YNd5 - 1100MVA)

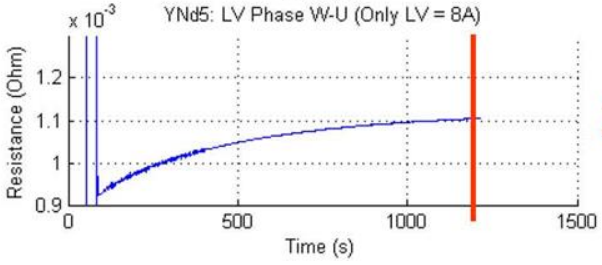
8A – LV only



23′

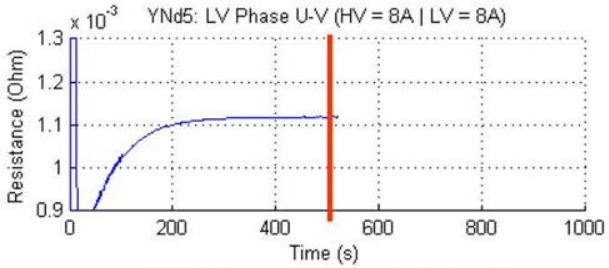


18′

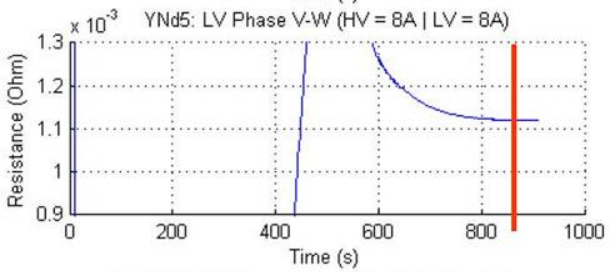


20′

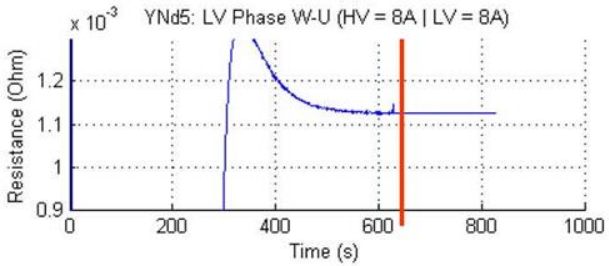
8A – HV and LV



9′



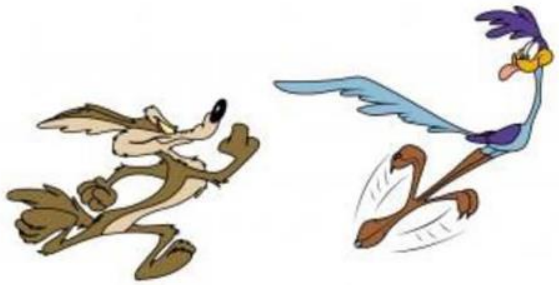
14′



11′

Field results with the new techniques

- YNyn0, 672MVA,345/138kv
  - ☺ Overall time for the 24 taps → 58'30''
- YNd 900MVA 230/24 kV
  - ☺ Overall time for the 21 taps → 2h40'

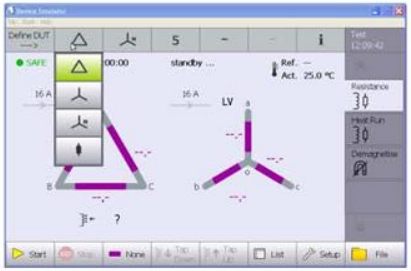


Others

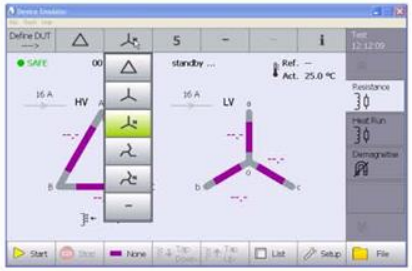
TETTEX 2293

✓Faster
✓Easier
✓Additional functions

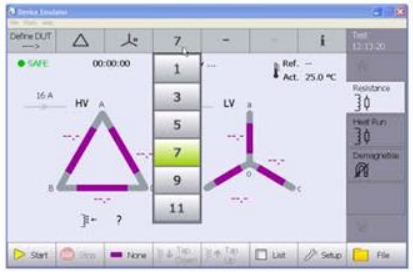
Resistance measurement with 2293



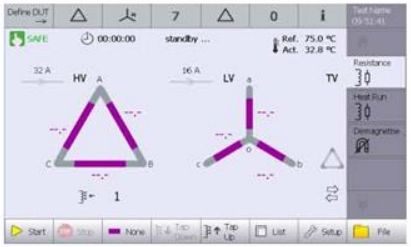
Selection of the HV winding



Selection of the LV winding

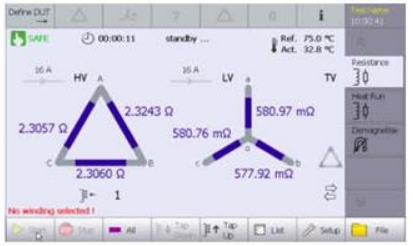


Selection of the phase shift



start button to initiate the resistance test

Automatic measurement



Measurement results

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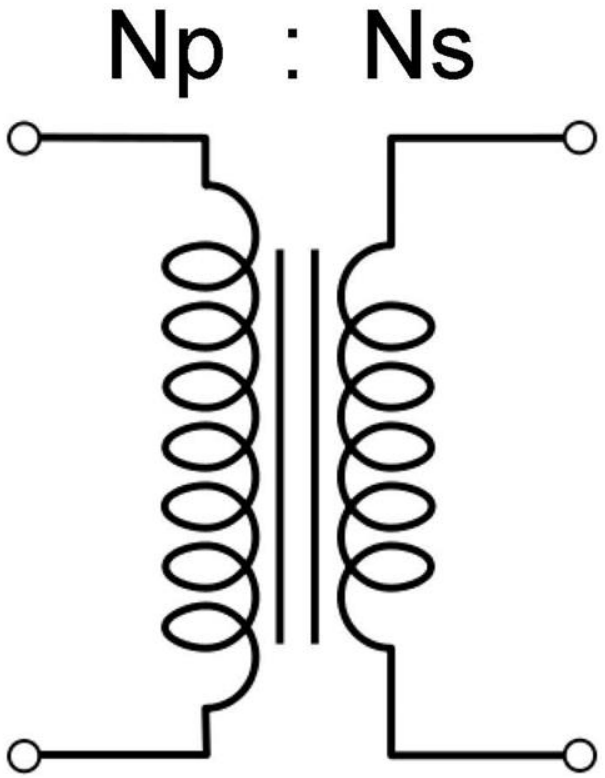
What is a Turns Ratio measurement

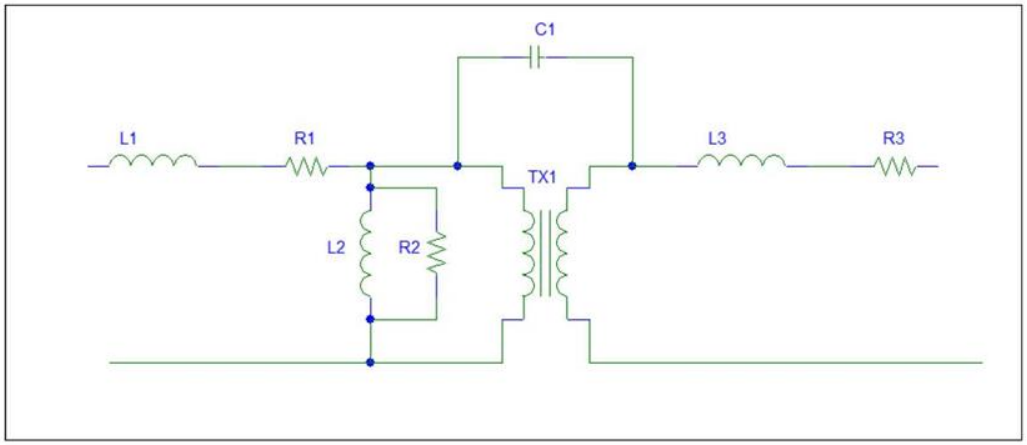
- The turns ratio of a transformer is defined as the number of turns on its secondary divided by the number of turns on its primary.
- The voltage ratio of an ideal transformer is directly related to the turns ratio

$$\frac{Vs}{Vp} = \frac{Ns}{Np}$$



What is a Turns Ratio measurement

Unfortunately, however, “real” transformers include a number of electrical properties that result in a voltage ratio that may not be equal to the physical turns ratio.

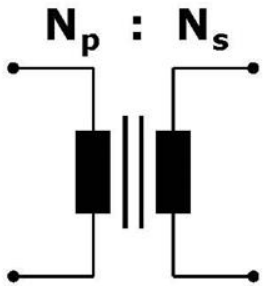


- **L1 & L3** represent the primary and the secondary leakage inductance caused by incomplete magnetic coupling between the windings.
- **R1 & R2** represent the resistance (copper loss) of the primary and secondary winding
- **C1** represent the inter-winding capacitance
- **L2** represent the magnetizing inductance core loss
- **R2** represent the core loss

Transformer Turns Ratio Measurement

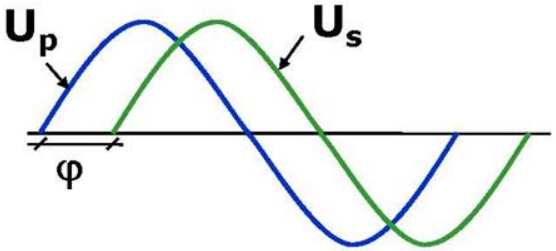
- Voltage ratio

$$r = \frac{U_P}{U_S} = \frac{N_P}{N_S}$$



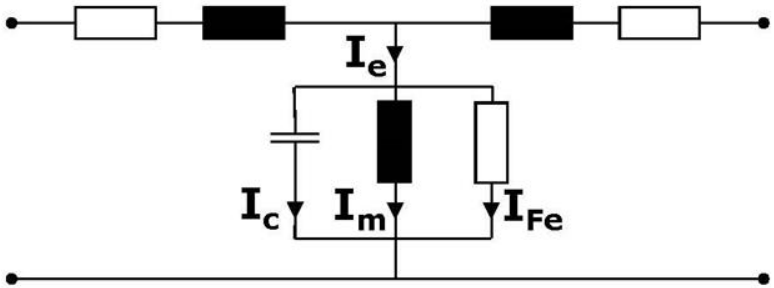
- Phase displacement

$$\varphi = \angle\{U_P(t), U_S(t)\}$$



- Excitation / Energization current

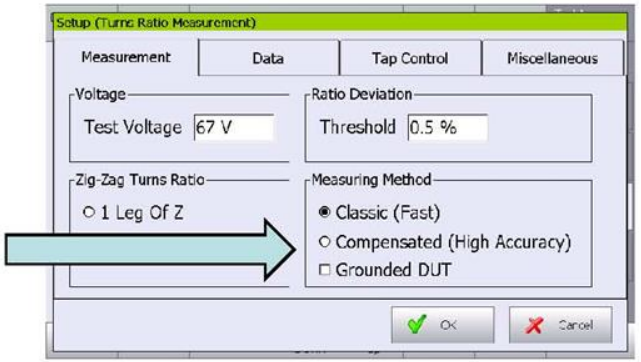
$$I_e = I_c + I_{Fe} + I_m$$



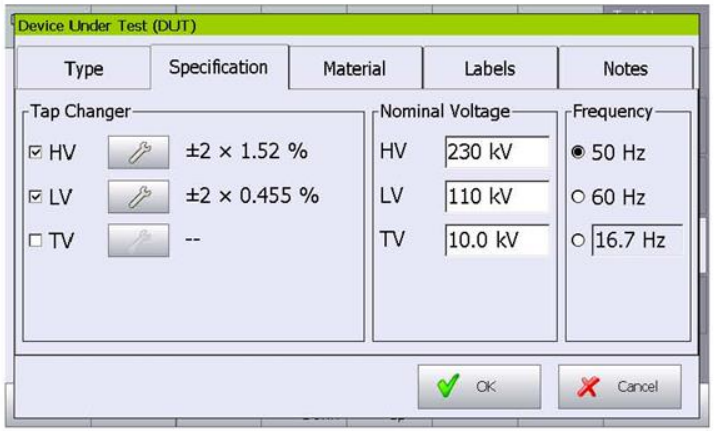
Ratio measurement using compensated mode

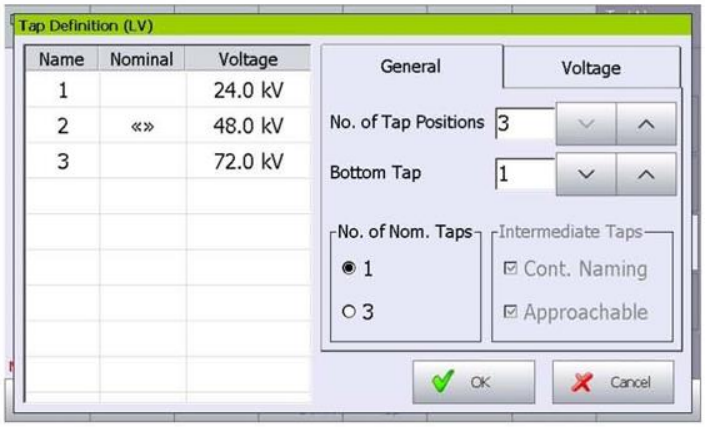
The 2293 has an advance (compensated) measuring mode

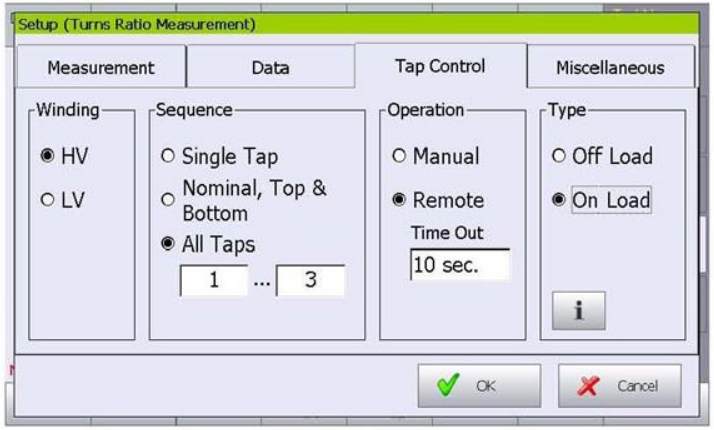
By using this advance mode, **results equivalent to 250V test voltage can be reached by using lower (and safer) test voltages**.

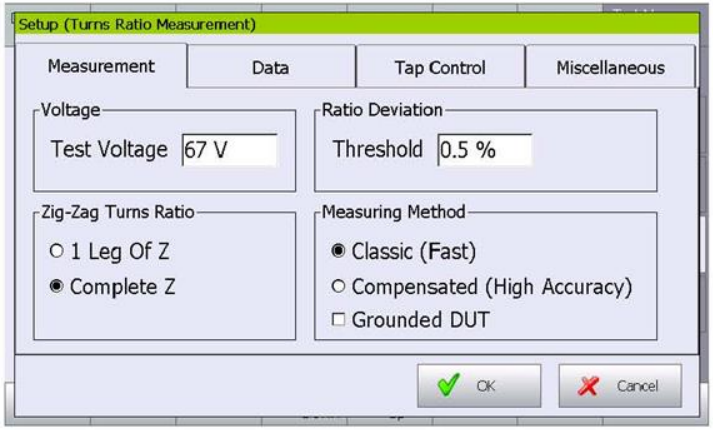


Turns Ratio: Settings

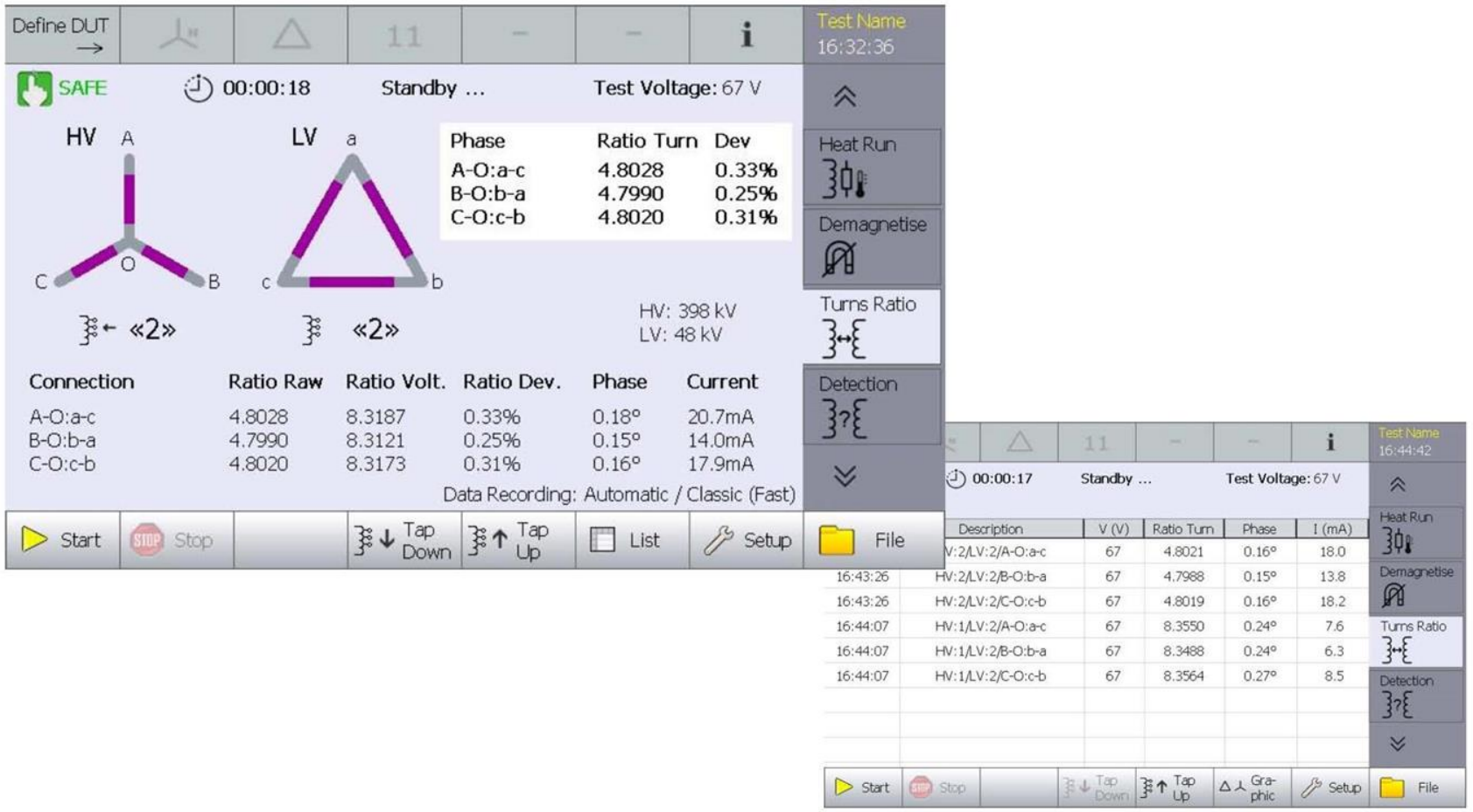








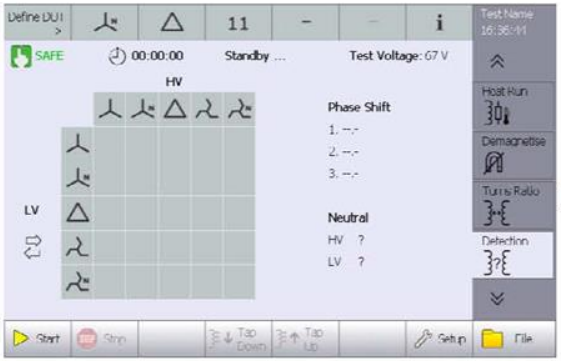
Turns Ratio Measurement



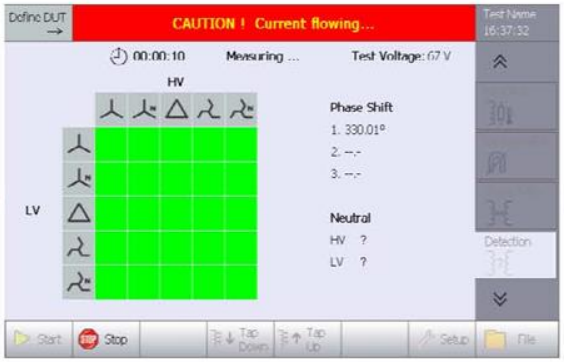
TTR APSW 2796 Software

The Automatic Winding Connection Identification (AWCI) aids testing of unknown transformer configurations. The AWCI acts like a nameplate guesser and detects the transformer configuration and vector group of the most common three phase transformers.

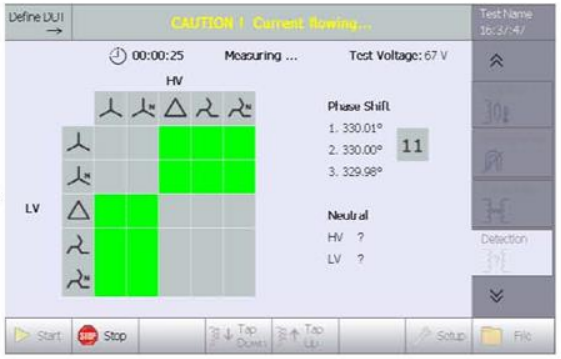
Transformer Configuration Detection



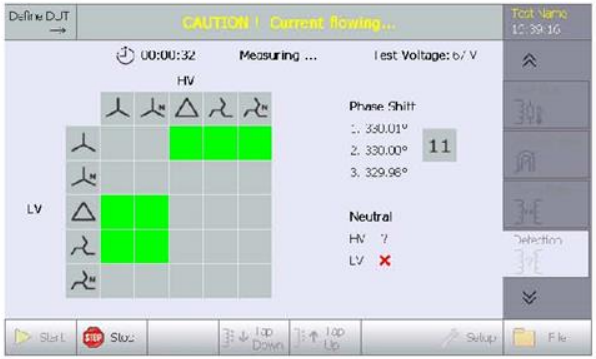
Starting Detection…



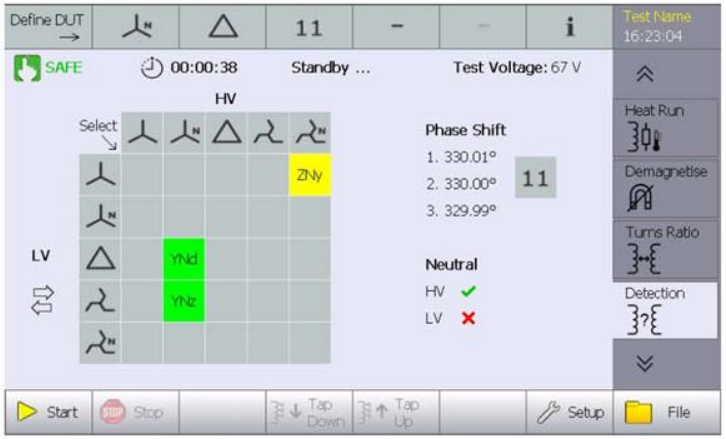
Detection of the Phase Shift between primary and secondary



Eliminating non-matching vector groups and defining clock-number



Detecting Neutrals on HV- and LV-side



The Detection Tool shows the remaining possibilities and in green the most probable configuration

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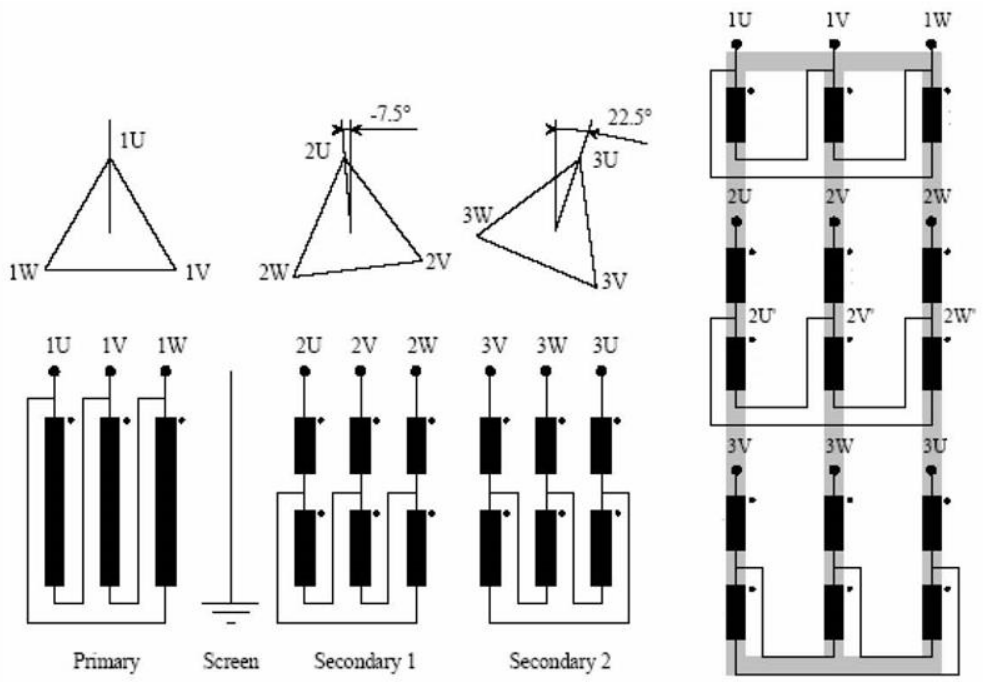
Arbitrary phase shifted transformers

- Arbitrary phase shifts or those that do not follow the 30° phase steps between the primary and secondary winding are common in special transformers like phase-shifting, rectifier / furnace and traction transformers.



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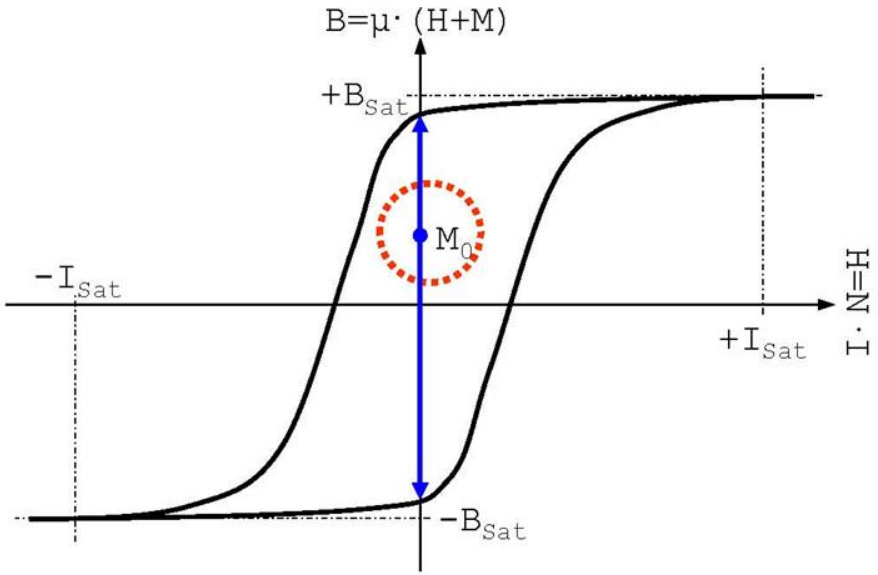
Residual Magnetization

Possible causes:

- disconnection from the grid
- DC current measurement

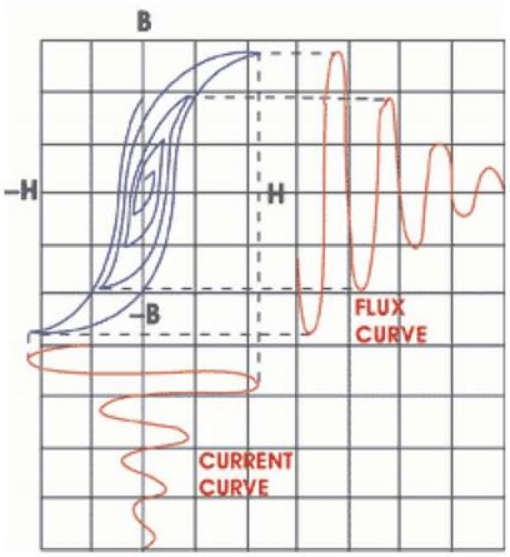


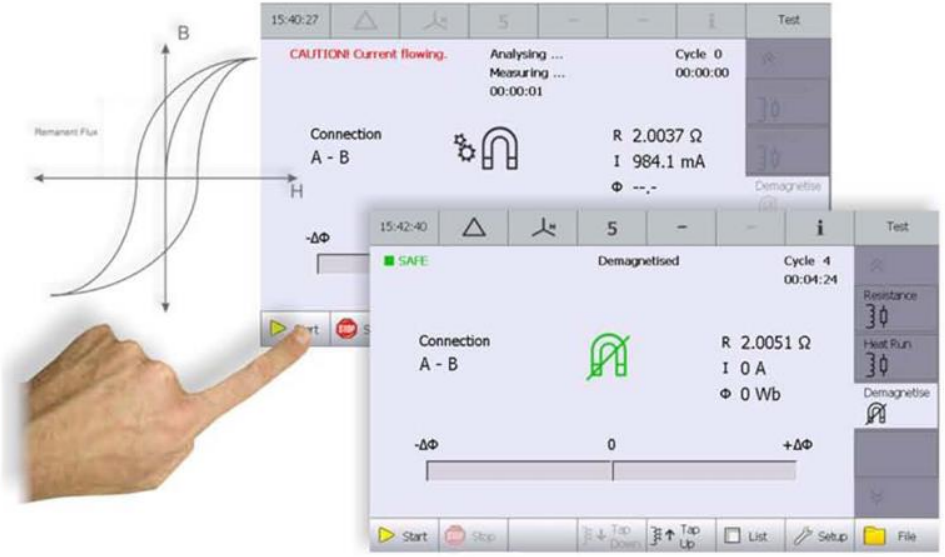
Consequences:

- faulty TTR and FRA measurements
- Possible dangerous state during reconnection to the grid

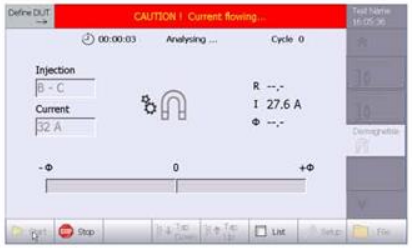
Demagnetization

- The 2293 measures the magnetic remanence and demagnetizes the core.



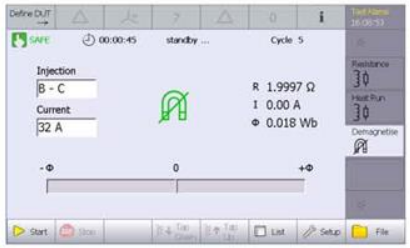


Demagnetization running



Current injection and resistance measurement

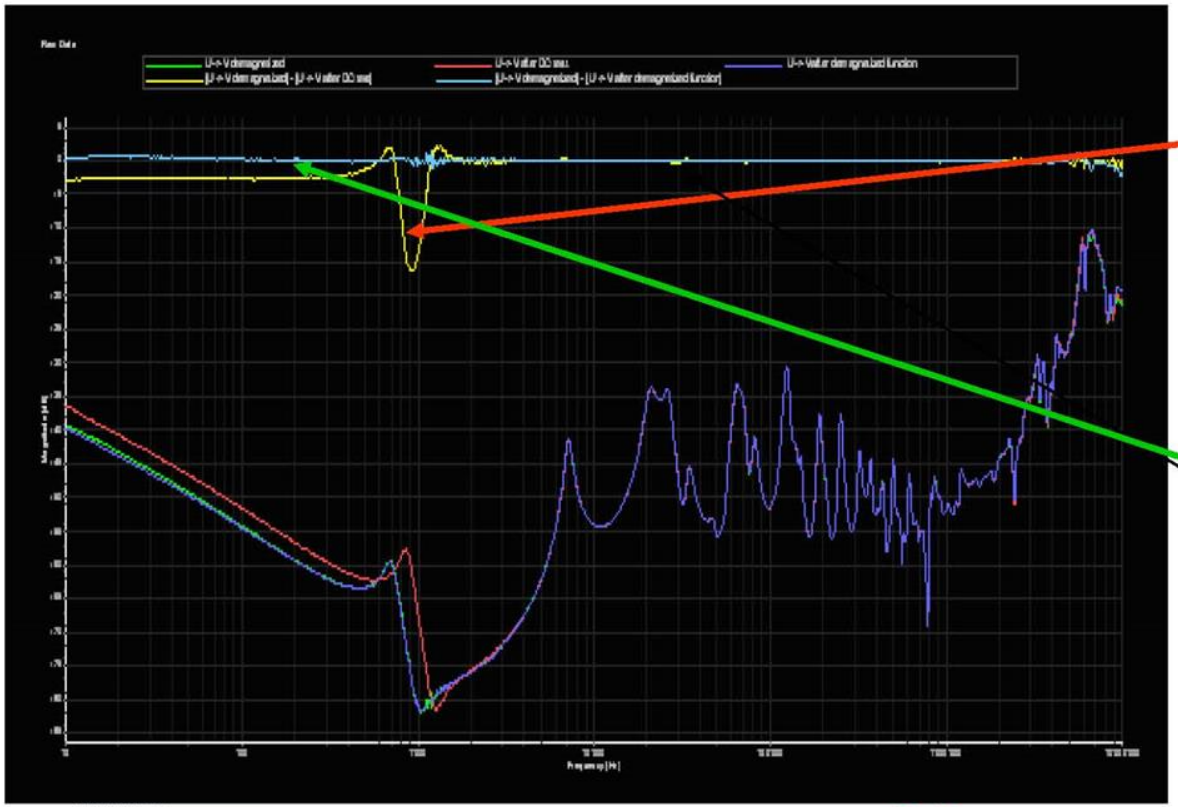
Transformer being demagnetized. The bar indicates the actual flux.



Transformer demagnetized

2293 demagnetized the transformer

- FRA test with transformer demagnetized, magnetized (after a resistance measurement) and de-magnetized with the 2293.



Yellow, difference between transformer magnetized/demagnetized

Light blue, differences between transformer demagnetized, and after winding resistance and demagnetization with the 2293.

No differences arise !

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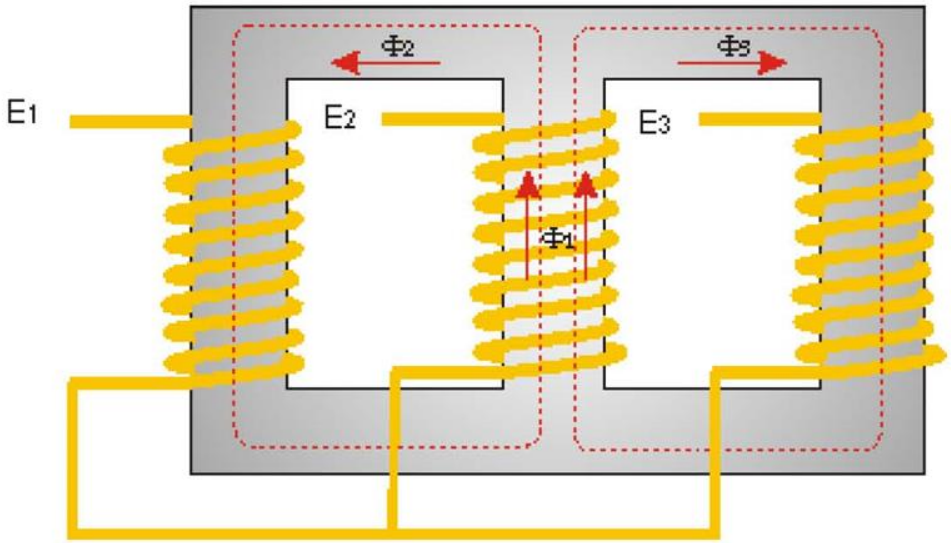
Magnetic Balance, generalities

- Magnetic Balance test is conducted on transformers to identify inter turn faults and magnetic imbalance.

$$E_{m(RMS)} = 4.44\Phi_m f N$$

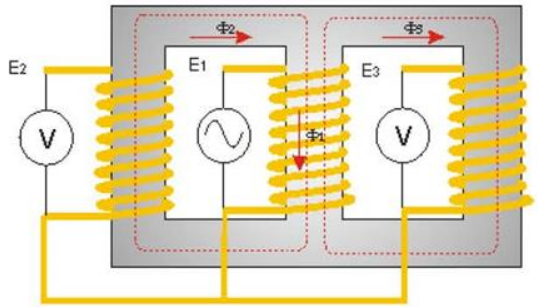
$$\Phi_1 = \Phi_2 + \Phi_3$$

N = Number of turns
F = Frequency
Φ = magnetic Flux



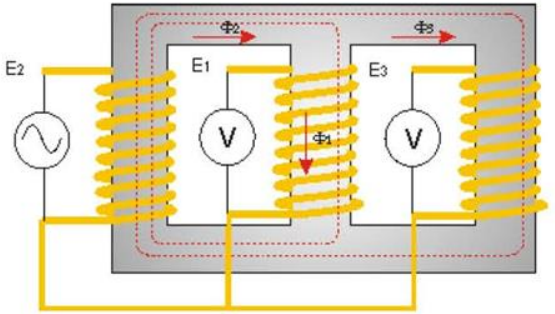
Magnetic balance procedure

- Test is done aplaying voltage on one phase, and reading the voltage on the other two, theorically.



$$\Phi_2 = \Phi_3 = \frac{1}{2}\Phi_1$$

$$E_2 = E_3 = \frac{1}{2}E_1$$

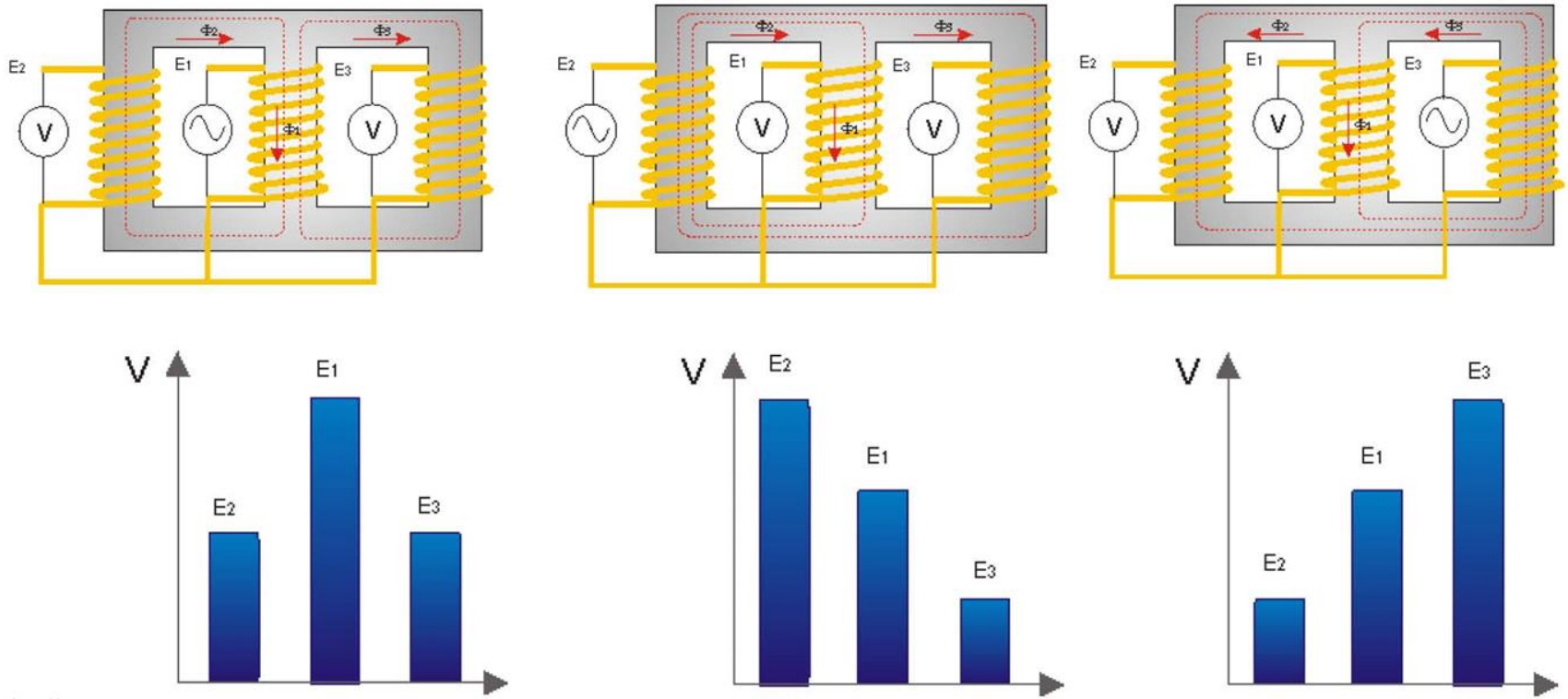


$$\Phi_1 = \frac{2}{3}\Phi_2 \,; E_1 = \frac{2}{3}E_2$$

$$\Phi_3 = \frac{1}{3}\Phi_2 \,; E_3 = \frac{1}{3}E_2$$

Magnetic Balance

- In practical, several parameters influence the flux distribution in the transformer, but the voltages must be similarly distributed between the limbs



Magnetic Balance in 2293

- The 2293 performs the magnetic balance test automatically and without any reconnection.
- Test results are shown graphically for a better understanding;
- automatic comparison of the results between phases is automatically done

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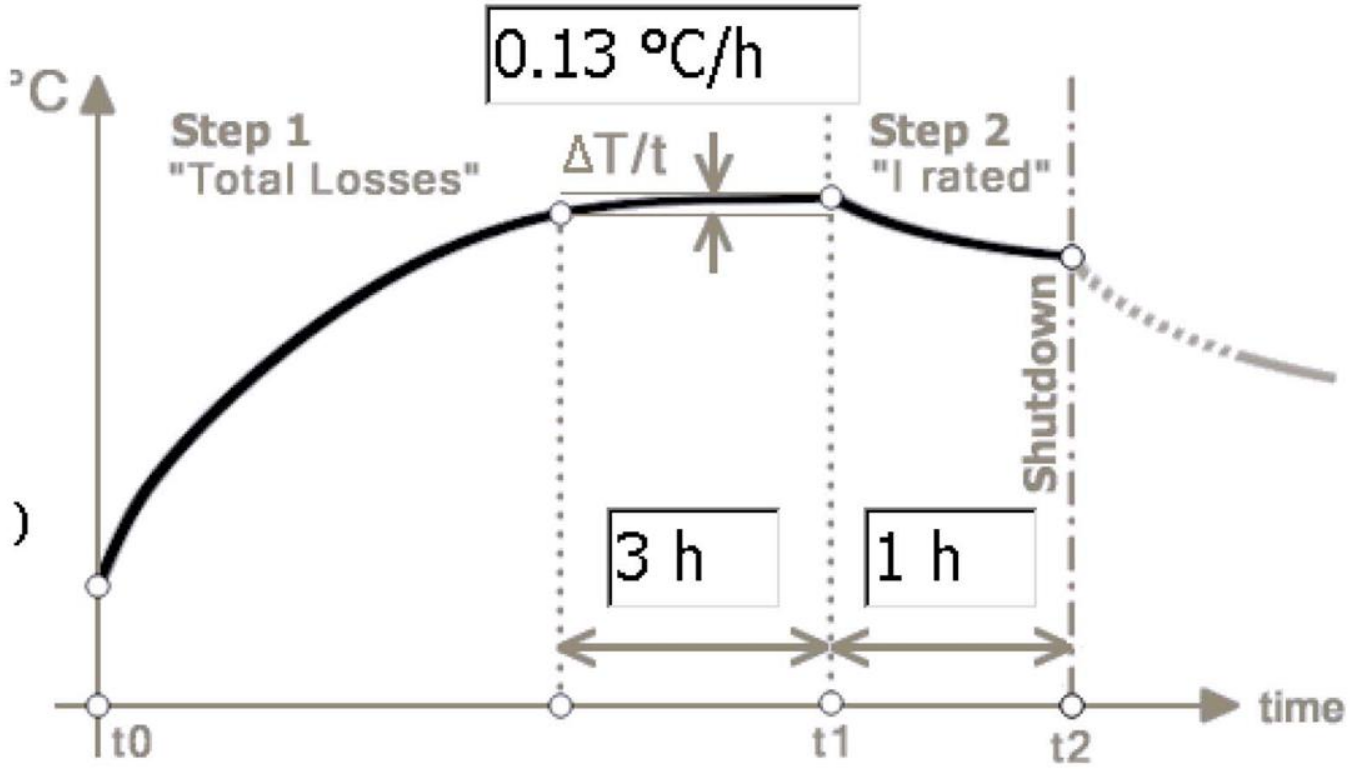
Heat run test

Heat run test on transformers consist of two steps;

- **Heat rise**, where the transformer runs at nominal losses and transformer temperature rises.
- **Cooling curve**, when transformer is disconnected and winding resistance is measured.

Heat run test graphic

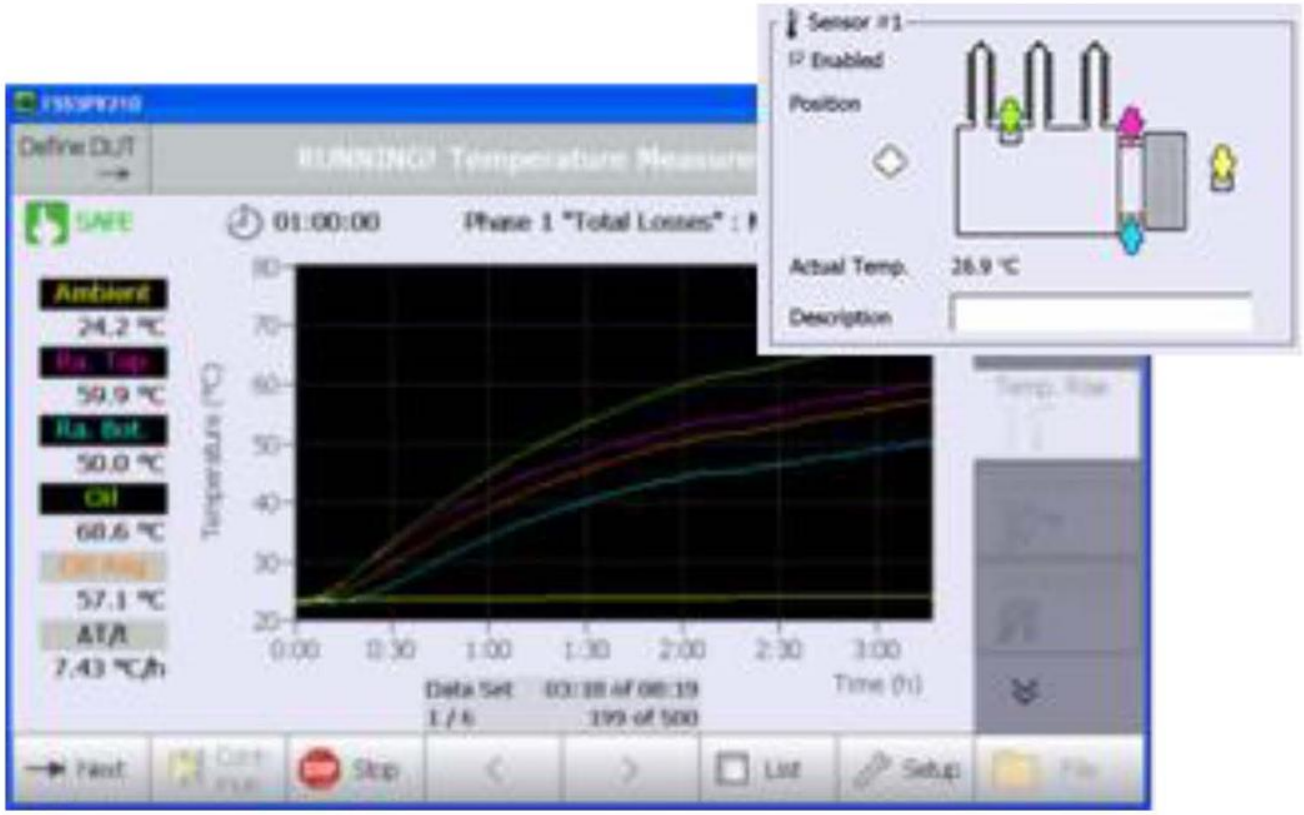


Heat run test

THE 2293 performs the measurements on both steps.

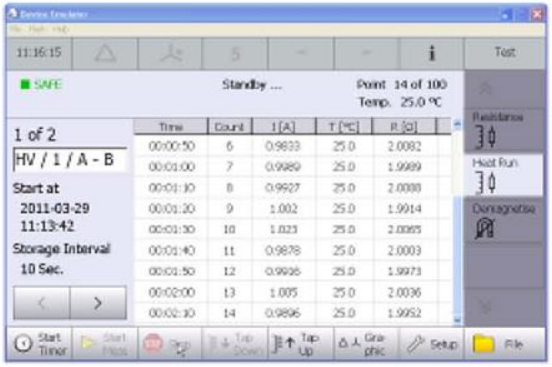
- It **monitors the transformer temperature** during the heat rise,
- it **measure HV and LV side resistances** simultaneously during the cooling curve.

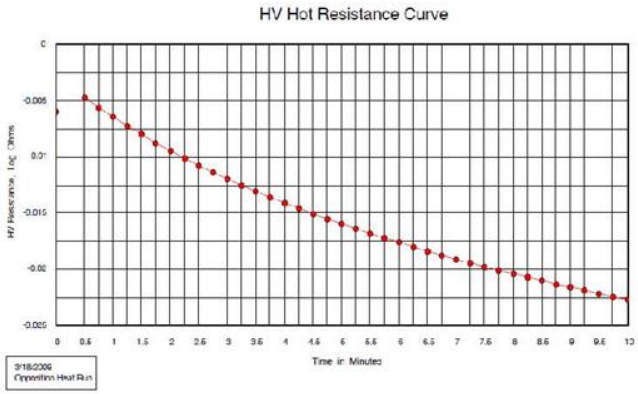
Heat run test



2293 Heat Run test

The 2293 acquire the necessary information (zero time and resistance over time) to draw the cooling curve and calculate the maximum temperature





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4. Ratio measurement
5. Demagnetization function
6. Attenuation/Transformer detection
7. Cooling curve measurement
8. Applications , unique selling points and sales tools

2293 Main applications

- **Power and distribution transformer manufacturers.**
  - ✓ Factory test
  - ✓ Quality assurement
- **Utilities and servicing companies**
  - ✓ Acceptance
  - ✓ Periodic maintenance on substations
  - ✓ Fault detection
- **Rotating machines manufacturers**
  - ✓ Factory test
  - ✓ Quality assurement
- **Repairing shops**
  - ✓ Fault detection
  - ✓ Reparation

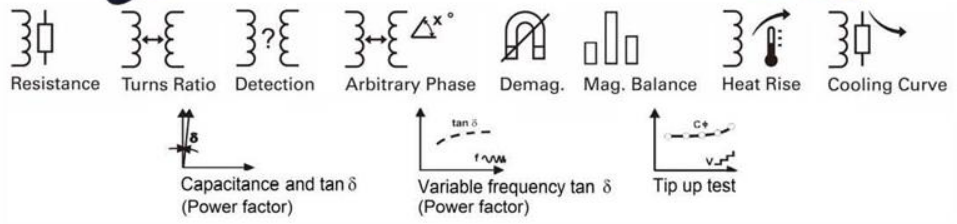
Optimized for high inductive apparatous !!!

2293 Unique selling points

- Multipurpose winding analyzer: **transformer winding resistance, turns ratio, type detection, arbitrary phase ratio measurement, demagnetisation, magnetic balance** and **heat run test** (heat rise and cooling curve) in one instrument.

- Advance modes (SWM and higher voltages during resistance, compensated mode during ratio, nameplate guesser…)
- Easiest and faster portable device available in the market

2293 & 2883 (Midas micro)



Combine the Winding Analyzer 2293 with the MIDAS micro 2883 for an entire test solution on transformers. Compatible file formats allow data exchange between the two units and measurements results are combined for further analysis or processing.

Sales tool – Quick fact sheet (under revision…)

Tettex 2293

Winding resistance meter with one-time-connection system

Tettex

Key Specifications

- 32 A (100 A comparable with SWM)
- 100 V test voltage
- 0.1 µΩ to 300 kΩ
- 0.1% accuracy
- Multichannel (trough internal switch)
- 6 temperature channels (up to 36 optional)

Accessories (selection)

2293/TEMPX	temperature probes
2293-TTR	TTR adaptor cable
2293/TAP	Tap changer cable
2293/10	Extension cables 10m

Scope of supply (selection)

cable set 10 m
carrying bag
test certificate, user manual

Key Selling Points

- Faster testing due to one-time-connection (once connected measures three phases and two windings)
- Demagnetization function
- Simultaneous Winding Magnetization method (SWM) and active discharging circuit reduces testing time
- full graphical test visualization through a touch screen
- automatic tap changer control (option)
- easy data transfer through USB interface
- Heat run test function

Main Applications

- Winding resistance measurement on transformers, rotating machines, instrument transformers
- Transformer demagnetization
- heat run tests

Main Customers

- manufacturers of transformers, rotating machines and instrument transformers
- utilities and service companies (contractors) for acceptance and maintenance

main competitor's products, claims and Tettex answers

Confidential Information

Raytech WR50-2

- **Claim 1**: *Raytech has higher measuring curent (50V/50A).*
- **Answer** : 2293 has 100V/32A ratings. Higher voltages speeds up the charging more then high currents. Together with SWM the 2293 is faster.
- **Claim 2**: *Raytech has heavy duty discharge circuit.*
- **Answer**: 2293 has active discharging circuit wich optimizes discharge.
- **Claim 3**: *Raytech has demagnetization function.*
- **Answer**: 2293 has improved demagnetization function

Megger MTO-210

- **Claim 1**: *10V/100V DC power supply is enough for most of the cases*
- **Answer**: For large power transformers long testing time and even not stable readings.
- **Claim 2**: *Lightweigh and mobile*
- **Answer**: 2293 is also mobile and lightweight.
- **Claim 3**: *Cheaper product that is enough*
- **Answer**: *The 2293 with SWM and one time connection system reduced drastically the overall measurement time and will return the aditional investment*

Vanguard WRM 40

- **Claim 1**: *Measures a 500MVA transformer in 5 minutes or less (36V/40A).*
- **Answer** : 2293 has 100V/32A ratings. Higher voltages speeds up the charging voltage more than high currents. Together with SWM the 2293 is faster.
- **Claim 2**: *Vanguard has auto discharge circuit*
- **Answer**: 2293 has active discharging circuit, safety switch (standard) and interlock connection (option).
- **Claim 3**: *Auto current ranging and wide meas. Range*
- **Answer**: 2293 has selectable current and wider range

DV power RMO 40TC

- **Claim 1**: *Generatores true DC ripple free current*
- **Answer**: 2293 generates also a true DC ripple free current
- **Claim 2**: *DV-Win software test could be performed from a PC, results can be aquired also in the PC*
- **Answer**: 2293 has a windows based graphical intuitive interface included, no connection to a PC needed. Results are exported to a PC using a memory stick.

Confidential Information

Additional Information

- **Leaflet**: www.tettex.com
- **Customer Presentation**: on request sales@tettex.com
- for any other question contact sales@tettex.com or +41 61 373 41 11

QuickFactSheet 2293, 22.07.2011, SG

swiss made.

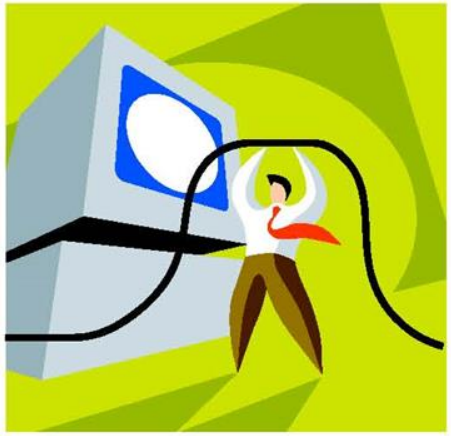
Designed by Tettex INSTRUMENTS

HUBBELL HIGH VOLTAGE TEST SOLUTIONS

Available Sales Tools

- Leaflet
- Comparison sheet
- Presentations
- Webpage

- **Onsite Demos**



Feedback needed.

Feedback is always wellcome !!!

Many thanks for your Attention!

Muchas gracias por su atención!

Vielen Dank für Ihre Aufmerksamkeit!

Merci pour votre attention!


Questions ?