



TRANSFORMER-LIFE-MANAGEMENT
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Frequency Converter as Power Supply for Transformer Testing

Frederic Dollinger
Haefely





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Frequency Converter as Power Supply for Transformer Testing



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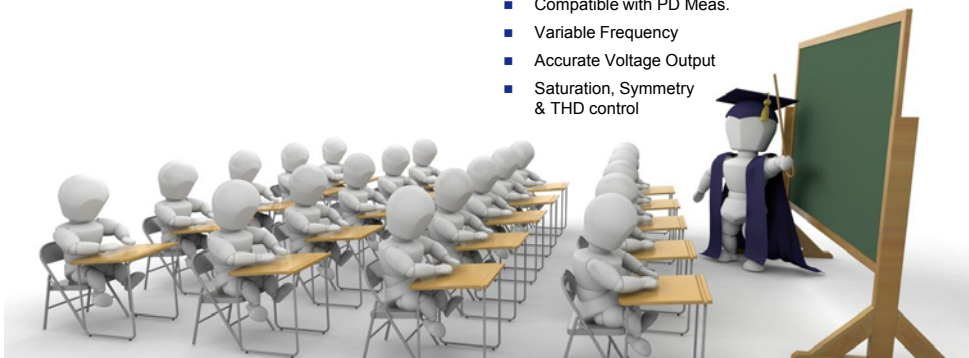
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Frequency Converter as Power Supply for Transformer Testing

- **1: Introduction to Frequency Converter**
 - F.C. Technology
 - Typical Application
 - How does F.C. work?
- **2: Why use F.C.?**
 - Compact Hardware
 - Maintenance / Service
 - Safety
 - Redundancy
 - Decoupled Power Supply
 - Compatible with PD Meas.
 - Variable Frequency
 - Accurate Voltage Output
 - Saturation, Symmetry & THD control



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Frequency Converter as Power Supply for Transformer Testing



1: Introduction to Frequency Converter

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 - F.C. Technology
 - Typical Application
 - How does F.C. work?



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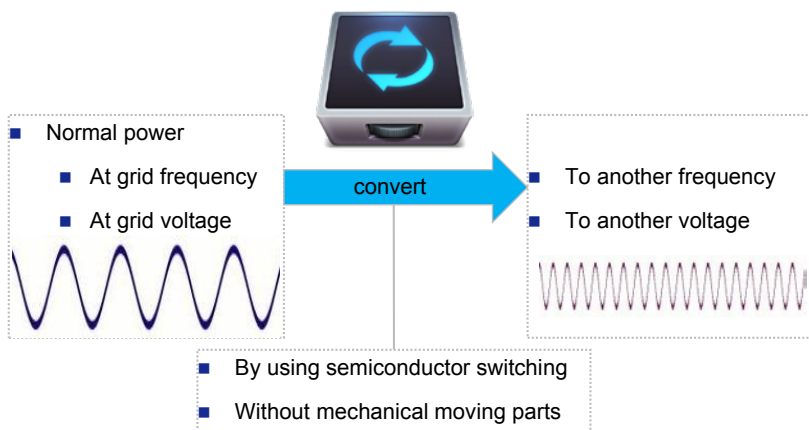
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F.C. Technology

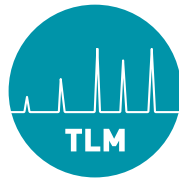
- F.C.: Frequency Converter or frequency inverter or frequency changer
- Device to convert



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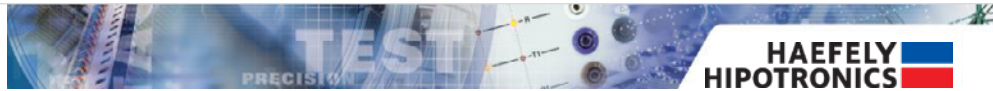
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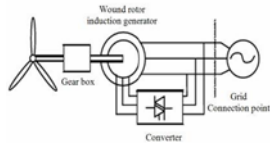


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Typical Applications



- Motor drive in industrial application: control speed and torque of AC motor (, pumps, fans, etc...)
- Airline industries:
 - airplanes use power at 400 Hz, the F.C. will power supply the airplane on the ground
 - On board F.C. as power supply to passengers for laptop or other devices
- Renewable energy system: F.C. is an essential component of doubly fed induction generators (DFIGs)

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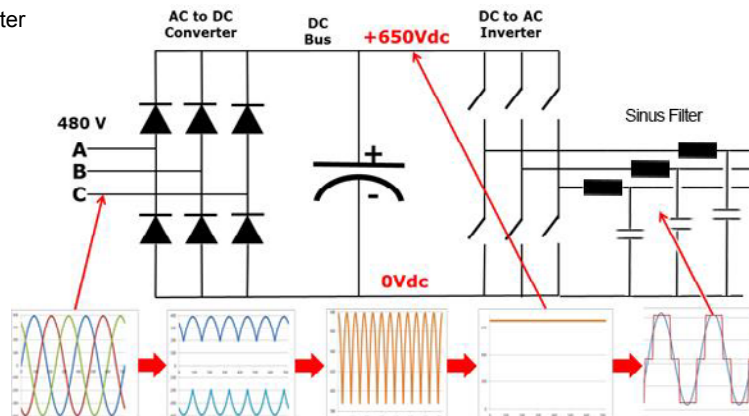
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How does F.C. work?

- 1: convert AC to DC
- 2: inverter DC to AC
- 3: Sine filter



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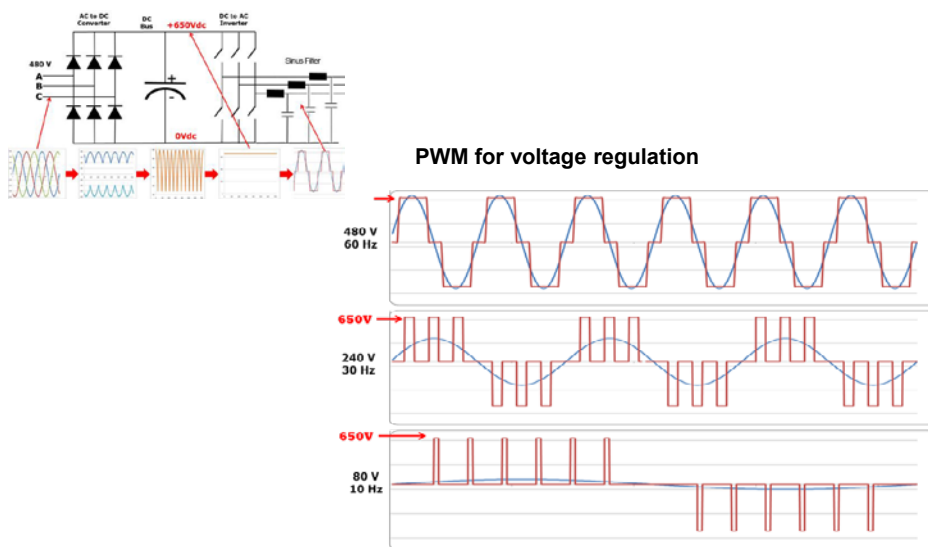


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How does F.C. work?



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2: Why use F.C?

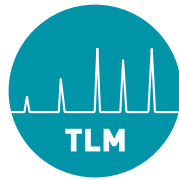
- **2: Why use F.C?**
 - Compact Hardware
 - Maintenance / Service
 - Safety
 - Redundancy
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 - Compatible with PD Meas.
 - Variable Frequency
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Compact hardware

- Optimized kW/kg and kW/m³ ratio



Power: 600 kVA
LxWxH: 4.5 m x 1.3 m x 1.3 m
Weight: 5.9 t
Spec. Volume: **12.7 m³ / MVA**
Spec. Weight: **9.8 t / MVA**



Power: 540 kVA
LxWxH: 1.2 m x 0.8 m x 2.2 m
Weight: 0.8 t
Spec. Volume: **3.9 m³ / MVA**
Spec. Weight: **1.5 t / MVA**






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Compact hardware

- Ease of integration in existing test lab 
 - Cabinet solution, 9' container or 20' container, depending on the power
 - Low noise emission (max. 80 dBA at 1m)
 - No vibration
- Plug & Play design 
 - Fast installation
 - Low risk of complication during commissioning
- Ease of transportation 
 - For delivery
 - In case factory change the location



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Maintenance / Service

- **Maintenance free:** no moving parts apart from cooling fans ✓
- **Standard components:** ✓
 - Commercial **standard F.C. hardware** from world's leading supplier with strong after sales service available worldwide
 - **Haefely Hipotronics software** for specific application, transformer testing
- **Service ready:** optimized for easy serviceability. All components are easily accessible and interchangeable ✓
- **Online monitoring and diagnostic** ✓



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Safety

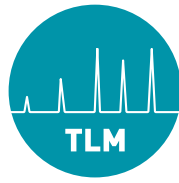
- **“Safety integrated”** ✓
 - PLC for F.C. and safety control
 - Smart and safe reactions to various situations
- **F.C.: high dynamic** ✓
 - Voltage or current trip detection
 - Short response times provide the highest safety level during unexpected situation



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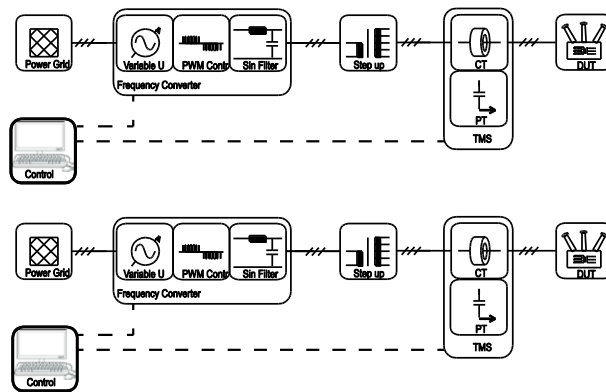
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Redundancy

- Parallel or standalone use ✓
- Easy to upgrade the power ✓



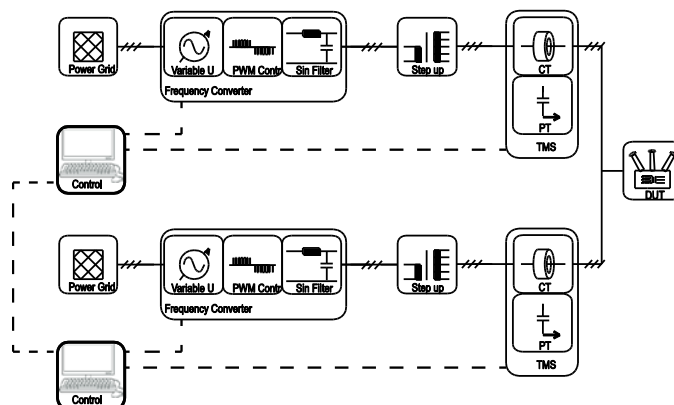
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Redundancy



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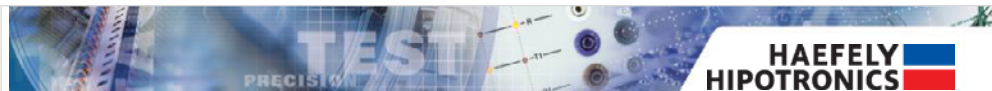
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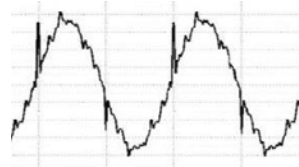
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Decoupled power supply

- Decoupling from:
 - Feeding power mains voltage ✓
 - Feeding power mains frequency ✓
 - Feeding power mains distortion ✓
 - Feeding power mains asymmetry ✓
- Frequency interface separation:
 - Network frequency interference will be filtered out and not impact the test system ✓
 - Test system frequency interference will not go back to the network ✓



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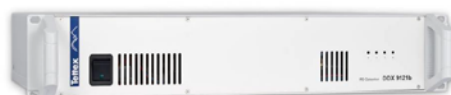
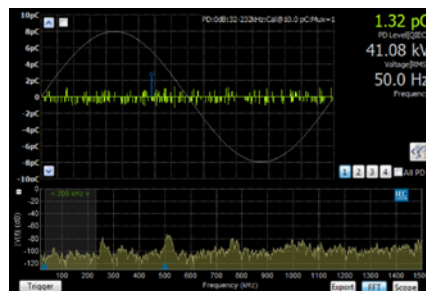
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Compatible with Partial Discharge measurement

- Various filtering stages enables partial discharge measurement according IEC and IEEE ✓



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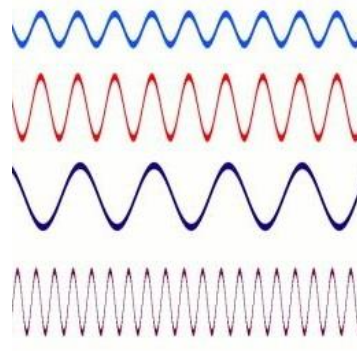
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Variable Frequency

- **Variable frequency:** from 50 Hz to 200 Hz ✓
 - Can perform applied voltage at 50 Hz and 60 Hz
 - Can measure losses at 50 Hz and 60 Hz
 - Can perform induced voltage at any frequency
 - Change the frequency without reconnection



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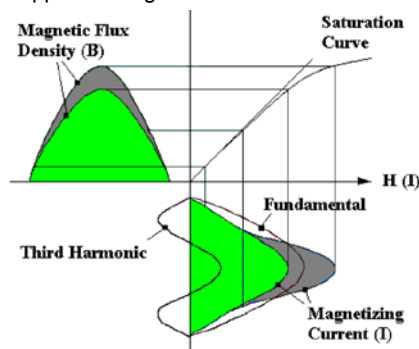
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Accurate voltage output

- **Accurate voltage output** ✓
(step less adjustment, feedback loop with the measurement)
 - Interesting for No Load loss:
1% deviation on the applied voltage would increase 1% to 3% the losses



During no load loss measuring, the transformer is in the saturation working area

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Saturation control

- Automatic & online saturation control ✓
 - In case of conventional frequency converter, the DC to AC inverter of the frequency converter has some tolerance in the pulse width modulation. This can generate a DC offset and some sub harmonics while testing a transformer, which can lead to saturation of the test system and the transformer under test.
 - This control is especially important during the no-load loss measurement



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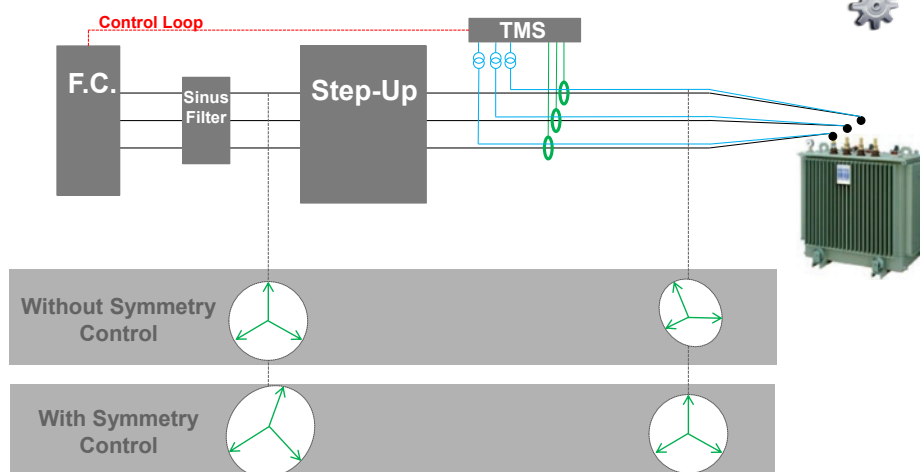
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Voltage symmetry control

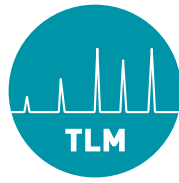
- Automatic & online voltage symmetry control ✓



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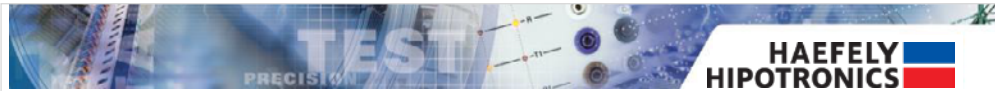
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Symmetry Control

Example on a 2'500 kVA, 33 kV / 400 V transformer

- Without Symmetry Control

	Phase A	Phase B	Phase C	SIMMING
Voltage RMS	232.147 V	234.035 V	230.442 V	233.209 V
Loss	1.073 kW	0.900 W	1.290 kW	2.909 kW
Loss(B)	0.328	0.211	0.482	0.343
Current (%)	33.852 %	26.483 %	27.967 %	29.434 %
U THD	2.450 %	2.170 %	2.760 %	2.460 %
V THD	2.450 %	2.170 %	2.760 %	2.460 %
Loss(B)	0.328	0.211	0.482	0.343
QPF Power	3.087 kvar	2.530 kvar	2.347 kvar	7.963 kvar
U THD	2.450 %	2.170 %	2.760 %	2.460 %

- With Symmetry Control

	Phase A	Phase B	Phase C	SIMMING
Voltage RMS	230.501 V	229.952 V	230.344 V	230.266 V
Loss	813.000 W	603.000 W	1.410 kW	2.826 kW
Loss(B)	0.293	0.307	0.531	0.385
Current (%)	28.852 %	20.431 %	27.560 %	25.614 %
U THD	0.865 %	1.050 %	0.868 %	0.926 %
V THD	0.865 %	1.050 %	0.868 %	0.926 %
Loss(B)	0.293	0.307	0.531	0.385
QPF Power	2.657 kvar	1.870 kvar	2.248 kvar	6.776 kvar
U THD	0.865 %	1.050 %	0.868 %	0.926 %

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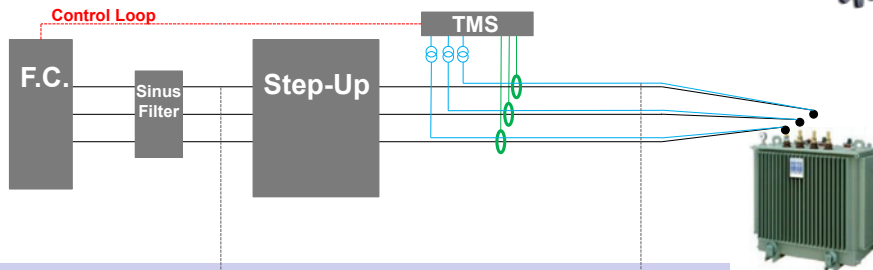
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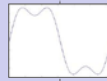
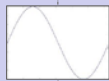


THD Control

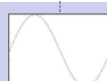
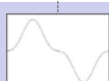
- Automatic & online voltage THD control



Without THD Control



With THD Control



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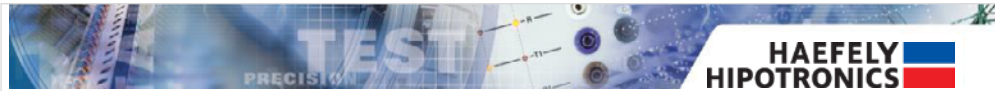
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THD Control

Example on a 2'500 kVA, 33 kV / 400 V transformer

- Without THD Control

	Phase A	Phase B	Phase C	SUM/AVG
Voltage RMS	228.974 V	232.116 V	230.091 V	230.394 V
Power	928.000 W	684.000 W	1.298 kW	2.910 kW
cosφ	0.352	0.320	0.502	0.397
Current (%)	27.081 %	21.962 %	26.531 %	25.191 %
U THD	7.710 %	7.250 %	7.820 %	7.590 %
I THD	7.710 %	7.250 %	7.820 %	7.590 %
cosφI	0.352	0.320	0.502	0.397
Reactive Power	2.472 kvar	2.022 kvar	2.235 kvar	6.729 kvar
I THD	7.710 %	7.250 %	7.820 %	7.590 %

- With THD Control

	Phase A	Phase B	Phase C	SUM/AVG
Voltage RMS	230.501 V	229.952 V	230.344 V	230.266 V
Power	813.000 W	603.000 W	1.410 kW	2.826 kW
cosφ	0.293	0.307	0.531	0.385
Current (%)	28.852 %	20.431 %	27.560 %	25.614 %
U THD	0.865 %	1.050 %	0.868 %	0.926 %
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cosφI	0.293	0.307	0.531	0.385
Reactive Power	2.657 kvar	1.870 kvar	2.248 kvar	6.776 kvar
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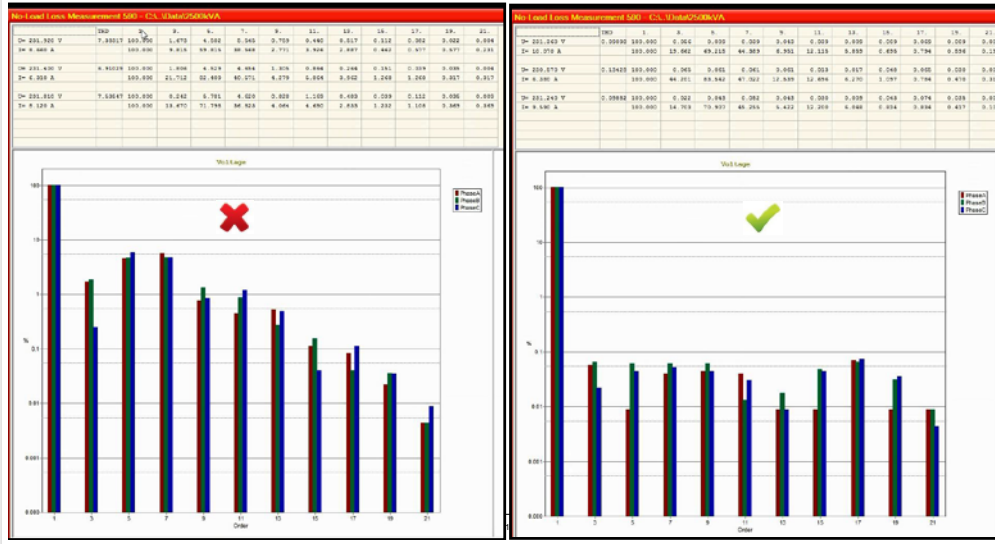


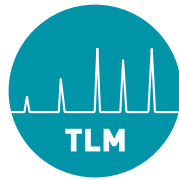
THD Control

Example on a 2'500 kVA, 33 kV / 400 V transformer

Without THD Control

With THD Control





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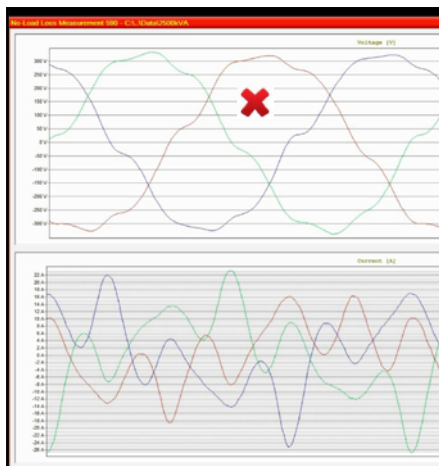
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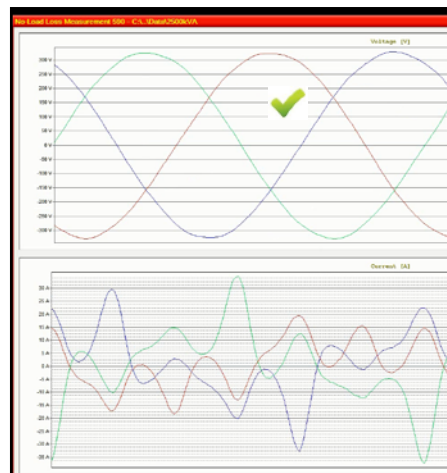
THD Control

Example on a 2'500 kVA, 33 kV / 400 V transformer

Without THD Control



With THD Control



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Wrap up

- F.C.: wide used hardware on market
- FC: Hardware with many benefices for the transformer test application
- Need customized control for transformer test application
- Symmetry and THD control:
 - Required to fulfill IEC & IEEE
 - More accurate / better loss reading
 - Especially important for low loss transformer design



KEY ADD ONE



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Any Questions?

PRECISION

TEST

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감사합니다 Natick
Danke Ευχαριστίες Dalu
Grazie Thank You Köszönöm
Tack
Спасибо Dank Gracias
谢谢 Merci Seé
ありがとう

Obrigado

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