Frequency Converter as Power Supply for Transformer Testing

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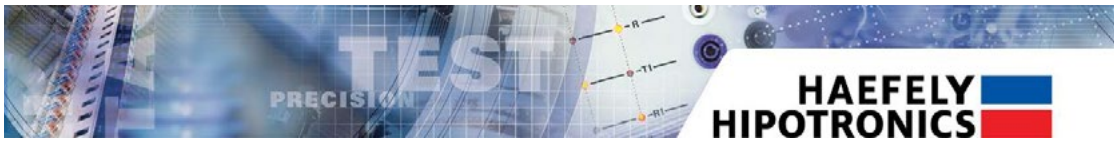
Frequency Converter as Power Supply for Transformer Testing



Frequency converter as power supply for transformer testing

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1. Introduction

Frequency converter technology is used more and more often in a variety of applications, as the knowledge about it has matured and as new control circuitry has become available. The transformer testing field is very conservative and is now making the move to use this technology for performing routine and type test. Frequency converters make for a compact and clean power supply and competently replace traditionally used voltage regulators and motor generators.

2. The 9 main benefits for using frequency converter as power supply for transformer testing

Main benefit	Features
1: Compact hardware	It has an optimized kW/kg and kW/m3 ratio, it generates no vibration. The containerized solution is a plug and play design, which makes transportation easy and factory relocation.
2: Maintenance free	Frequency converter technology is maintenance free, as there is no moving parts apart from the cooling fan.
3: Ease of service	The frequency converter used for transformer testing is based on commercial standard hardware with customized software. As standard hardware, spare parts are available all around the word. Online monitoring makes service case very efficient.
4: Safety	“Safety integrate”: the converter reacts smart and safe to various situations with voltage and currents trip detection. Short response times provide the highest safety level during unexpected situation.
5: Redundancy	Frequency converters can be used in parallel; in this case double power is available for testing. This feature allows setting a 2 test bays configuration as standalone or parallel, for testing two transformers simultaneously or one twice larger transformer.
6: Decoupled power supply	The DC link provides decoupling from the feeding power mains voltage, frequency, distortion and asymmetry. There is a clear frequency interface separation between the test system and the company workshop.
7: Compatible with partial discharge measurement	Frequency converter associated with various filtering enables partial discharge measurement; with extremely low back ground noise.
8: Variable frequency	Variable frequency from 50 to 200 Hz allows performing the applied voltage test and the loss measurement at 50 Hz and 60 Hz. The induced voltage test can be performed at any frequency, allowing finding the ideal frequency with the lowest current, which will increase the testing capability.
9: Advanced control software	There is a real time feedback loop from the measurement to the frequency converter controller, to adjust the voltage symmetry and reduce the total harmonics distortion.

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3. Improved measurements

The IEC 60076-1:2011 specifies for all tests a frequency within 1% of the rated frequency, a voltage total harmonic distortion below 5% and a difference between minimum and maximum phase voltage below 3%.
This specification is a mandatory, but higher performances can be achieved for better readings of the no load loss measurement.
During no load loss, the voltage distortion having peaked waves with higher r.m.s. leads to higher no losses reading. Same behaviour applies in case of voltage asymmetry. Frequency converters with real time feedback loop from the measurement can drop the total harmonics distortion below 1% and the voltage symmetry below 1% and no load loss can be improved from 3%. For example, see Fig. 1.

Fig. 1. (a) THD impact on no load loss on a 2.5 MVA transformer

4. Conclusion

In the overall process, a transformer is only as good as it can be tested and the frequency converter technology opens new possibilities thanks to real time feedback loop.

References

[3] IEC 60076-1:2011 [11.1.1]

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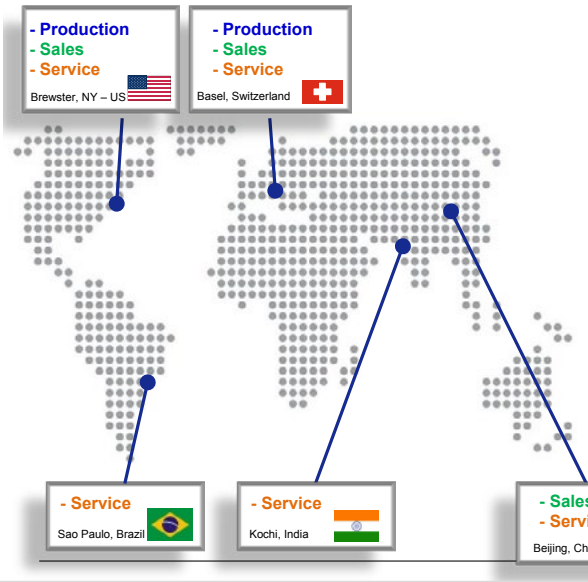
About Us



HAEFELY HIPOTRONICS

- Employees: 260+
- Production Areas: USA, Switzerland
- Sales Centers: USA, Switzerland, China
- Service Points: USA, Switzerland, China, India
- Representatives: Worldwide

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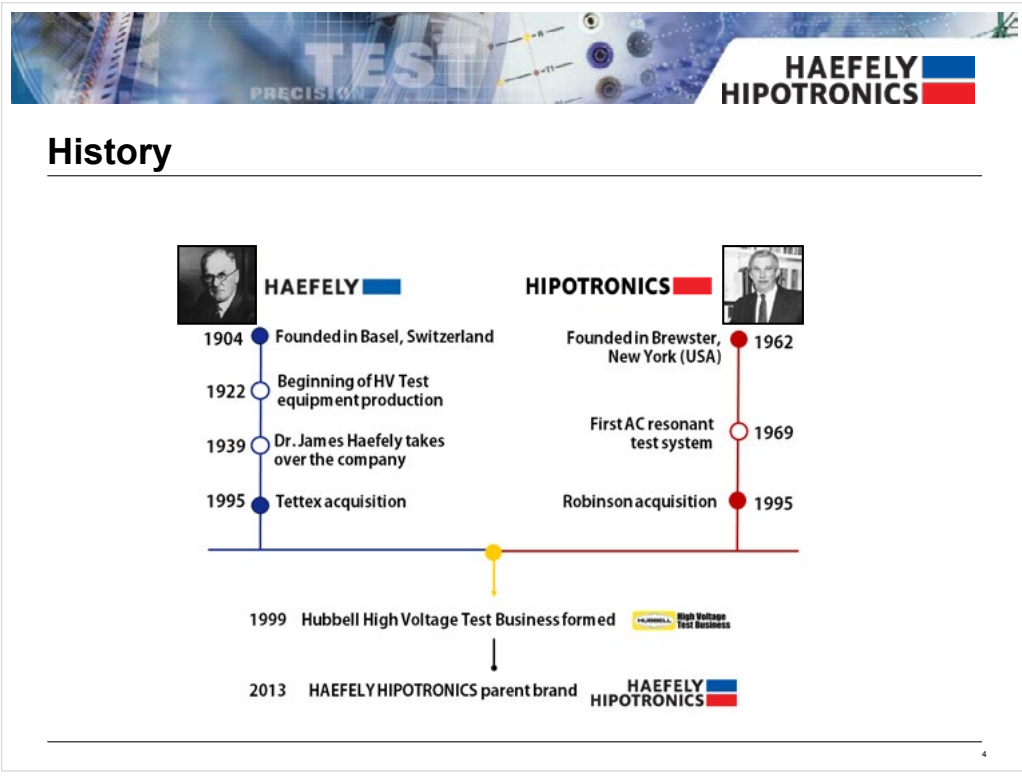

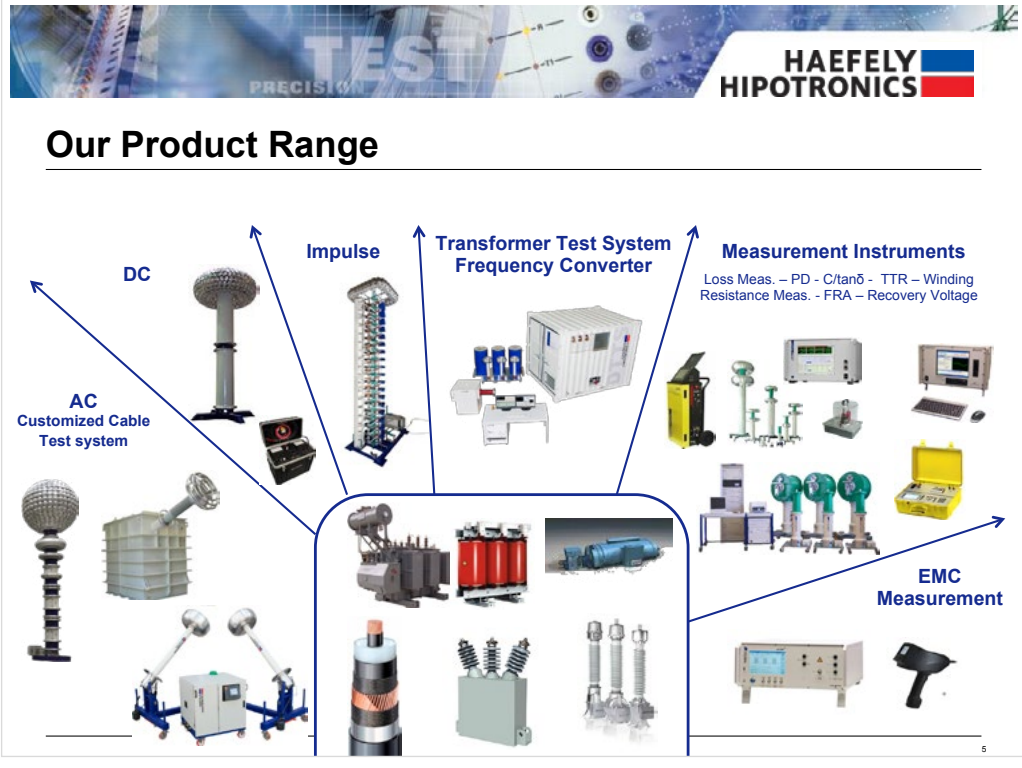

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Agenda

- Introduction to Frequency Converter
- 9 Benefits of Frequency Converter
- Improved Measurements

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Introduction to Frequency Converter

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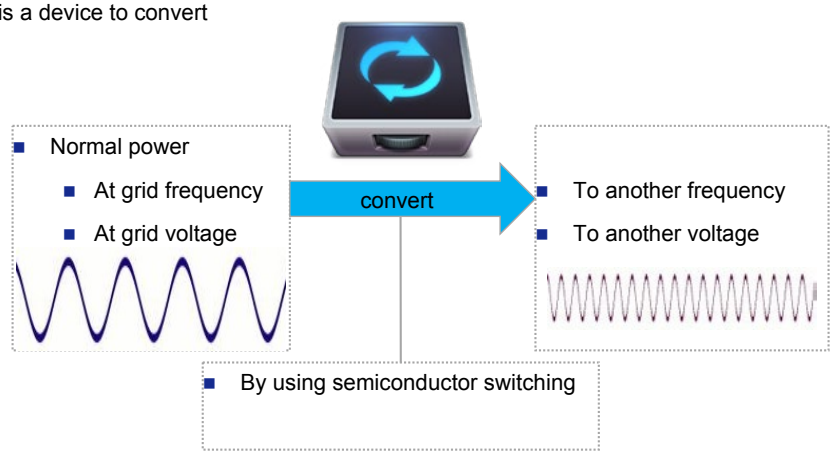
Frequency Converter as Power Supply for Transformer Testing

What is a Frequency Converter?

- **Frequency Converter or F.C.:** electronic power supply or frequency inverter or frequency changer
- It is a device to convert



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Market

- Global F.C. market: USD 18.85 Billion (2017)
- Comparison: power transformer market: USD 20.7 Billion (2015)
- Main players: (2012)
  - ABB Ltd (Switzerland): 19% market share
  - Siemens Industry Inc. (U.S.): 13.8 % market share
  - Schneider Electric SA (France): 8.5 % market share

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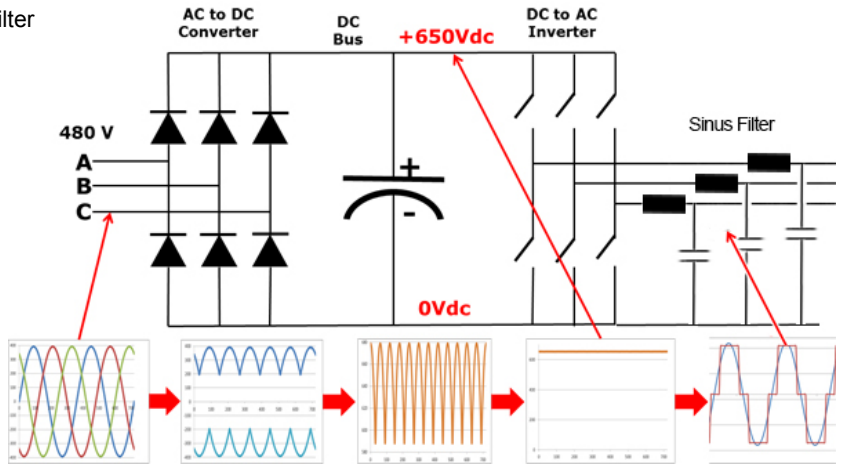
How does electronic power supply work?

- 1: Convert AC to DC
- 2: Inverter DC to AC
- 3: Sinus filter



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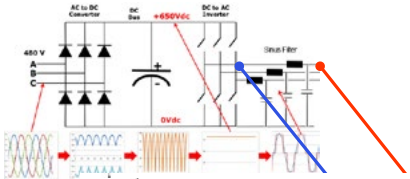
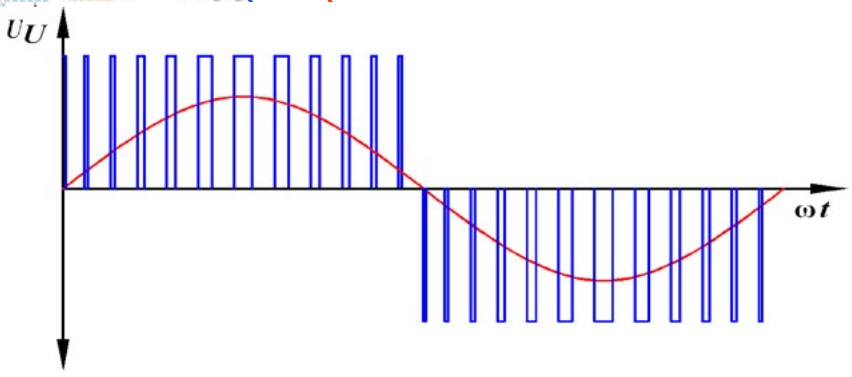
How does F.C. work?



PWM: Pulse Width Modulation



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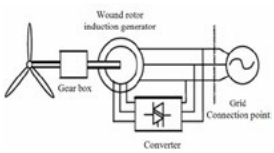
Typical applications



- 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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9 Benefits of Frequency Converter

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Frequency Converter as Power Supply for Transformer Testing

1: Compact hardware

Compact hardware

F.C.

- Optimized kW/kg and kW/m^3 ratio
- No Vibration

- Ease of integration in existing test lab
  - Plug & play design
- Ease of transportation
  - For delivery
  - In case of factory relocation

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2: Maintenance free

Compact hardware

Maintenance free

F.C.

- Maintenance free
  - No maintenance plan or agenda to follow

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3: Ease of service

Compact hardware
Maintenance free
Ease of service
F.C.

- Ease of service
  - Commercial standard hardware
  - Haefely Hipotronics software
  - Strong after sales service available
- Online monitoring and diagnostic

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4: Safety

Compact hardware
Maintenance free
Ease of service
Safety
F.C.

- **"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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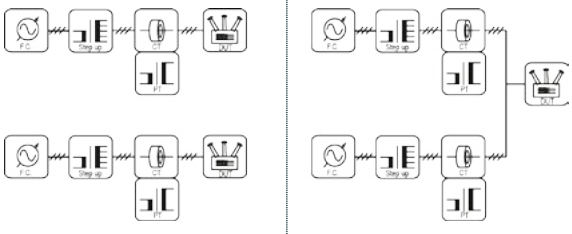
5: Redundancy

Compact hardware
Maintenance free
Ease of service
Safety
Redundancy
F.C.

- Parallel or standalone use
- Easy to upgrade the power



- Standalone
- Parallel

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6: Decoupled power supply

Compact hardware
Maintenance free
Ease of service
Safety
Redundancy
Decoupled power supply
F.C.

- 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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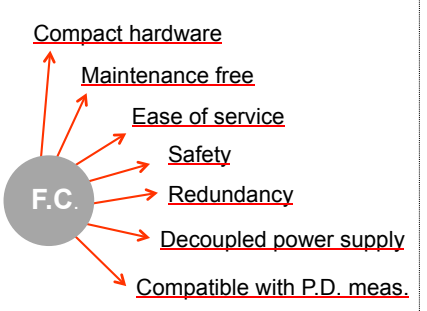
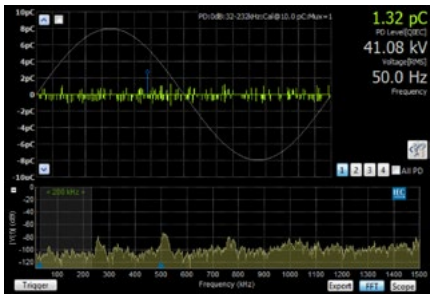
7: Compatible with partial discharge measurement



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



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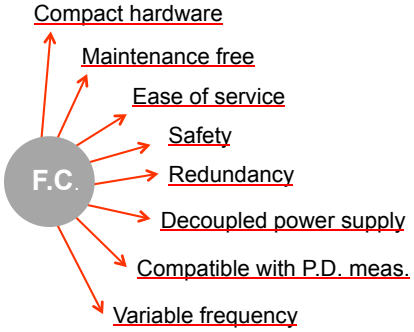
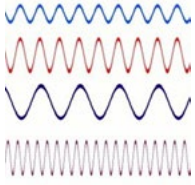
8: Variable frequency



- **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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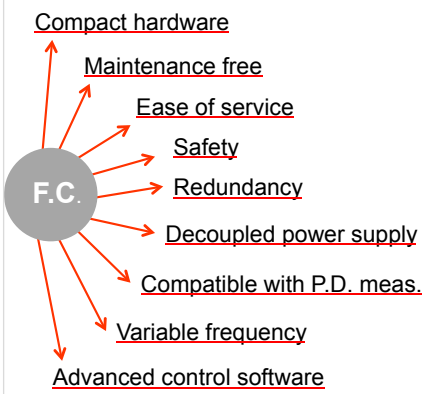
9: Advanced control software



- Voltage Symmetry control
- Voltage THD control

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Improved Measurements

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IEC Reminder

- IEC 60076-1:2011 [11.1.1]: For **all** measurement and tests:
  - Frequency: within 1 % of the rated frequency
  - Voltage: THD < 5%
  - Symmetry: Difference between min & max Phase voltage < 3%

- IEC 60076-1:2011 [11.5]: No-Load loss:
  - Relative diff. between mean and r.m.s. voltage < 3%

$$P_o = P_m (1 + d)$$

$$d = \frac{U' - U}{U'}$$

U: r.m.s value
U': mean value
P_m: meas. No load loss
P_o: corrected loss
d: correction factor

- Note:
  - Peaked waves with higher r.m.s. lead to higher losses
  - Shallow waves with a smaller r.m.s. value cause lower losses

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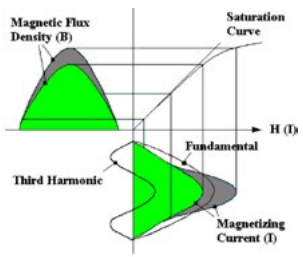
Influence of asymmetric waveshape

- **Asymmetry cause:**
  Transformer 3 legs geometry

- **Asymmetry problem:**
  Unbalanced 3 phase voltage can lead to core saturation and **it can lead to higher no load losses**



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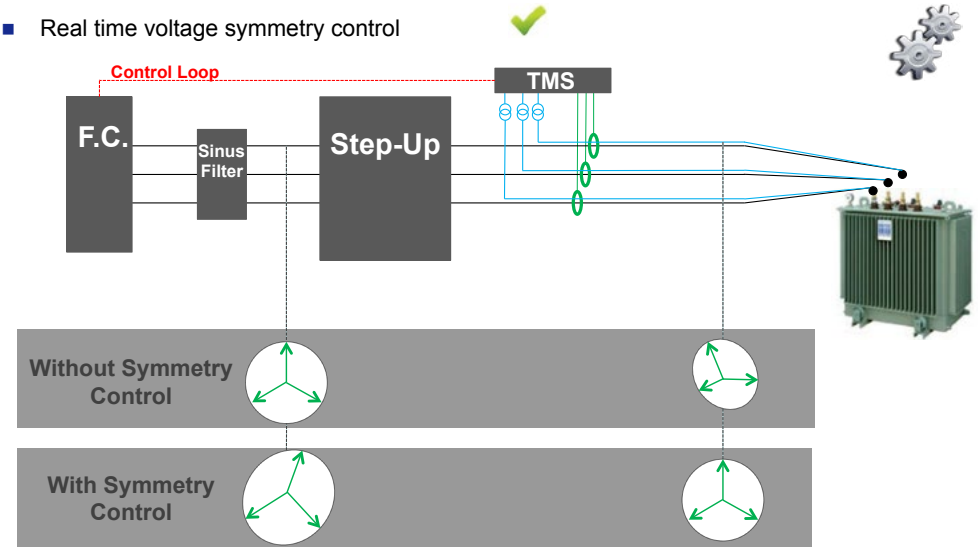
Voltage symmetry control

- Real time voltage symmetry control



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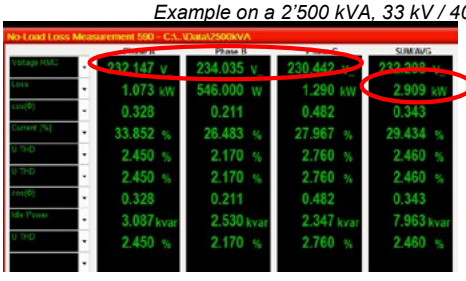
Voltage symmetry control

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

- Without Symmetry Control



3%

- With Symmetry Control

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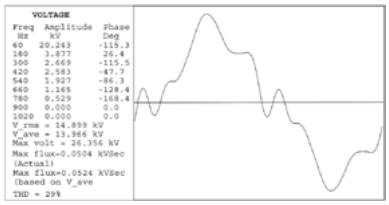
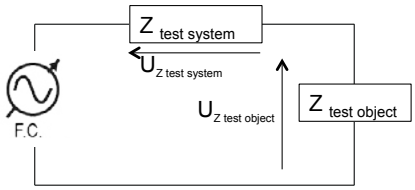
Influence of distorted waveshape

- **T.H.D.:**
  Total Harmonic Distortion



- **T.H.D. cause:**
  T.H.D. on the voltage waveshape comes mainly from the short circuit impedance of the test system



- **T.H.D. problem**:
  Peaked waves with higher r.m.s. **can lead to higher losses**

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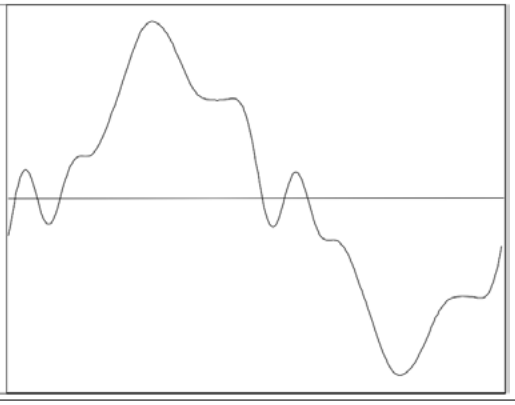
Influence of distorted waveshape

- Actual peak voltage: 26.356 kV
- Rated peak voltage: 19.5 kV
- Difference: 35 %
- To high distortion lead to peak voltage which may reach values above dielectric withstand of the insulation:
- Possible damage or failure of the transformer

VOLTAGE

Freq Hz	Amplitude kV	Phase Deg
60	20.243	-115.3
180	3.877	26.4
300	2.669	-115.5
420	2.583	-47.7
540	1.927	-86.3
660	1.165	-128.4
780	0.529	-168.4
900	0.000	0.0
1020	0.000	0.0

V_rms = 14.899 kV
V_ave = 13.966 kV
Max volt = 26.356 kV
Max flux=0.0504 kVSec
(Actual)
Max flux=0.0524 kVSec
(based on V_ave
THD = 29%



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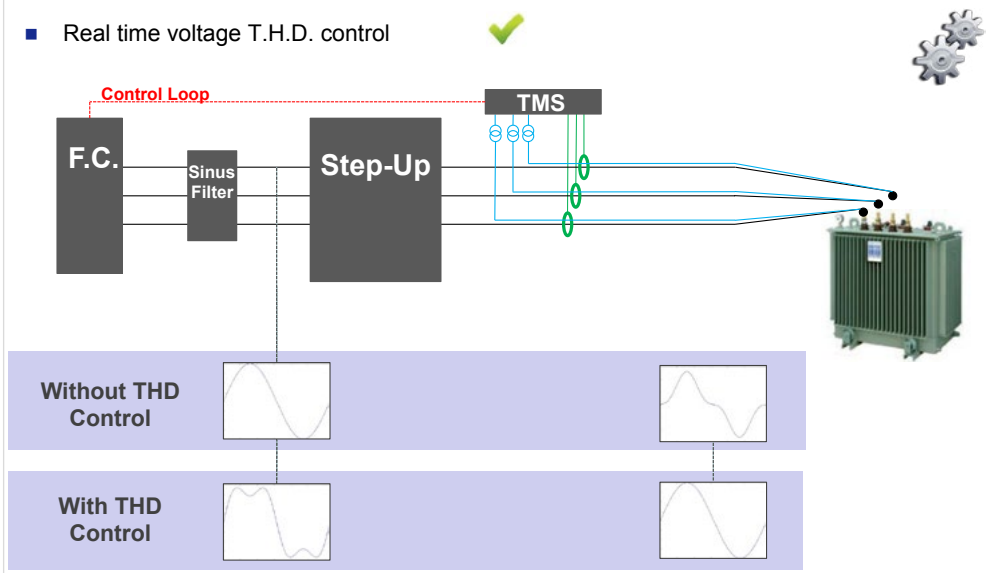
T.H.D. Control

- Real time voltage T.H.D. control



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T.H.D. Control

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

- Without THD Control

3%

- With THD Control

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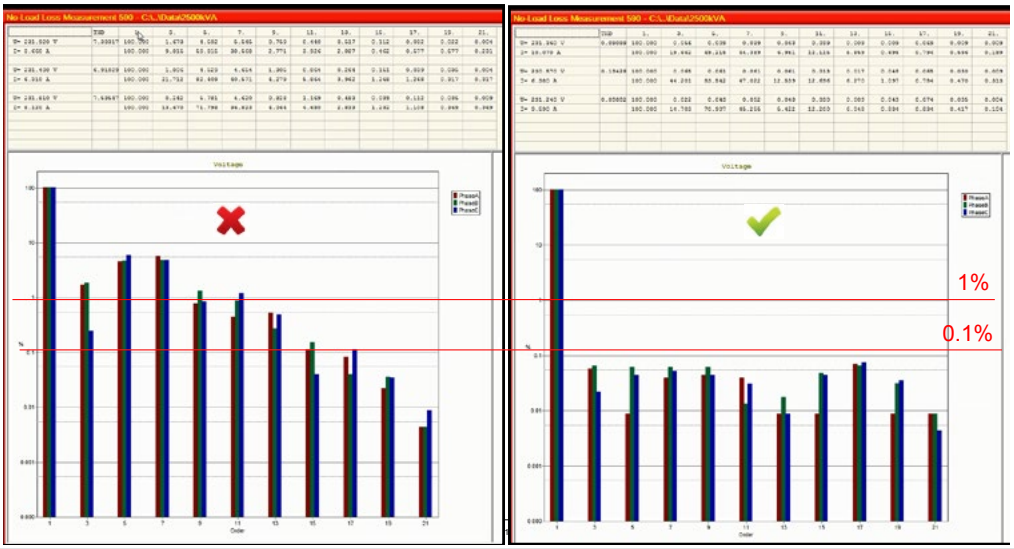
T.H.D. Control

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

Without THD Control

With THD Control

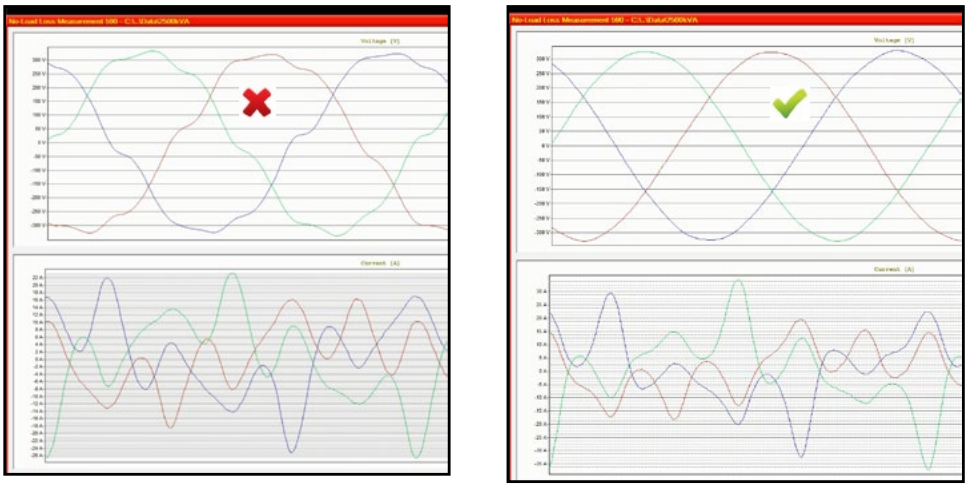


T.H.D. Control

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

Without THD Control

With THD Control



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Wrap Up

- Frequency Converter is a widely used hardware on market
- Hardware with multiple benefits for the transformer test application
- Need customized control for transformer test application
- Symmetry and T.H.D. 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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Our solutions for distribution to power transformer

- Distribution Transformer Test System
  < 5 MVA test object
- Power Transformer Test System
  > 200 MVA test object
- Our references: 38 systems installed all around the world

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Frequency Converter as Power Supply for Transformer Testing

Conclusion / The Vision

- Build a high quality transformer:
  - Good design
  - Good quality of materials
  - Good manufacturing machines
  - Good testing

- "In every chain of reasoning, the evidence of the last conclusion can be no greater than that of the weakest link of the chain, whatever may be the strength of the rest.“
  Thomas Reid's *Essays on the Intellectual Powers of Man*, 1786

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