RECHERCHE

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ESSAIS

CERTIFICATION

EXPERTISE
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FORMATION

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INDUCTIVE VTs: EFFECT OF TEMPERATURE AND VIBRATIONS

Daniela ISTRATE, Mohamed AGAZAR

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ITs UNDER REALISTIC CONDITIONS

Assessment of combined influence factor impact on ITs

- Context
- Measurement setup and testing platform
  - Principle
  - Generation system
  - Measuring system
- Test conditions
  - Temperature profile
  - Vibration parameters
  - Harmonic injection
- Results
  - Influence of separate factor
  - Influence of combined factors
- Conclusions

CONTEXT

- LITERATURE SHOWS THAT ITs CAN INTRODUCE SIGNIFICANT ERRORS IN PQM
- SPECIFIC NEEDS EXPRESSED BY IEC TC38 “INSTRUMENT TRANSFORMERS” :
  - **Define accuracy and uncertainty limits of ITs in PQ measurements**
  - **Develop suitable reference measuring systems and traceable test procedures**
  - **Assess the performance with multiple influence factors**
- LNE STUDIED TEMPERATURE, VIBRATIONS AND HARMONICS

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

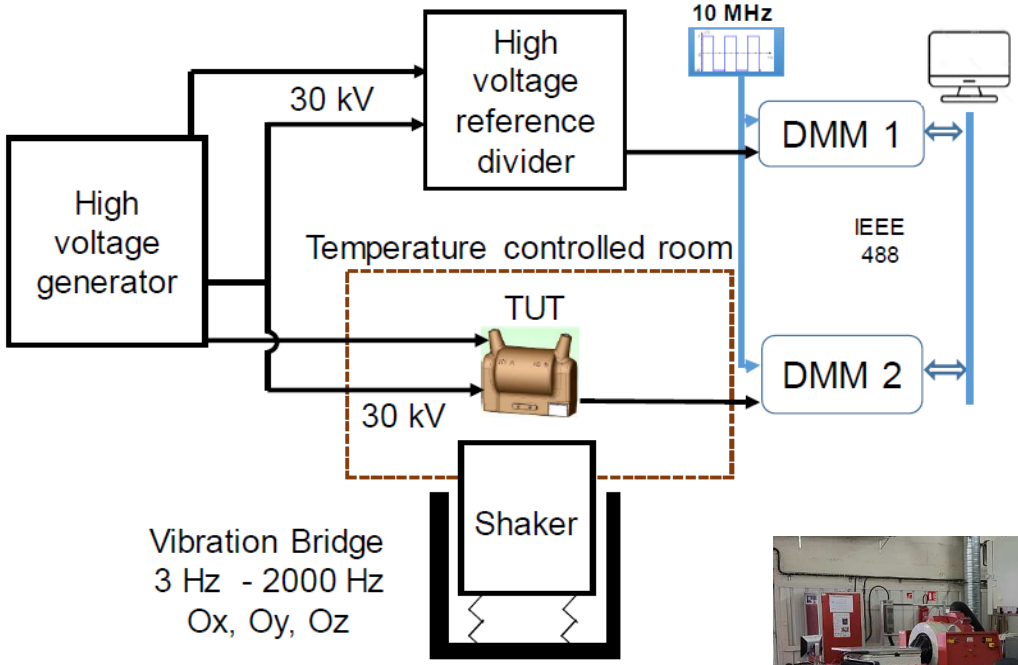
EURAMET

IT4PQ Instrument Transformers for Power Quality

Inductive Voltage Transformers

Temperature		Very Low
Burden		Low
Positioning		Very low
Vibration		?
Self heating		Low
Frequency linearity up to 9kHz		Very High
Voltage (current) linearity		Very High
Long term stability		Very low
Magnetic field		Medium
Electric field		Medium
Influence of overvoltages (overcurrents)		Very High
Short-circuited secondary		Very high
Open secondary		Very Low
Influence of current on voltage		Low
Influence of voltage on current		X

PRINCIPLE OF MEASUREMENT & TESTING PLATFORM



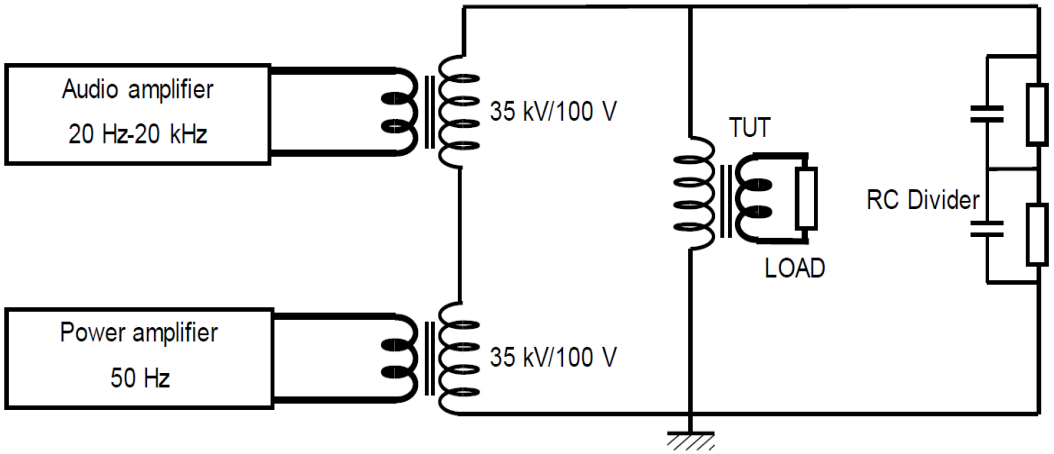
Comparison with a reference system

Peak to peak displacement: 50 à 75 mm

Removable temperature chamber

- Temperature : - 70°C to 150 °C.
- Speed : 10 °C/min
- Humidity : 10 to 95 %
- Volume : 1,3 m^3

GENERATION SYSTEM



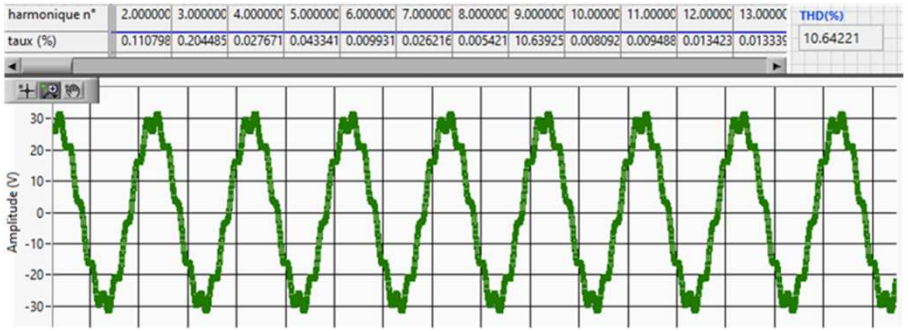
Harmonics order	Relative amplitude to the fundamental of 30 kV
2 to 60	10 %
60 to 84	3.3 %
84 to 90	1 %
90 to 96	0.33 %

Example:

20 kV, 50 Hz

+

2 kV, 450 Hz



2 step-up transformers

100 V/35 kV

class 1

Max I_s = *10 A*

Power amplifier

Bandwidth: 20 kHz

Output: 15 A/120 V

MEASURING SYSTEM

Measurands

Ratio error

$$\varepsilon_n = \frac{k_r V(S_n) - V(P_n)}{V(P_n)}$$

Phase displacement

$$\varphi_n = \varphi(S_n) - \varphi(P_n)$$

where:

ε_n - ratio error at the frequency n,

$k_r = Vp/Vs$ - rated TUT scale factor

$V(P_n)$ - primary voltage @ frequency n

$V(S_n)$ - secondary voltage @ frequency n

LNE voltage divider with uncertainties

Ratio error

(0,13.*f*+20) ppm

Phase displacement

(0,13.*f*+20) µrad

2 DMM 3458A

DC sampling mode

Adapted sampling frequency

$$f_s = \frac{N}{M} f_v$$

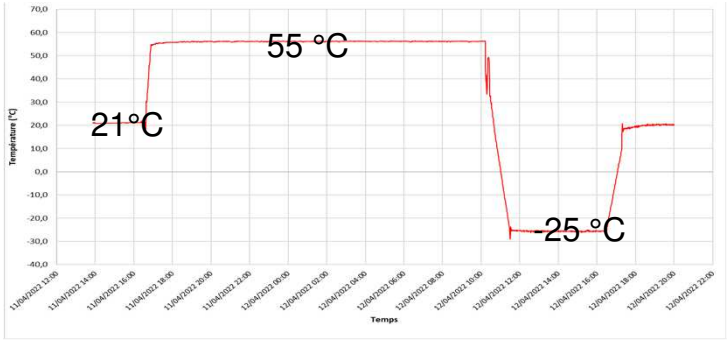
N – number of samples

M – Number of periods

f_v – frequency of the acquired voltage

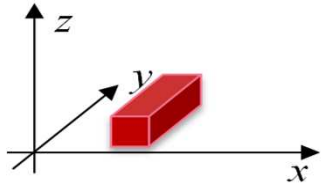
TEST CONDITIONS

Temperature



Vibrations

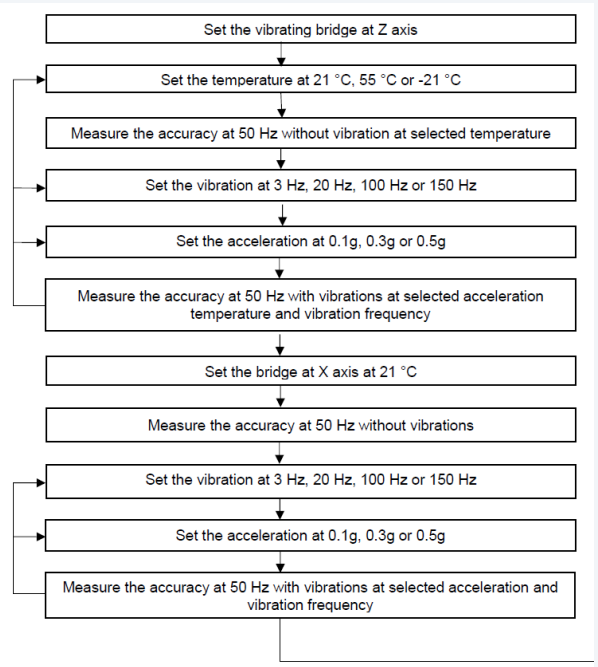
Axis
OX (along the width)
OY (along the length)
OZ (along the height)



Vibration frequency :
3 Hz, 20 Hz, 100 Hz and 150 Hz
Acceleration :
0.1g, 0.3g, 0.5g (g = 9,81 m/s^2)

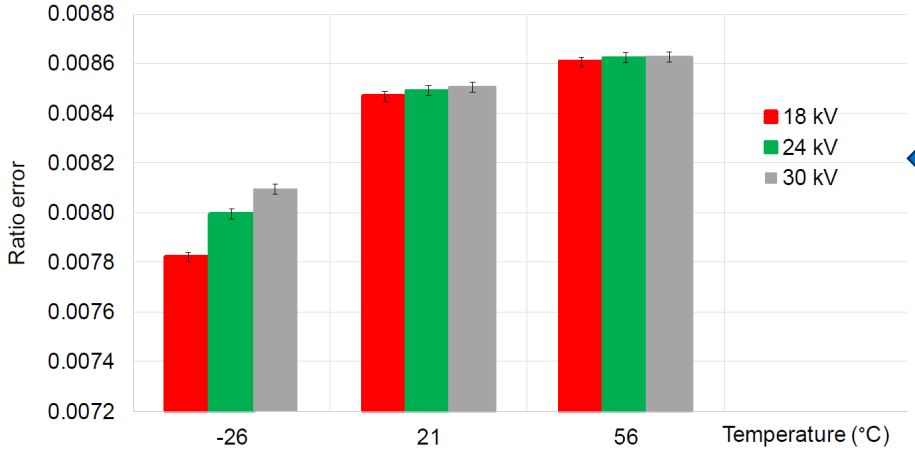
Harmonics

30 kV, 50 Hz
+
1.5 kV, one harmonic with frequency from 150 Hz up to 4000 Hz.



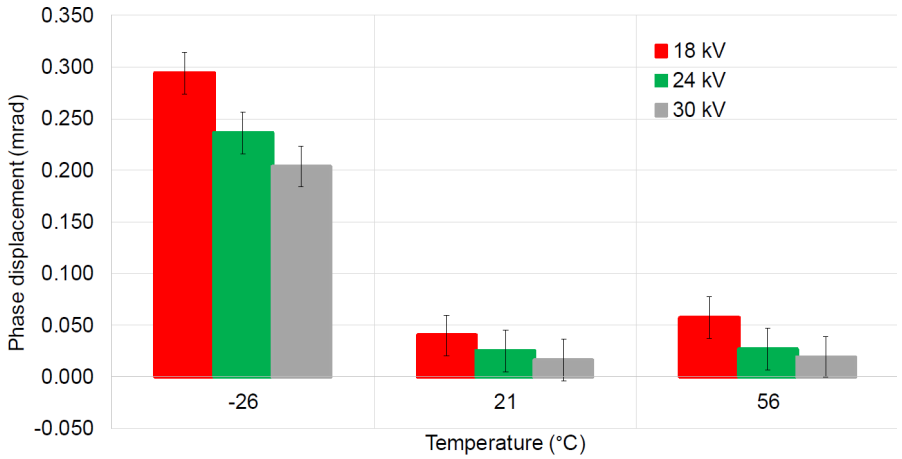
RESULTS

➢ INFLUENCE OF TEMPERATURE



Ratio error

Phase displacement



The highest influence is at -25 °C.

Higher influence at low voltage (18 kV)

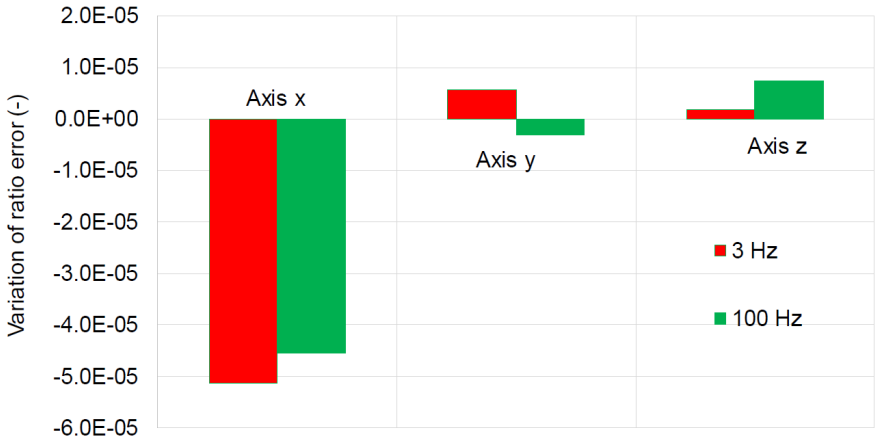
The differences with respect to 21°C:

For ratio error :
$-6.0 \cdot 10^{-4}$

For the phase displacement :
254 µrad

RESULTS

➢ INFLUENCE OF VIBRATIONS



Supply voltage of the TUT:
24 kV, 50 Hz
Vibrations with
0,5g acceleration

Variation of ratio error with respect to no vibration case

Variation of phase displacement With respect to no vibration case

Vibrations with the highest impact :
- along the width of the TUT, axis X
- with frequency of 3 Hz
- with acceleration of 0.5g (4,9 m/s^2)

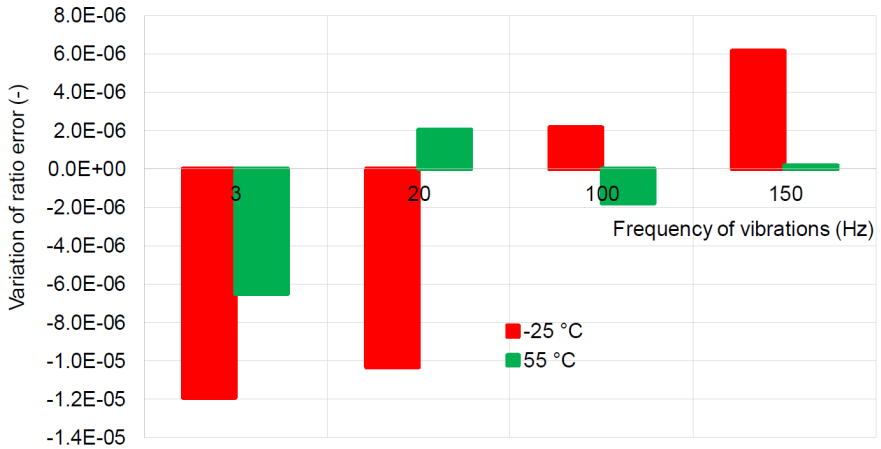
Variation of ratio error : -5. 10^{-5}
Variation of phase displacement : few µrad

When changing
- the orientation,
- the frequency or
- the acceleration of vibrations,

the deviations are less than those produced by the temperature.

RESULTS

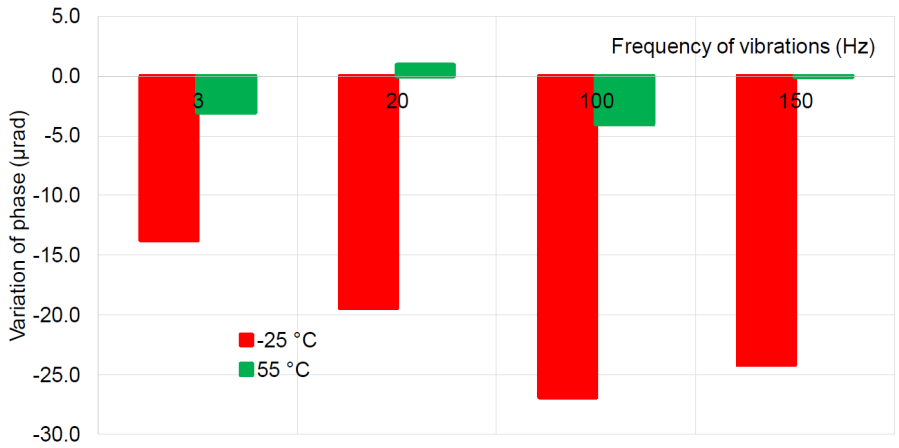
➢ INFLUENCE OF COMBINED TEMPERATURE & VIBRATIONS



Supply voltage of the TUT: 30 kV, 50 Hz
Vertical vibrations with 0,5g acceleration

Variation of **ratio error** with respect to +21°C & no vibration case

Variation of **phase displacement** with respect to +21°C & no vibration case



Ratio error: the highest deviation from the reference situation is obtained at
-25 °C @ 3 Hz vertical vibrations.
Variation of ratio error : -1.5. 10^{-5}

Phase displacement : more impact at -25 °C @ 100 Hz vertical vibrations
Variation of phase displacement : -27 µrad

The two parameters applied simultaneously **did not reveal greater effects** than when they were applied separately.

RESULTS

➢ COMBINED TEMPERATURE, VIBRATIONS & HARMONICS

Ratio error and phase displacement @ 50 Hz even if one harmonic exists.

Supply voltage of the TUT: 30 kV, 50 Hz
Vertical vibrations, 0.5g (m/s²) with 20 Hz frequency

Reference values @ each temperature :
0 vibrations ; 0 harmonics.

Harmonic (Hz)	-25 °C Δε (-)	-25 °C Δφ (µrad)	21°C Δε (-)	21°C Δφ (µrad)	+55 °C Δε (-)	+55 °C Δφ (µrad)
150	2.1E-05	2.5	2.2E-05	-10.2	-7.0E-06	-0.9
250	1.8E-05	-3.9	2.7E-05	5.3	6.0E-06	-1.6
350	1.7E-05	-22.0	6.5E-06	11.5	1.0E-05	3.4
450	7.0E-06	-17.2	1.3E-05	17.5	1.3E-05	11.8
550	-1.7E-06	13.8	-3.9E-06	-4.2	1.4E-05	2.2
650	-9.0E-06	-8.1	-1.4E-05	-14.0	2.9E-06	-18.1
1000	-2.0E-05	3.6	3.0E-06	-4.9	2.1E-05	6.4
2000	-2.3E-06	18.0	6.9E-07	-10.1	-9.4E-07	-8.2
3000	2.4E-05	-8.9	1.8E-05	-11.1	-8.9E-06	-24.4
4000	9.2E-06	15.5	8.6E-08	-6.0	2.8E-05	-5.9

The maximum variation is less than 30 ppm on the ratio error, respectively less than 30 µrad on the phase displacement.

These variations do not go beyond the accuracy class of the transformer.

The TUT operation **is not affected by the presence of harmonics and vibrations**.

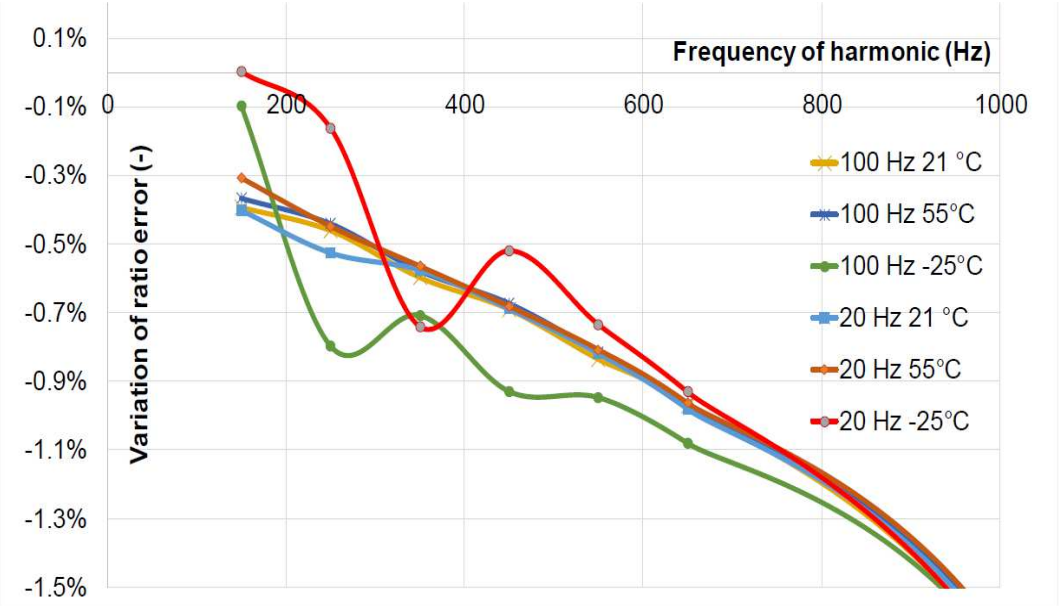
RESULTS

➢ FREQUENCY RESPONSE OF THE TUT UNDER TEMPERATURE AND VIBRATION

Supply voltage of the TUT: 30 kV, 50 Hz
Vertical vibrations, 0.5g (m/s^2) with 20 Hz @ 100 Hz frequency
Harmonics : 1,5 kV from 150 Hz up to 4 kHz

$$\varepsilon_n = \frac{k_r V(S_n) - V(P_n)}{V(P_n)}$$

Variation of **ratio error** with respect to 50 Hz ratio error



Using the studied inductive voltage transformer to measure disturbances present on the supply voltages can be done up to 650 Hz and with **increased error (deviation up to 1.1% from the 50 Hz precision).**

CONCLUSIONS

The **temperature** is the parameter with the highest influence on the transformer performances.

At 30 kV, -25 °C:

a variation of 400 ppm is obtained for the ratio error and
a variation of 200 µrad is obtained for the phase displacement.

The mechanical vibrations have much less influence,

the ratio error varies with 50 ppm
the phase displacement varies with tens of µrad.

The presence of the combined factors: temperature, vibrations and one-tone harmonic has a very low impact on the inductive VT.

Variations in ratio error of less than 30 ppm,
Variations in phase displacement of less than 30 µrad

Inductive voltage transformer measure disturbances present on the supply voltages **with increased error and up to 650 Hz.**

Thank you for your attention.