High-precision current sensors for billing measurements in the high-voltage grid

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Introduction

For the billing of electrical energy, inductive current transformers are used for currents in low, medium and high voltage networks, which transform the primary current down to the standard values of 1 or 5 A. In Germany, these current transformers require a type test from the Physikalische-Technische Bundesanstalt[1] in Brunswick (PTB) for system voltages up to 123 kV.

For these current transformers, different accuracy classes are defined according to international standard. For billing purposes, the accuracy classes from class 0.5 are accepted. The class description corresponds to the percentage amplitude error at 100 % nominal current.

In the lower current range of the current transformers, larger percentage deviations are tolerated as shown in the diagram. This can be attributed to the physical properties of the iron cores that are used. The necessary magnetizing current often takes up a larger percentage of the secondary current in relation to the secondary current in the lower current range, and accordingly, also generates a larger percentage error. For this reason, the current transformer is also characterized in the literature as a non-linear measuring device.

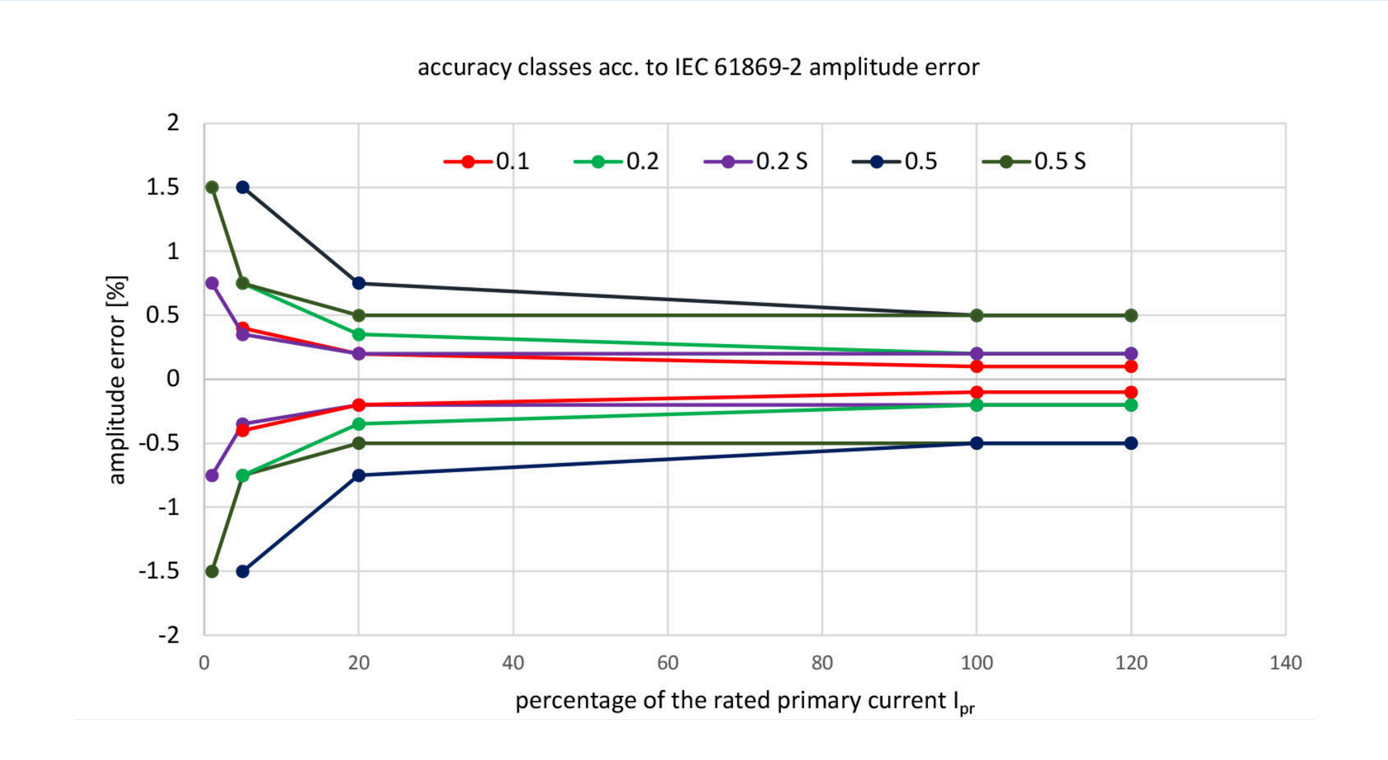

Figure 1: Accuracy classes acc. to the IEC 61869-2 - amplitude error

[1] PTB – the National Metrology Institute of Germany

Functionality of current transformers

In addition to the amplitude of the primary current that drives the current transformer, the load on the current transformer is also partly responsible for any actual error. In the electrical equivalent circuit, it is clear that the voltage drop across the connected measuring device and the connecting cables also influences the voltage drop across the iron core and thus the operating point of the current transformer.

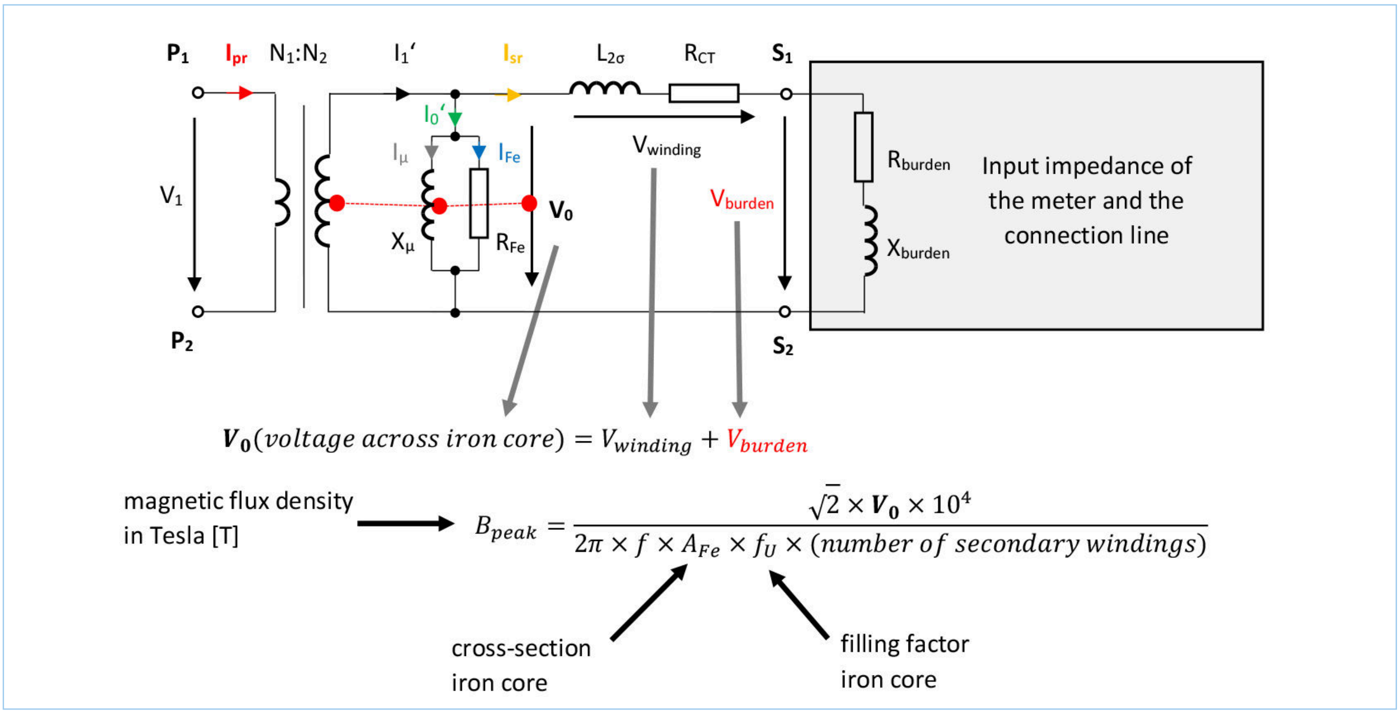

Figure 2: Electrical equivalent circuit of an inductive current transformer

Load values outside the range specified in the documentation can significantly increase the error values.

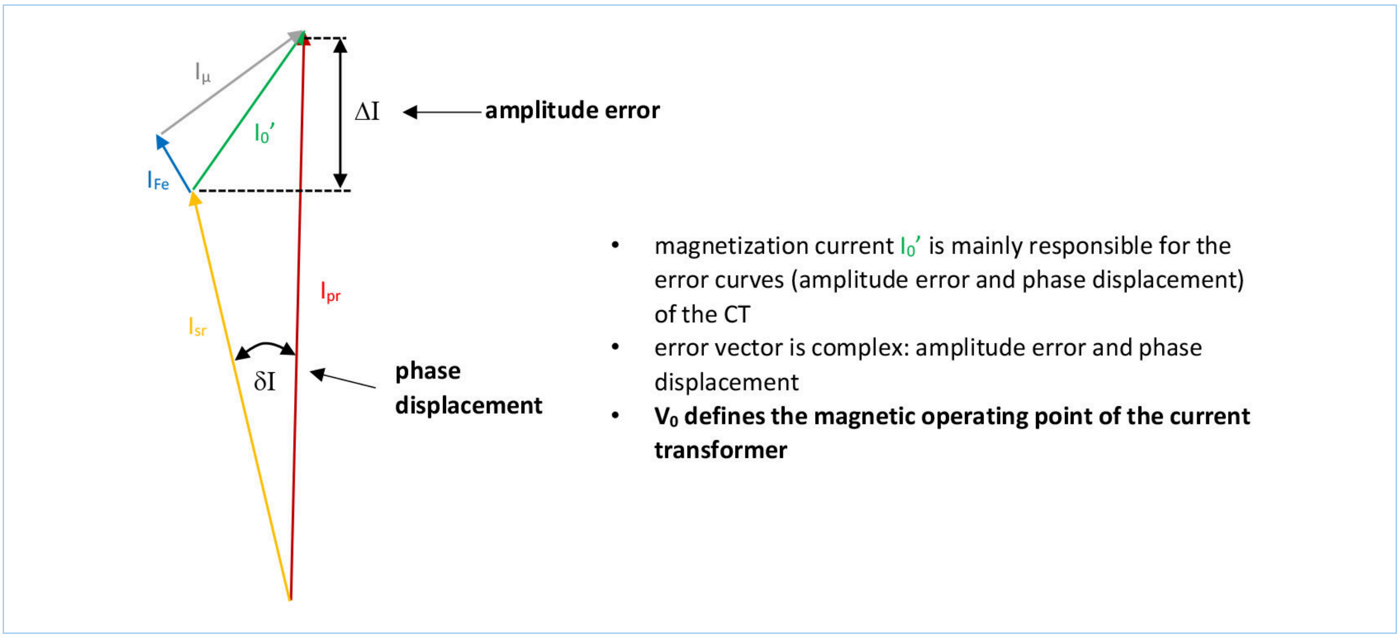

Figure 3: The magnetizing current is mainly responsible for the ratio error of the current transformer

Experts believe that approximately 60% of all current transformers in operation in Europe are loaded outside of their specifications.

Effects of the accuracy errors on the power calculation

If the metering operator has done everything correctly and even selected the highest accuracy class 0.1 for the current transducers, the possible financial deviations in a medium-voltage billing station are quite significant.

	Einheit	CT (600 : 5 A)		VT (20,000/√3 : 100/√3 V)
Amplitude error	[%]	0.1		0.1
Electricity tariff	[EUR/kWh]		0.2	
Term	[years]		20	
Complete electrical work (3-phase) in 20 years	[TWh]		3.64	
Financial equivalent for 3-phase system in 20 years	[m. EUR]		728.29	
Over-charged amount with regards to transformer errors in 20 years	[m. EUR]		**1.46**	

Figure 4: Billing inaccuracies in a medium voltage system

For higher voltage applications, the deviations will be even larger. For this reason, in some reference projects of above 123 kV, high-precision zero-flux transducers are used for billing purposes instead of conventional current transformers. The accuracy of zero-flux sensors is in the range of 0.001 percent and better. The behavior of these sensors is almost linear, which means that highly accurate measurements can be made even at lower current values.

Since this sensor technology is not a conventional inductive current transformer, PTB type test is generally not possible. Nevertheless, these sensors can be used in the high-voltage range (≥ 123 kV) or at a rated current of more than 5 kiloamperes, since these applications are not covered in the measurement and verification directive in Germany. Instead, the two contracting parties can agree on the technology that is to be used.

Zero-flux Sensor

In initial projects, zero-flux sensors for billing measurements are used in feedthrough CTs, in conjunction with conventional protection and measuring cores.

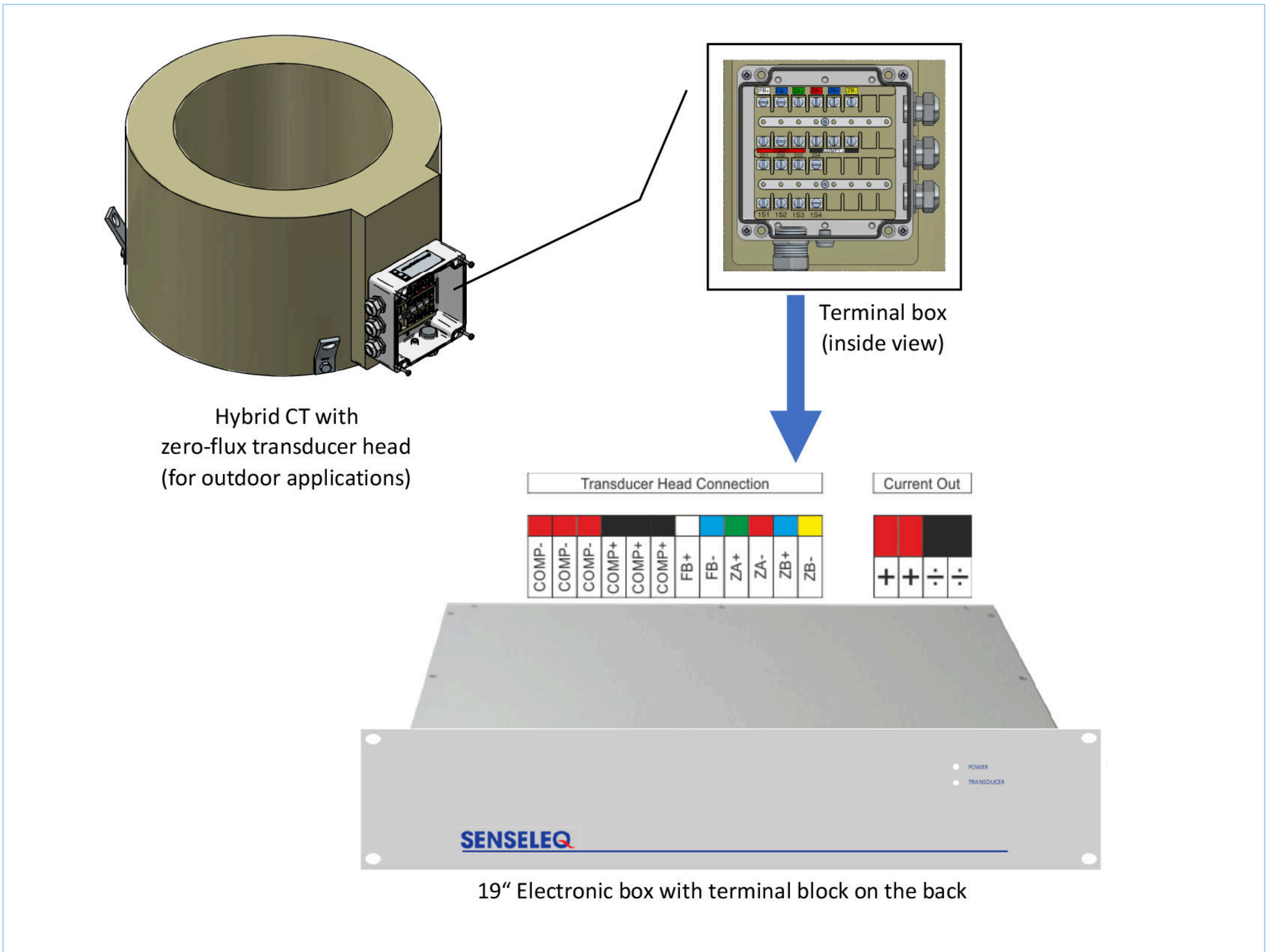

Figure 5: Zero-flux sensor in cast resin for outdoor applications from SENSELEQ

While the sensor head for the zero-flux transducer system, like inductive current transformers, consists of purely passive elements, the electronics required for the zero-flux principle are protected and installed inside a building close to the meter. The output signal of 1 A is then fed to the conventional electricity meter.

In addition to the excellent accuracy at the nominal frequency, harmonic currents up to 9 kHz can also be measured with high accuracy in the respective voltage level in accordance with the Technical Installations Directive.

Even geomagnetically-induced currents in the DC range can be detected by these transducers.

Accuracy of the SENSELEQ Sensor

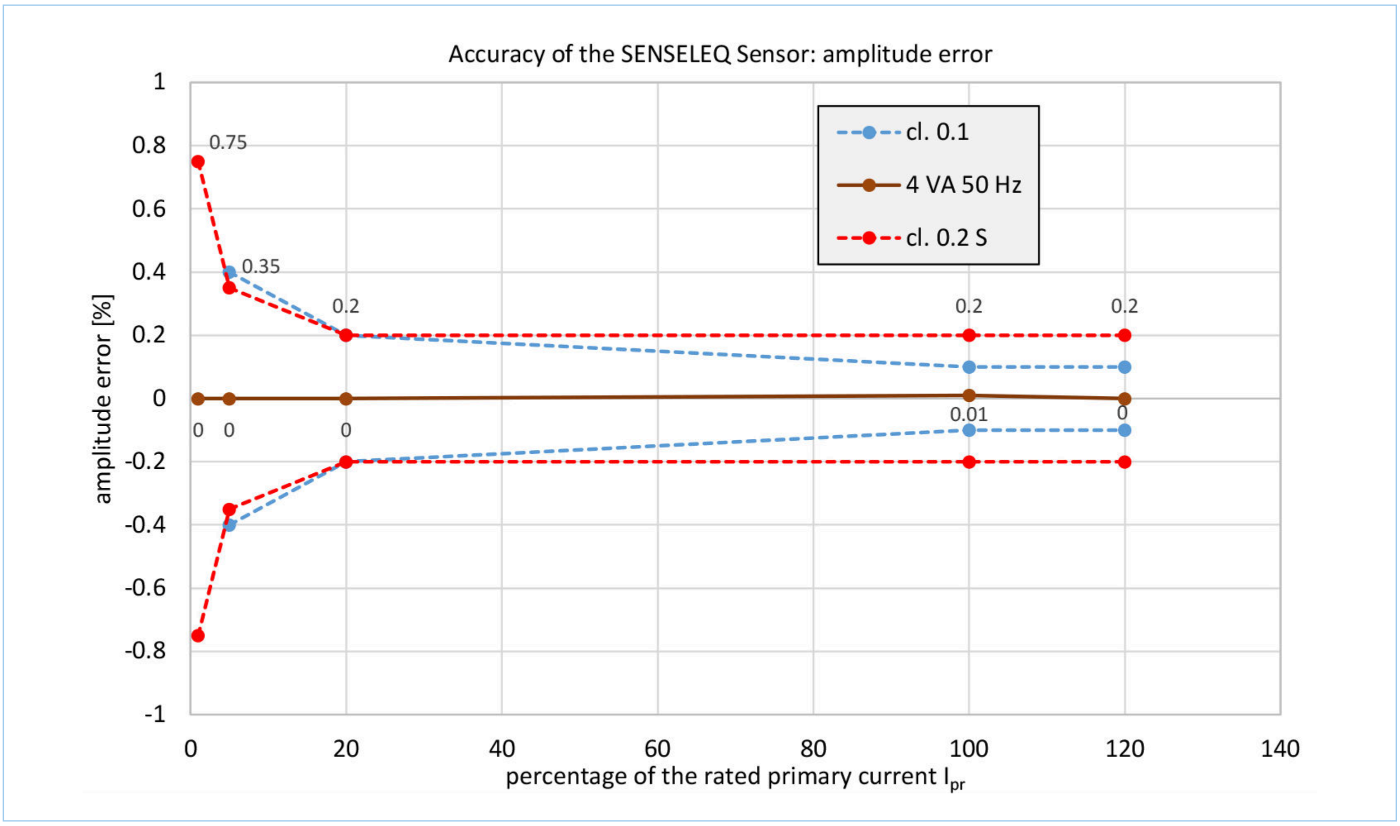

Figure 6: Amplitude error of a zero-flux sensor with the ratio 2500:1

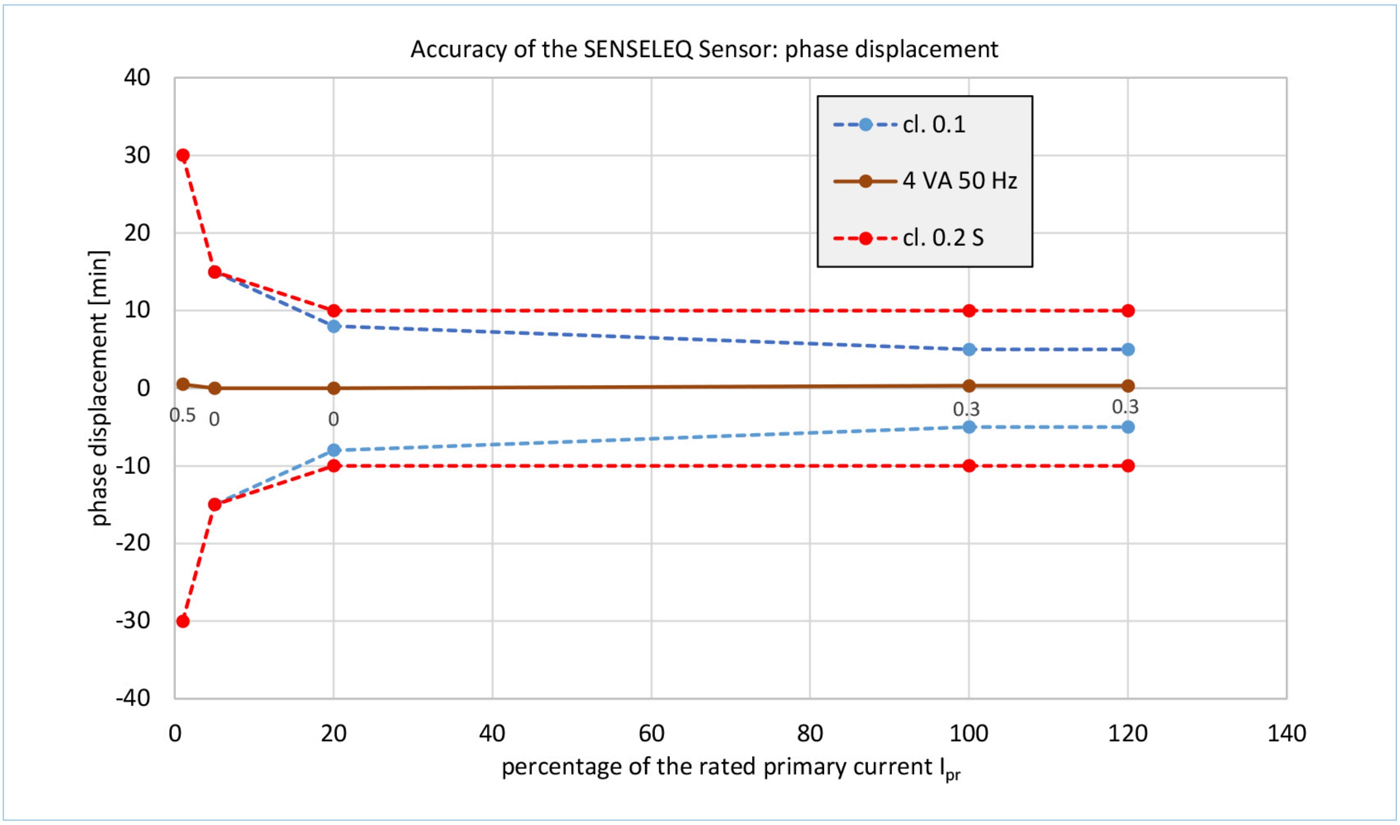

Figure 7: Phase displacement of a zero-flux sensor with the ratio 2500:1

Contact

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