CURRENT TRANSFORMERS AND POWER LINE TRANSFORMERS FOR SMART METERING

CURRENT TRANSFORMERS FOR ELECTRONIC ELECTRICITY METERS
PLC TRANSFORMERS FOR AUTOMATIC METER READING

ADVANCED MATERIALS – THE KEY TO PROGRESS

VACUUMSCHMELZE

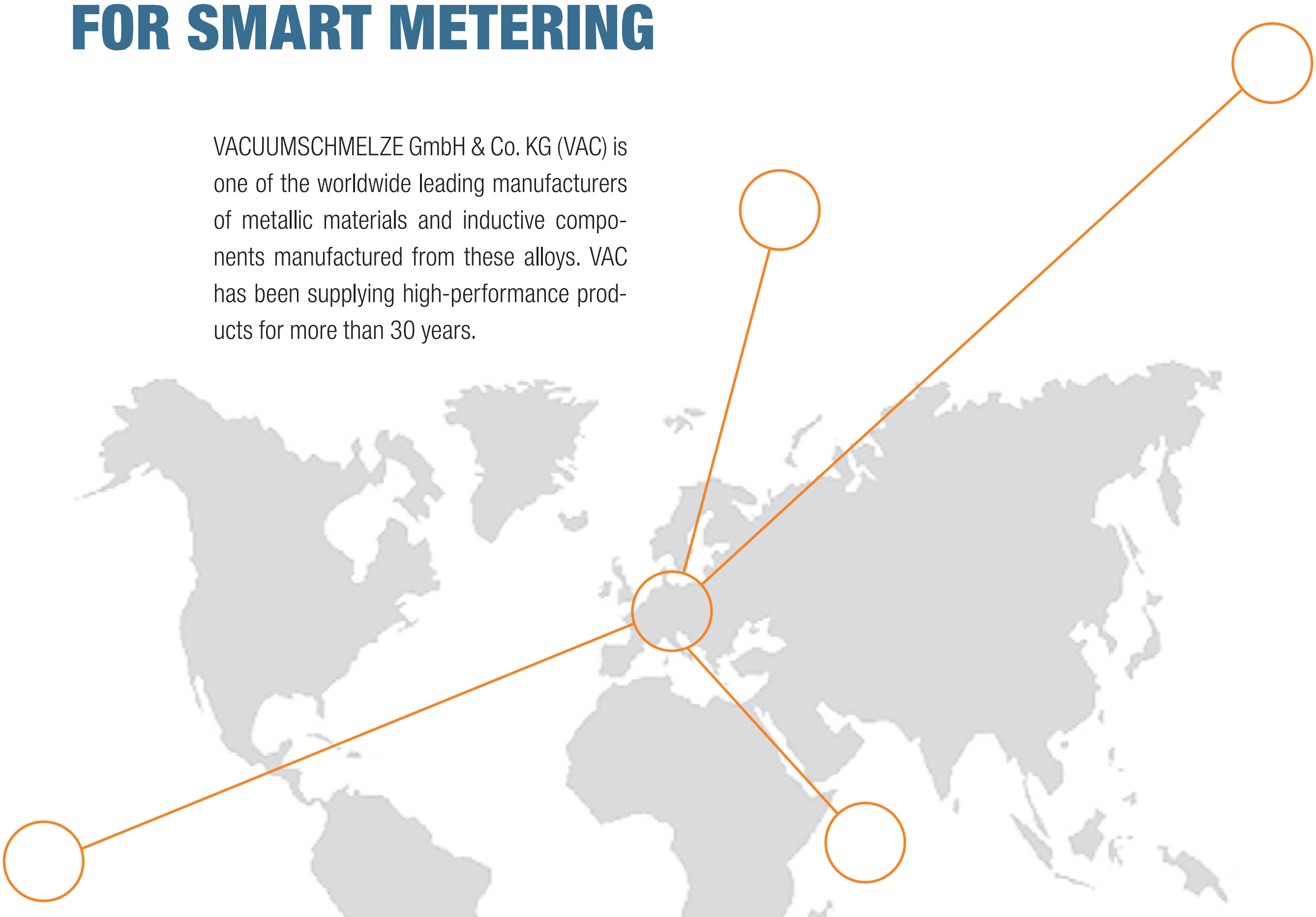
THE COMPANY
VACUUMSCHMELZE

The company has a staff of approximately 4.500, is represented in 40 countries spread across all continents and currently registers a turnover of more than EUR 350 million. The headquaters and operational center of VAC is in Hanau, Germany. The company also has production plants in Slovakia, Finland, Malaysia and China.

CONTENTS

CURRENT TRANSFORMERS AND POWER LINE TRANSFORMERS FOR SMART METERING

VACUUMSCHMELZE GmbH & Co. KG (VAC) is one of the worldwide leading manufacturers of metallic materials and inductive components manufactured from these alloys. VAC has been supplying high-performance products for more than 30 years.



SMART METERING

For more than ten years we have focused on high-precision current transformers for use in electronic electricity meters. Developing and improving our own materials like VITROVAC® and VITROPERM®, produced by rapid solidification technology, we are in a leading position to serve the metering industry with high-performance current transformers.

Our R&D and Engineering departments can provide outstanding competence in designing cores and components for the metering industry worldwide. In total more than 30 million meters operate with VAC materials.

Technical standards define requirements for accuracy for measuring of power in different operation modes. In Europe and other non-European countries these are usually the standards IEC 62053 -21, -22, -23 and, for the American market, the standards of the ANSI C12.xx series.

® registered trademark of VACCUUMSCHMELZE GmbH & Co. KG

CURRENT TRANSFORMERS FOR SMART METERING

MEASUREMENT PRINCIPLES

The key component in smart meters is the current transducer. There is a number of functional principles for implementation of the current transducer.

The shunt resistor is a favourite choice because of its very low cost and good linearity, but designers have to be aware of its disadvantages. Because of the regulations concerning maximum power consumption (2 W per phase acc. to IEC 62053 -21, -23), its resistance is limited to some hundreds of $\mu\Omega$. This low value results in very low secondary voltages at low primary currents.

These have to be very carefully filtered and amplified to keep the meter's specified accuracy in the low current level. Heat dissipation within the meter is another critical point to be considered. In cases of multi-phase meters or single-phase meters with external interface, additional galvanic separation has to be provided to prevent hazardous operation or short-circuit conditions between the phases. In most cases optocouplers and separation transformers will additionally be needed, increasing the meter's overall cost.

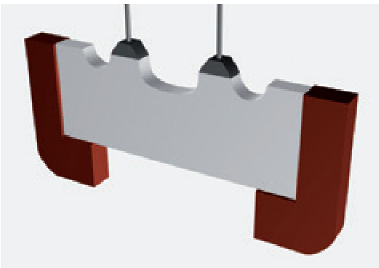
Another favourite principle is the Rogowski coil, which does not exhibit saturation effects due to its coreless operation. The disadvantage of this is common to all open magnetic circuits and results in very interference-sensitive operation. Costly shielding has to be provided to keep measurement errors small at low primary currents. Designs using Hall sensor devices have to be clearly separated: the low-cost types can suffer from ageing effects which can deteriorate accuracy over time; stabilised designs will control these effects, but at the cost of complicated compensation circuitry.

OVERVIEW OF ESTABLISHED MEASUREMENT PRINCIPLES IN ELECTRICITY METERS

- Current Transformers

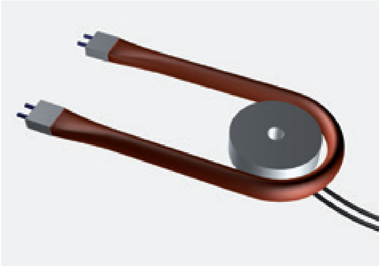
Safe Galvanic Separation
High Dynamic Range

- Shunt



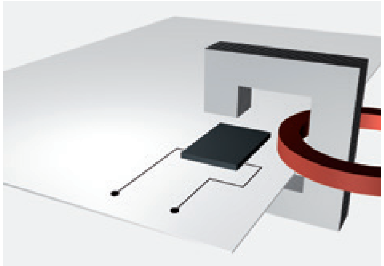
Low Dynamic Range
No Galvanic Separation

- Rogowski



Coreless Coil
Very Small Signals
Requires Integrator

- Hall Sensor



Semiconductor Material
Material Ageing
Complex Signal Processing

In comparison to other principles, toroidal-core current transformers with low burden resistors have several obvious advantages:

• closed magnetic circuit:	less sensitive to interference fields usually no shielding required
• magnetic function principle without semiconductors:	high long-term stability no need for additional circuitry
• simple assembly involving few parts:	low assembly expenses, compact designs attractive prices easy to mount

Characteristics	Current Transformer	Shunt	Rogowski Coil	Hall Sensor
Dynamic Range / Linearity	+	+	+	+
Temperature Stability	+	0	++	+
Corrosion / Reliability	++	--	++	++
Energy Dissipation	++	--	++	++
Galvanic Insulation	++	--	++	++
Output Signal Level	++	-	0	0
Mounting	++	+	--	--
Sensitivity against external AC + DC Fields	0	-	--	--

++ : excellent   + : good   0 : average   - : weak   -- : disadvantageous

The properties of the toroidal core current transformers, such as maximum transmissible primary current, amplitude and phase error as well as linearity, are basically determined by the material used for the magnetic core. The three areas of application mentioned place different demands on the respective materials:

For meters according to IEC 62053-22 and ANSI C12.xx, the best materials are those with high permeability in connection with the comparatively high flux density ranges of the metallic materials and only slight changes in properties as a function of the temperature. Current transformers with high-grade amorphous VITROVAC or nanocrystalline VITROPERM alloys from VAC offer extra advantages to the users:

- very small and high linear phase and amplitude error
- easily compensable phase error
- extreme low temperature dependence

Meters according to IEC 62053 -21, -23 must have tolerance to DC current components (‚direct current tolerance') which can saturate conventional current transformers when unipolar alternating currents occur, e.g. from power supply units with primary side diodes.

Magnetic cores made of very linear but still highly excitable amorphous and nanocrystalline low permeability alloys from VAC are used for this. These provide the current transformer with excellent properties:

- standard compliant DC tolerance without air gap
- negligible small amplitude error
- extreme linear, easily compensable phase curve
- low temperature dependence

PRINCIPLE OF CIRCUITRY

Phase and amplitude errors are critical for electricity measurement accuracy when current transformers are used. With meters of medium accuracy without DC tolerance, both have very low absolute values and can therefore be easily compensated by a simple correction in the circuit.

Current transformers with DC tolerance have the special feature of a relatively high absolute phase error value at high constancy, whereas the amplitude error is negligibly small. This causes an energy measurement error which varies only slightly with the primary current and which adopts impermissibly high values on complex loads (e.g. inductive load with $\cos\varphi = 0.5$) if the phase error is not carefully compensated.

Since the specified scatter of the secondary inductance L cannot be reduced at will, the phase error of the individual current transformer is scattered to the same extent. An individual correction is therefore recommended to stay reliably within the error limits. This can be performed with a suitable digital signal processor (DSP) which is digitally adjusted to the implemented current transformer in a calibration run at a single current value (e.g. at I_b). Particularly high accuracy can be achieved when the phase error curve is measured at several currents and is approximated between these for correction.

This is often impossible, or only possible to a certain extent, in devices with DSPs of a simple internal structure. Here correction is possible by means of an RC low-pass connected in series with the analogue current measuring input (see page 9).

Because of the scatter of the L-values, adapted use of grouped C-values may be necessary.

If further modifications of the operating parameters are necessary, we offer recalculation of the error characteristics upon request.

SUMMARIZED OVERVIEW OF 60 A AND 100 A CURRENT TRANSFORMERS

60 A and 100 A are the most important current ranges worldwide. The following table shows available variations for both current ranges:

I_{max}	Order Code T60404-		Design		Alloy			Shielding	DC Tolerance
			Wire	Pin	VITROPERM	VITROPERM Compact	VITROVAC		
60 A 100 A	...E4624-X... ...E4626-X...	101	X				X		X
		501					X		X
		121	X		X				X
		521		X	X				X
		131	X			X			X
		531		X		X			X
		151	X				X	X	X
		171	X			X		X	X
		002	X		X				
		502		X	X				

BLOCK DIAGRAM OF AN ELECTRONIC ELECTRICITY METER

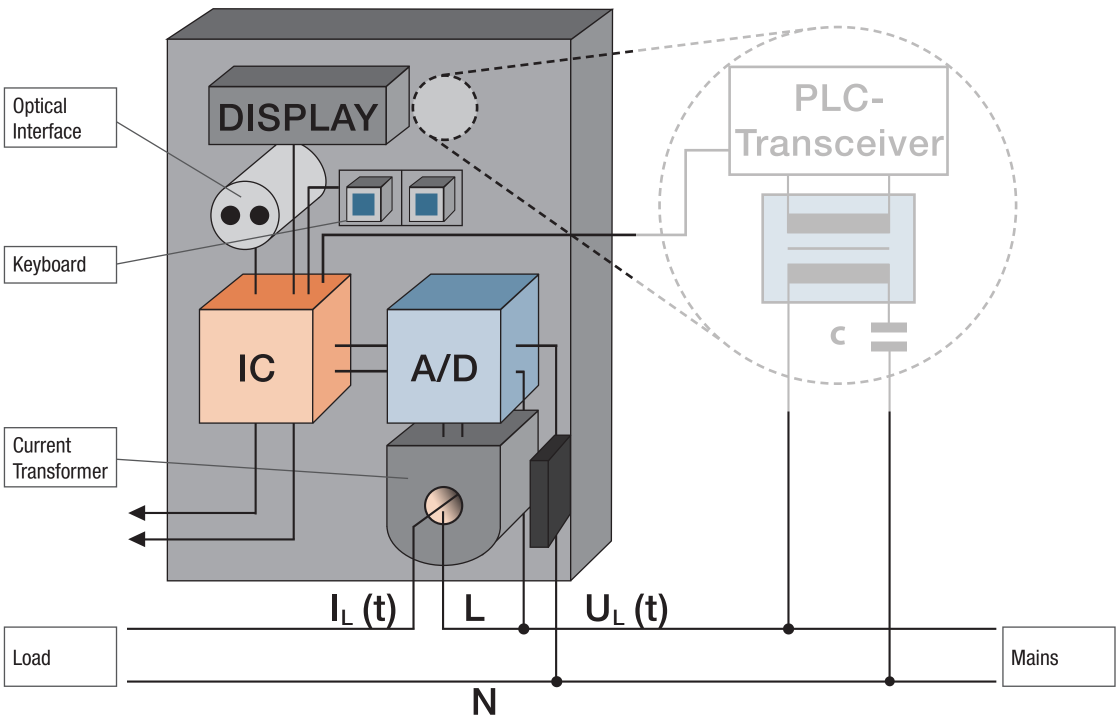


TABLE 1: CURRENT TRANSFORMERS WITH DC TOLERANCE ACCORDING TO IEC – BASED ON VITROVAC

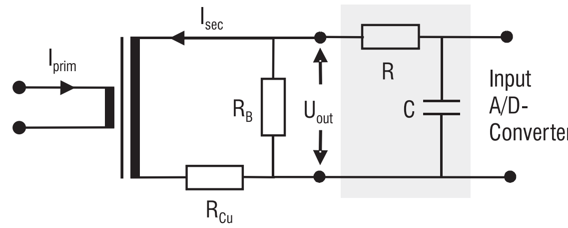
Order Code T60404-...	Error Curves [fig./ page]	Primary Current Range I_{max} $[A_{rms}]$	$\hat{I}_{peak}$ $[A_{0p}]$	Ratio 1 : [ ]	Phase Error φ(I) [°]	Characteristic Values L [H]	R_{DC} [Ω]	R_B [Ω]	U_B $[V_{rms}]$	Dimensions Inner dia. Ø [mm]	Width D [mm]	Heigth H [mm]	Pin/ Wire
...E4622-X101	1/17	20	20	2500	3.62	4.6	54	37.5	0.3	5	28.5	14.5	Wire
...E4623-X101	2/17	40	40	2500	4.15	3.7	66	18.8	0.3	5.5	28	16	Wire
...E4624-X101	3/18	60	60	2500	4.06	3.0	55	12.5	0.3	8	30.5	15	Wire
...E4624-X501	3/18	60	60	2500	4.06	3.0	55	12.5	0.3	8.5	31	14	Pin
...E4625-X101	4/18	80	80	2500	5.15	2.4	59	9.4	0.3	8	30.5	15	Wire
...E4625-X501	4/18	80	80	2500	5.15	2.4	59	9.4	0.3	8.5	31	14	Pin
...E4626-X101	5/19	100	100	2500	4.48	2.1	44	7.5	0.3	9.5	35	15	Wire
...E4626-X501	5/19	100	100	2500	4.48	2.1	44	7.5	0.3	11.5	34	14	Pin
...E4627-X101	6/19	120	120	2500	4.07	1.8	34	6.25	0.3	12	39	18	Wire

TABLE 2: CURRENT TRANSFORMERS WITH DC TOLERANCE ACCORDING TO IEC – – BASED ON VITROPERM

Order Code T60404-...	Error Curves [fig./ page]	Primary Current Range I_{max} $[A_{rms}]$	$\hat{I}_{peak}$ $[A_{0p}]$	Ratio 1 : [ ]	Phase Error φ(I) [°]	Characteristic Values L [H]	R_{DC} [Ω]	R_B [Ω]	U_B $[V_{rms}]$	Dimensions Inner dia. Ø [mm]	Width D [mm]	Heigth H [mm]	Pin/ Wire
...E4622-X121	7/20	20	20	2500	2.0	9.23	70.6	37.5	0.3	5	30.9	16.0	Wire
...E4623-X121	8/20	40	40	2500	2.1	6.5	60	18.75	0.3	7	33.8	16.9	Wire
...E4624-X121	9/21	60	60	2500	2.3	5.05	51.5	12.5	0.3	8	37.5	18.1	Wire
...E4624-X131	10/21	60	60	2500	3.5	3.8	71.5	12.5	0.3	8	32.7	16.3	Wire
...E4624-X531	10/21	60	60	2500	3.5	3.8	71.5	12.5	0.3	8	32.7	16.3	Pin
...E4625-X121	11/22	80	80	2500	2.4	3.5	42	9.38	0.3	10	40.8	18.5	Wire
...E4625-X131	12/22	80	80	2500	3.4	3.33	62	9.38	0.3	9	36.8	17.4	Wire
...E4626-X121	13/23	100	100	2500	2.4	2.77	35.5	7.5	0.3	10.5	43.2	19.8	Wire
...E4626-X131	14/23	100	100	2500	3.3	3.1	49	7.5	0.3	9	38.1	17.7	Pin
...E4626-X531	14/23	100	100	2500	3.3	3.1	49	7.5	0.3	9	38.1	17.7	Pin
...E4627-X121	15/24	120	120	2500	4.1	3.1	37	6.25	0.3	12.5	45.5	19	Wire

APPLICATION NOTE:
RC COMPONENTS FOR COMPENSATION OF PHASE ERROR

The excellent soft magnetic properties of the VAC core material for DC-tolerant CTs leads to a negligible small amplitude error as well as to extremely low and linear temperature dependence. Due to the low permeability, a phase error of typically 4° to 5° occurs which is easy to compensate on account of its high constancy of typically +/- 0.05°. Compensation can be effected digitally by appropriate correction in the microprocessor and analogously by a RC low-pass in front of the input of the A/D converter. A number of major metering chip providers supply tailored solutions for optimum performance and accuracy in combination with these CT types.



$$C = (R_{CU} + R_B) / \omega^2 \cdot R \cdot L$$

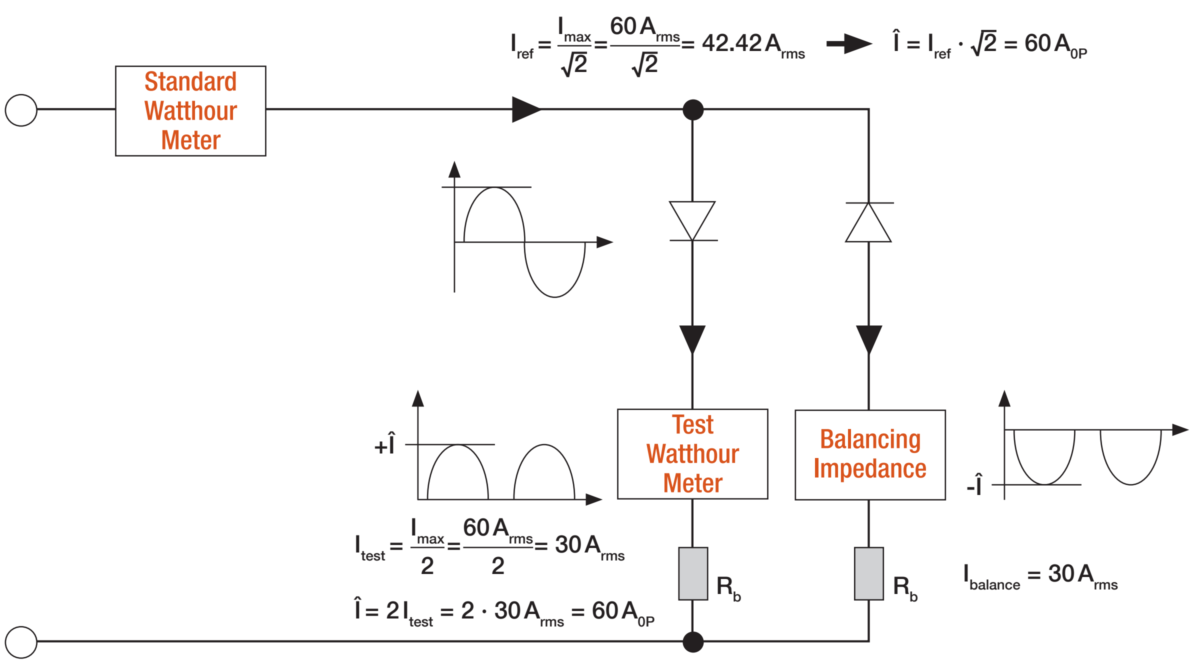
Condition for value of R:

RB <<R<<IZI of converter;

typical value R = 1 kΩ

Typ. C values: 150 ... 300 nF

DC TOLERANCE TEST ACCORDING TO IEC 62053-21, -23



The diagram above shows a typical test of DC tolerance of a 60 A electricity meter. The Balancing Impedance is another meter from the same series. During this test, the meter shows 30 A_{rms}, which is equal to 60 A_{0P}, for only half-rectified sinusoidal currents.

TABLE 3: SHIELDED CURRENT TRANSFORMERS FOR ANTI-TAMPERING

Order Code T60404-...	Error Curves [fig./ page]	Primary Current Range I_{max} [A_{rms}]	$\hat{I}_{peak}$ [A_{0p}]	Ratio 1 : [ ]	Phase Error φ(I) [°]	Characteristic Values L [H]	R_{DC} [Ω]	R_B [Ω]	U_B [V_{rms}]	Dimensions Inner dia. Ø [mm]	Width D [mm]	Heigth H [mm]	Pin/ Wire
...E4622-X011	20/26	6	-	2000	0.37	105	115	100	0.3	5.5	28	15.9	Wire
...E4622-X012	21/27	6	-	2000	0.17	238	115	100	0.3	5.5	28	15.9	Wire
...E4623-X171	8/20	40	40	2500	2.1	6.5	60	18.75	0.3	6	38.5	20	Wire
...E4624-X151	3/18	60	60	2500	4.06	3.0	55	12.5	0.3	8	32.9	17.1	Wire
...E4624-X171	9/21	60	60	2500	3.5	3.8	71.5	12.5	0.3	8	36.9	19.2	Wire
...E4625-X151	4/18	80	80	2500	5.15	2.4	53.5	9.4	0.3	8	32.9	17.1	Wire
...E4626-X151	5/19	100	100	2500	4.48	1.97	55	7.5	0.3	9.5	35.8	17.2	Wire

TYPICAL CHARACTERISTIC OF THE AMPLITUDE ERROR IN THE FIELD OF A PERMANENT MAGNET

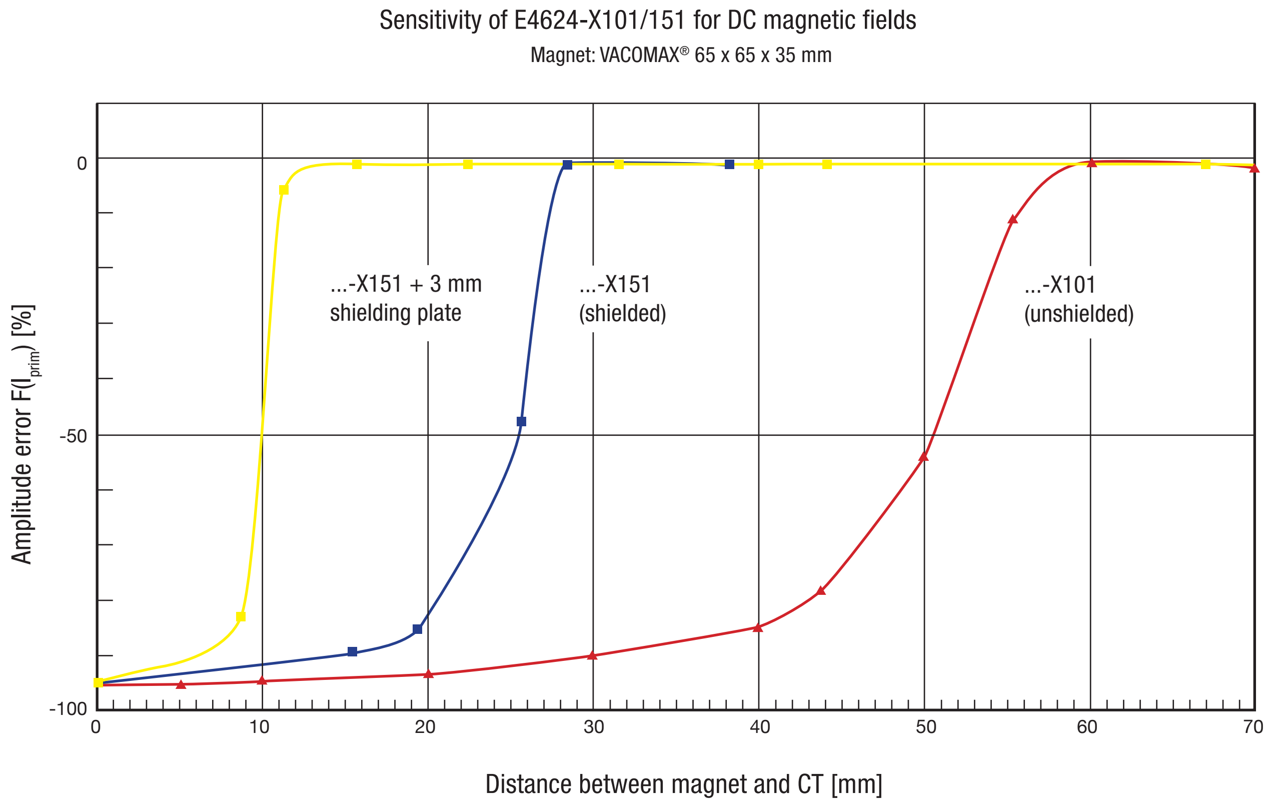


Diagram above shows a comparison of different shielding configurations. For optimum protection against external magnetic fields CTs from . . .–X151 series and a 3 mm shielding plate are needed.

TABLE 4: CURRENT TRANSFORMERS WITHOUT DC TOLERANCE FOR DIRECT CONNECTION													
Order Code T60404-...	Error Curves [fig./ page]	Primary Current Range		Ratio	Phase Error	Characteristic Values				Dimensions			
		I_{max} [A_{rms}]	$\hat{I}_{peak}$ [A_{0p}]	1 : [ ]	φ(I) [°]	L [H]	R_{DC} [Ω]	R_B [Ω]	U_B [V_{rms}]	Inner dia. Ø [mm]	Width D [mm]	Heigth H [mm]	Pin/ Wire
...E4622-X002	16/24	20	-	2500	0.18	113	54	37.5	0.3	5	28.5	14.5	Wire
...E4623-X002	17/25	40	-	2500	0.12	155	61	18.8	0.3	5.5	28	16	Wire
...E4624-X002	18/25	60	-	2500	0.13	122	55	12.5	0.3	8	30.5	15	Wire
...E4624-X502	18/25	60	-	2500	0.13	122	55	12.5	0.3	8.5	31	14	Pin
...E4626-X002	19/26	100	-	2500	0.11	97	44	7.5	0.3	9.5	35	15	Wire
...E4626-X502	19/26	100	-	2500	0.11	97	44	7.5	0.3	11.5	34	14	Pin

TABLE 5: CURRENT TRANSFORMERS WITHOUT DC TOLERANCE FOR INDIRECT CONNECTION													
Order Code T60404-...	Error Curves [fig./ page]	Primary Current Range		Ratio	Phase Error	Characteristic Values				Dimensions			
		I_{max} [A_{rms}]	$\hat{I}_{peak}$ [A_{0p}]	1 : [ ]	φ(I) [°]	L [H]	R_{DC} [Ω]	R_B [Ω]	U_B [V_{rms}]	Inner dia. Ø [mm]	Width D [mm]	Heigth H [mm]	Pin/ Wire
...E4629-X007	20/26	6	-	2000	0.37	105	112	100	0.3	7.0	23.0	11.0	Wire
...E4622-X501	20/26	6	-	2000	0.37	110	115	100	0.3	6.3	24.5	11.5	Pin
...E4629-X010	21/27	6	-	2000	0.17	238	114	30	0.3	7.0	23	11	Wire
...E4622-X503	21/27	6	-	2000	0.17	238	114	100	0.3	6.3	24.5	11.5	Pin
...E4658-X043	22/27	6	-	1500	0.4	35	46	75	0.3	5.0	16.8	9	Pin

TABLE 6: CURRENT TRANSFORMERS FOR ANSI MARKET

Order Code T60404-...	Error Curves [fig./ page]	Primary Current Range		Ratio	Phase Error	Characteristic Values				Dimensions			
		I_{max} [A_{rms}]	$\hat{I}_{peak}$ [A_{0p}]	1 : [ ]	φ(I) [°]	L [H]	R_{DC} [Ω]	R_B [Ω]	U_B [V_{rms}]	Inner dia. Ø [mm]	Width D [mm]	Heigth H [mm]	Pin/ Wire
...E4629-X007	23/28	20	-	2000	0.21	105	112	30	0.3	7.0	23.0	11.0	Wire
...E4622-X501	23/28	20	-	2000	0.21	110	115	30	0.3	6.3	24.5	11.5	Pin
...E4629-X010	24/28	20	-	2000	0.17	238	114	30	0.3	7.0	23.0	11.0	Wire
...E4622-X503	24/28	20	-	2000	0.17	238	114	30	0.3	6.3	24.5	11.5	Pin
...E4627-X001	25/29	200	-	1000	0.11	24.6	13.5	1.5	0.3	8.5	30.0	17.5	Wire
...E4628-X001	26/29	320	-	1000	0.10	22	12.7	0.94	0.3	11.0	35.0	18.5	Wire

EXPLANATIONS OF TABLES 1 TO 6:

Noted values are typical at room temperature (25 °C)

All types are designed as bar-type CTs with one primary turn ($N_1 = 1$).

I_{max} = maximum AC primary current with defined errors
$\hat{I}_{peak}$ = max. half wave rectified AC amplitude without saturation (for Class 1 meter (IEC 62053 -21, -23): $F(\hat{I}_{max}) < 3\,\%$)
φ (I) = max. phase error for $I < I_{max}$
F(I) = max. amplitude error for $I < I_{max}$
N_2 = number of secondary turns
L = inductance at moderate excitation level (I < Imax)
R_{DC} = winding resistance
R_B = burden resistor
U_B = output voltage across burden resistor R_B at I_{max}
Ø = diameter of centre hole
D = maximum width of component in mm
H = maximum thickness of component in mm

For further details please see datasheets, which are provided on www.vacuumschmelze.com.

EXAMPLES FOR CUSTOMISED CURRENT TRANSFORMER DESIGNS

In addition to the illustrated standard types, customised developments (see above) are also possible when sufficiently large quantities are needed. Please ask for our latest CT checklist, fill out as completely as possible and send it back to us.

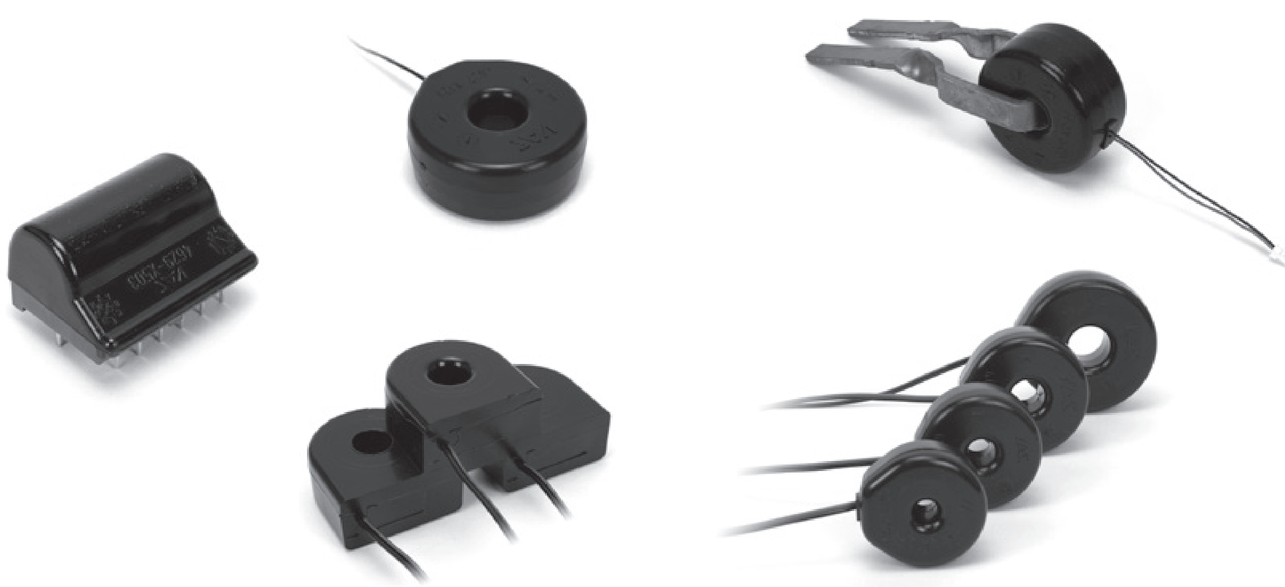
If the sensitivity of the current transformer to external magnetic fields in special applications is still too high, we recommend shielded versions of CTs (see table 3 on page 10). If required, for anti-tampering issues each CT can be encapsulated with a pair of deep drawing caps.

For additional protection against manipulation by external fields from permanent magnets, a metal plate may be placed between CT and the magnet (see diagram on page 10).

DIELECTRIC STRENGTH TEST:

For standard type housings the following values are valid for the insulation between a bare copper primary conductor and the secondary winding (different test values on request):

$U_{p\,rms}$ = 2,5 kV (50 / 60 Hz, 1 min) and
$U_{p\,max}$ = 6 kV (1,2 µs / 50 µs – test pulse)



PLC TRANSFORMERS FOR SMART METERING

In the years to come, 'Smart Grids' will take on greater significance and electronic electricity meters newly installed for this purpose will increasingly be networked to enable processes including remote meter reading.

Electronic electricity meters must therefore be able to communicate, and secure data transfer must be guaranteed. Various communication technologies are available for Automatic Meter Reading (AMR). In the case of wired transfer technologies, power line communication (PLC) is one of the favoured technologies.

VAC component characteristics are aligned and optimized for low EMC interference, low distortion and high dielectric strength. These key parameters for PLC transformers offer particularly significant advantages for users with respect to secure data transmission.

BLOCK DIAGRAM OF AN ELECTRONIC METER WITH PLC READ-OUT SYSTEM

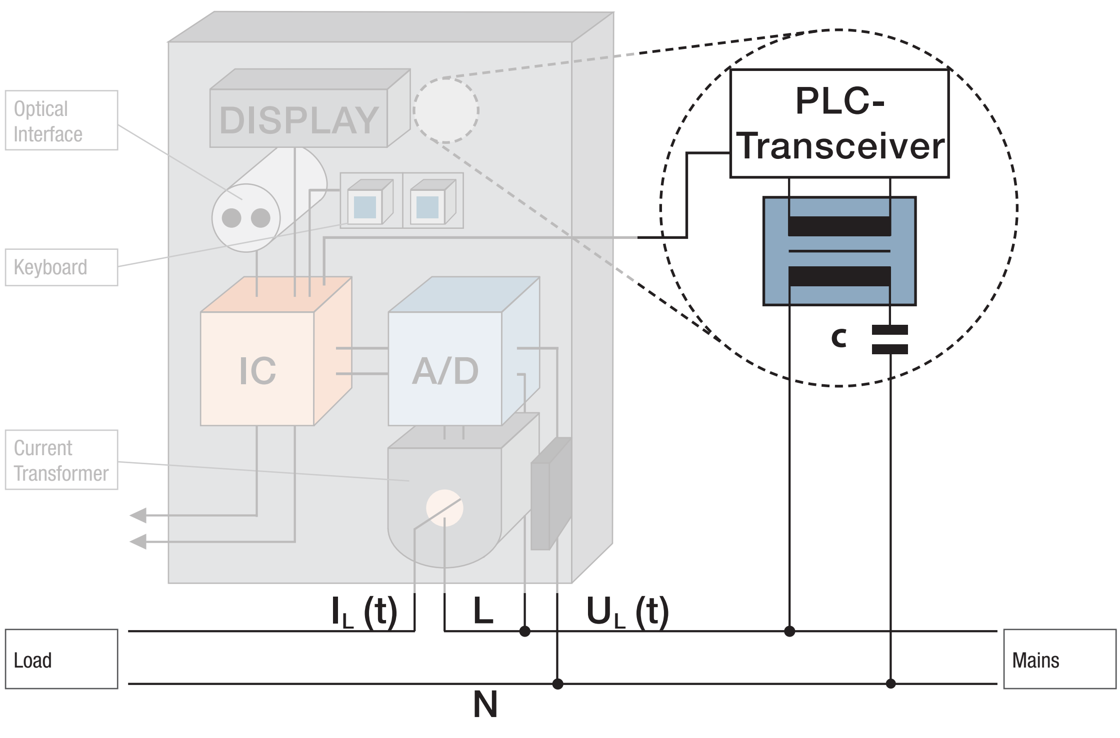


TABLE 7: PLC TRANSFORMERS FOR METERING APPLICATIONS

Order Code T60403-K…	Turns Ratio	L [mH]	R_{cu} [mΩ]	L_s [μH]	Capacitor C_K [pF]	HV Test* [kV_{rms}]	Design**
5024-X044	1:1	1.4	200 : 200	0.3	25	6	SMD
4081-X004	1:1	1.4	200 : 300	0.3	25	4	PTH flat
4085-X004			200 : 300				PTH upright
5024-X078	1:1	2.5	200 : 300	0.9	50	3	SMD
4096-X046	1:1	1.3	100 : 150	1	12	6	PTH
4096-X047	1:1	1.3	100 : 200	10	5	6	PTH
4096-X048	1:1	1.3	100 : 200	10	5	6	PTH
4021-X139	1.67:1	0.5	300 : 200	5	5	6	PTH
5024-X097	1.68:1	1.2	220 : 160	5.8	17	1.5***	SMD
4031-X009	2:1	1.0	140 : 80	0.67	17	4	PTH
5024-X079	2:1	1.4	350 : 120	2	50	3	SMD
5024-X090	1:1:2	0.88	100 : 100 : 100	0.4	30	3	SMD
5024-X092****	1:1:2	0.7	250: 250 : 500	0.99	37.5	4	SMD
5024-X099****	1:1:2	0.7	250 : 250 : 500	0.99	37.5	3	SMD
5032-X102	1:1:2	0.7	135 : 135 : 230	0.73	25.27	7.5	SMD

* = reinforced insulation according to EN60950
** = mechanical outline; for details see VAC datasheet (available upon request)
*** = operational insulation
**** = extended performance in the low frequency range

TABLE 8: PLC TRANSFORMERS CROSS REFERENCE LIST

Order Code T60403-K…	Echelon		Maxim	On Semi	Renesas	STM		TI	Yitran
	PLT-21 PLT-22	PLT3120 PLT3150	MAX2990 MAX2991	AMIS 49587	M16C/6S	ST7536 ST7537	ST7538 ST7540	C2000	IT800
5024-X044	X	X			X	X	X		X
4081-X004	X	X			X	X	X		X
4085-X004									
5024-X078	X	X					X		X
4096-X046	X	X	X				X		X
4096-X047	X	X					X		X
4096-X048			X						
4021-X139	X	X					X		
5024-X097	X	X							
4031-X009				X			X		
5024-X079				X					
5024-X090		X			X		X		X
5024-X092*		X			X		X	X	X
5024-X099*		X			X		X	X	X
5032-X102					X				X

* = extended performance in the low-frequency range

TYPICAL TEMPERATURE DEPENDENCE OF PHASE AND AMPLITUDE ERRORS

Fig. 1: 20 A with DC Tolerance, T60404-E4622-X101

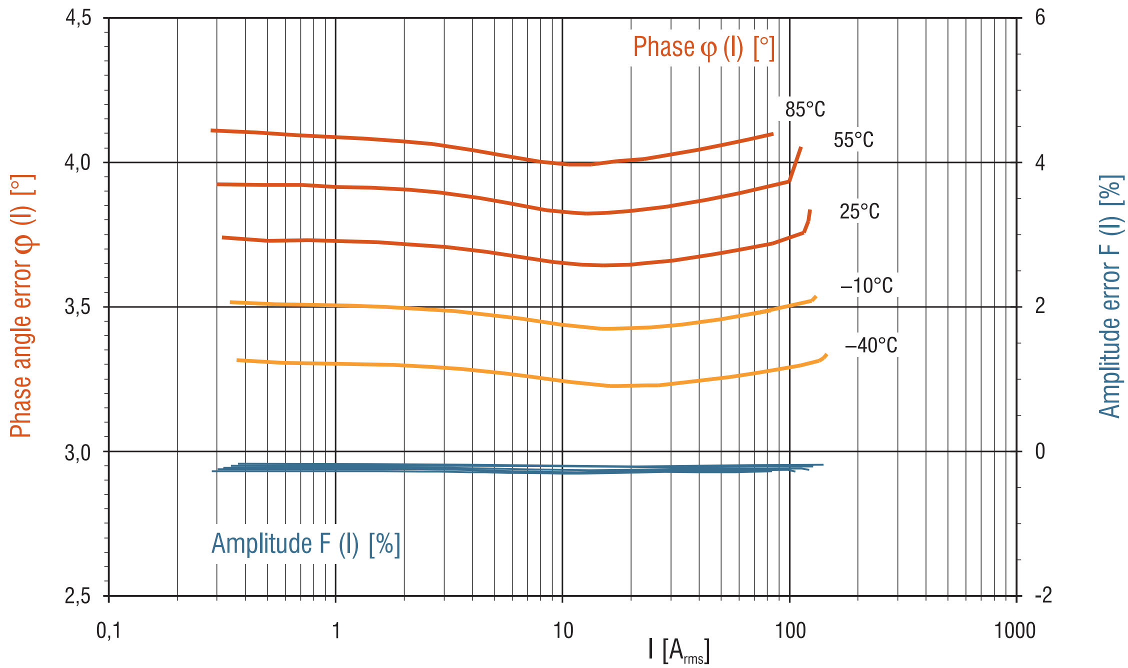


Fig. 2: 40 A with DC Tolerance, T60404-E4623-X101

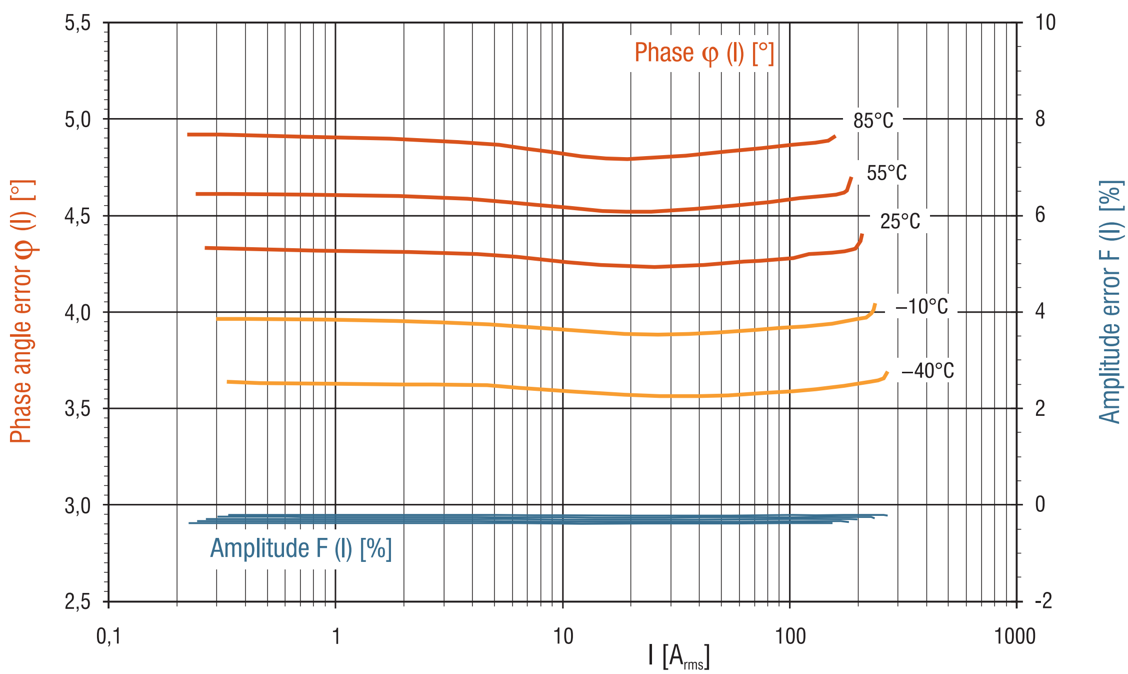


Fig. 3: 60 A with DC Tolerance, T60404-E4624-X101/-X501/-X151

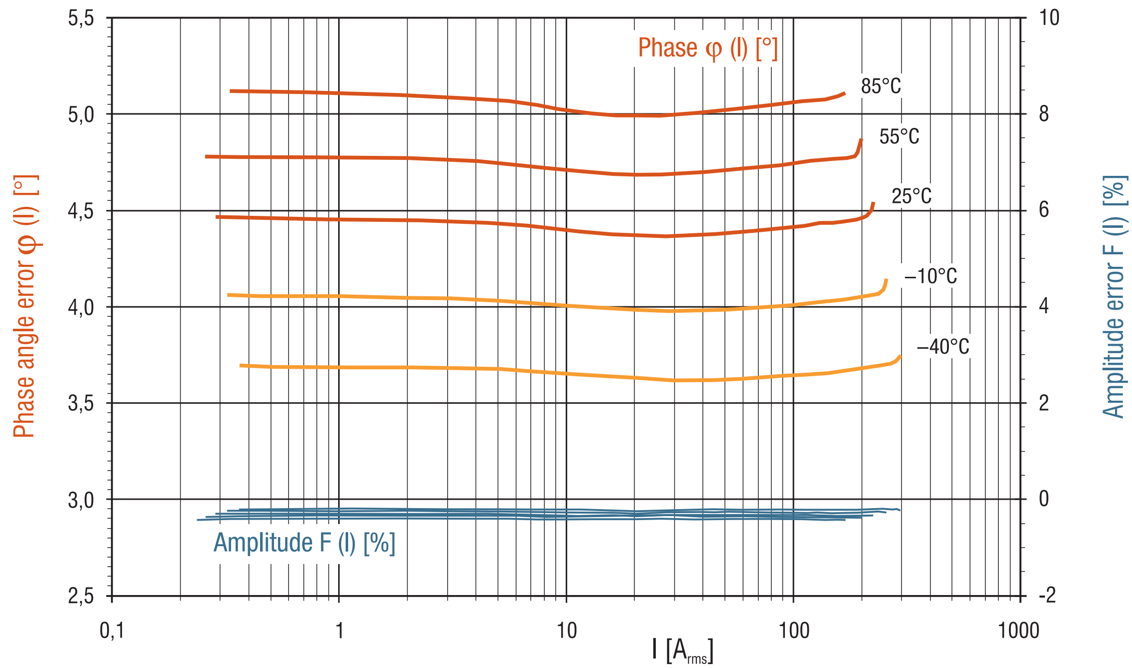


Fig. 4: 80 A with DC Tolerance, T60404-E4625-X101/-X501/-X151

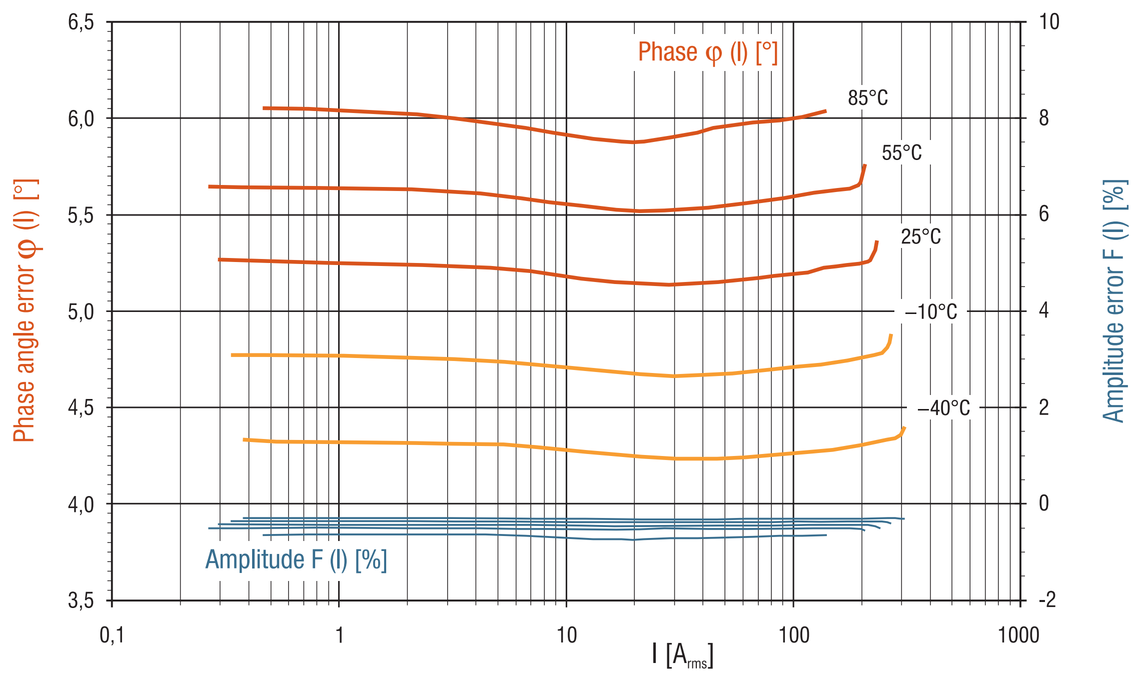


Fig. 5: 100 A with DC Tolerance, T60404-E4626-X101/-X501/-X151

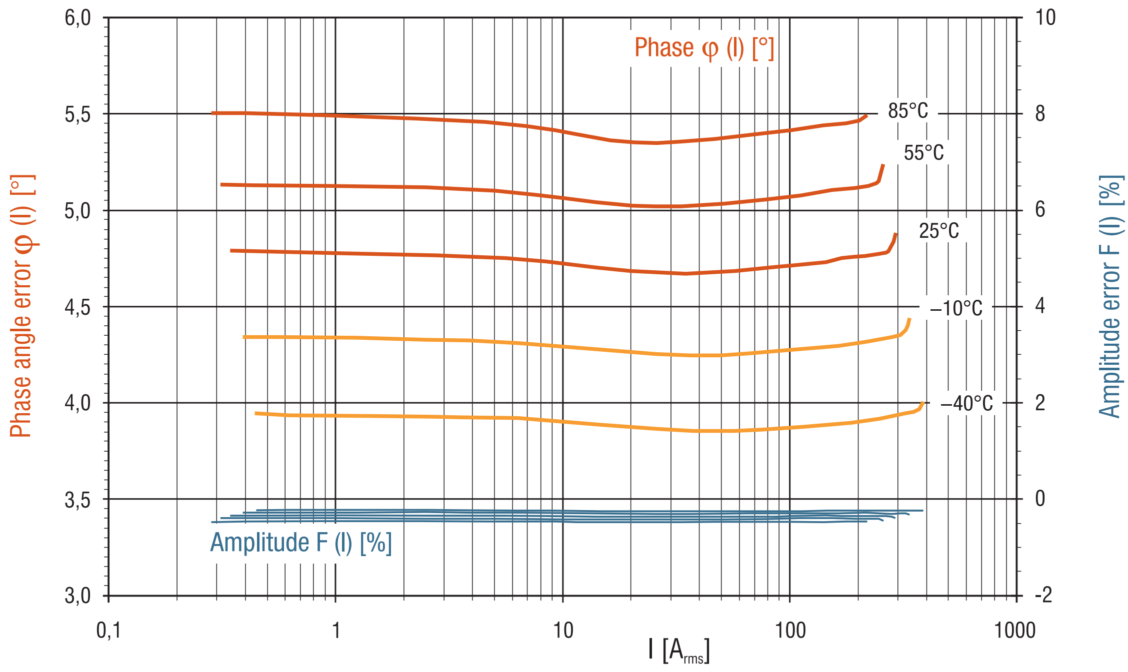


Fig. 6: 120 A with DC Tolerance, T60404-E4627-X101

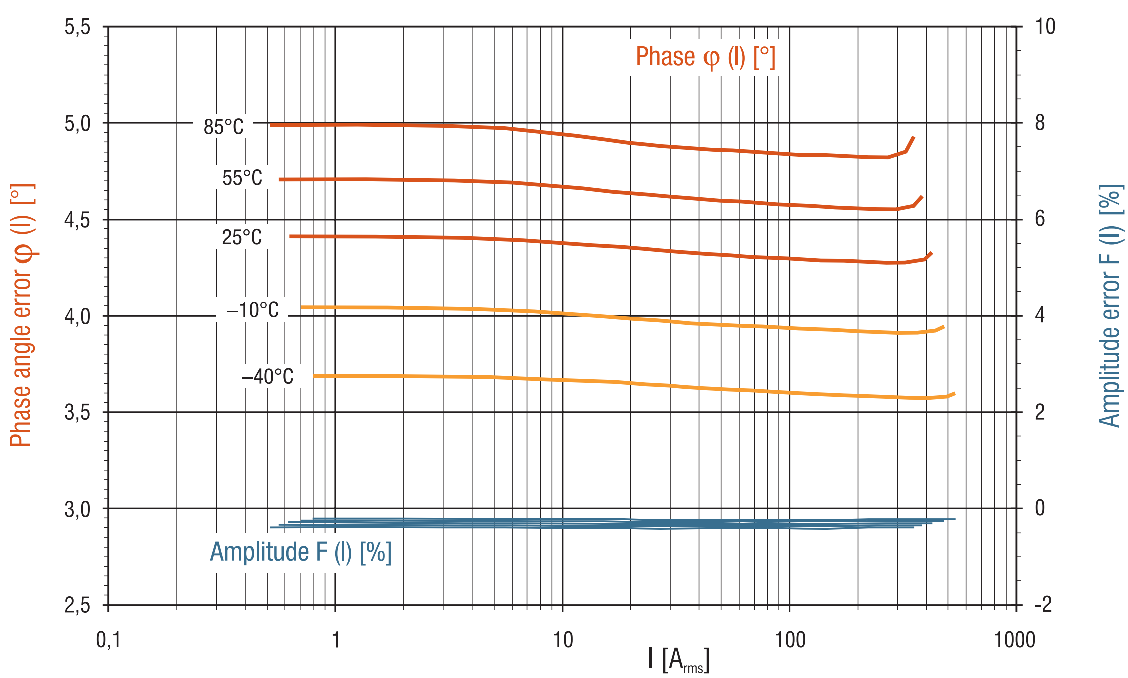


Fig. 7: 20 A with DC Tolerance, T60404-E4622-X121

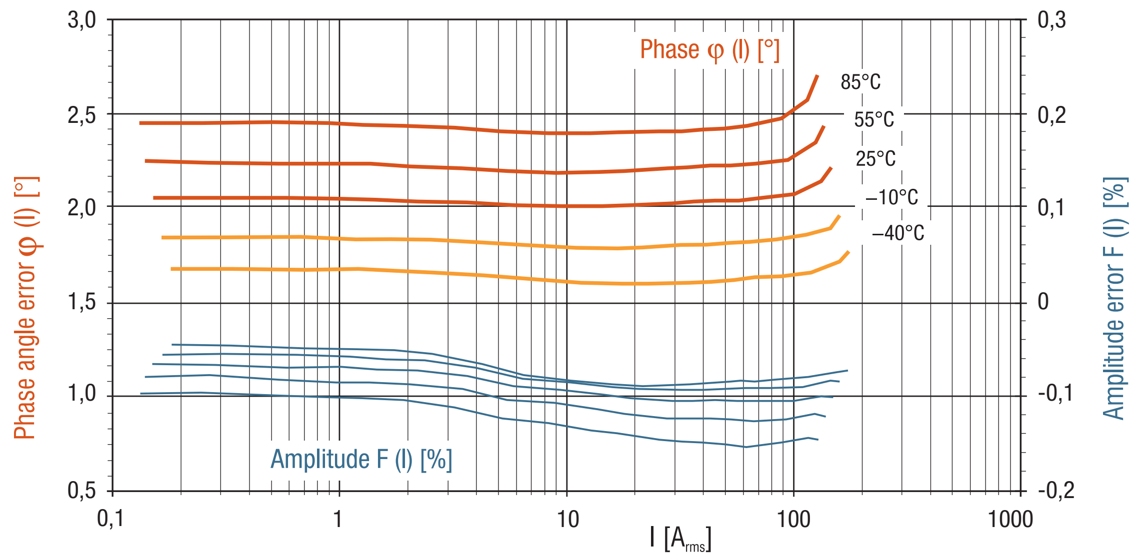


Fig. 8: 40 A with DC Tolerance, T60404-E4623-X121/-X171

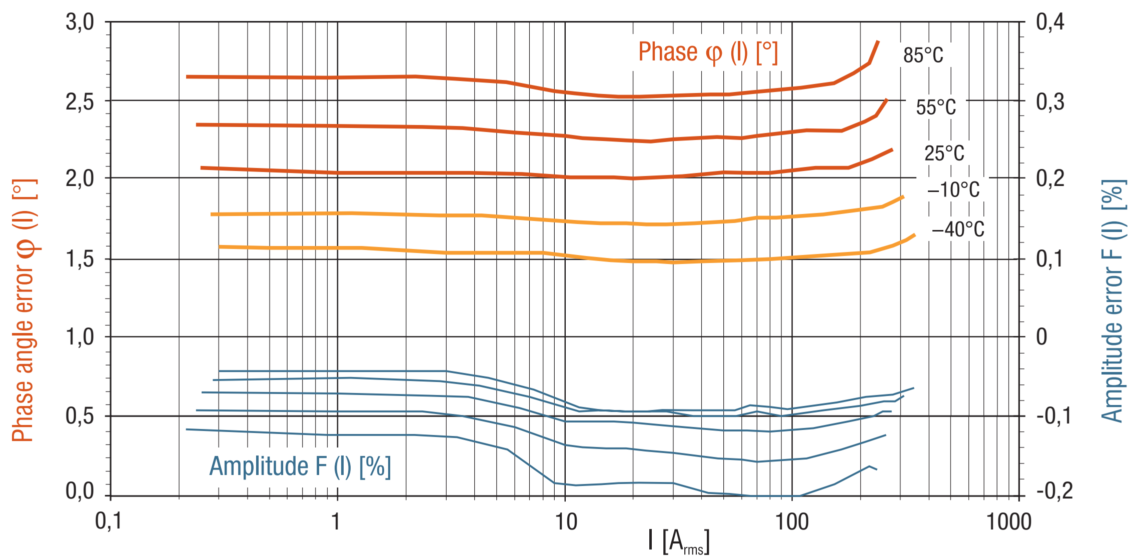


Fig. 9: 60 A with DC Tolerance, T60404-E4624-X121/-X171

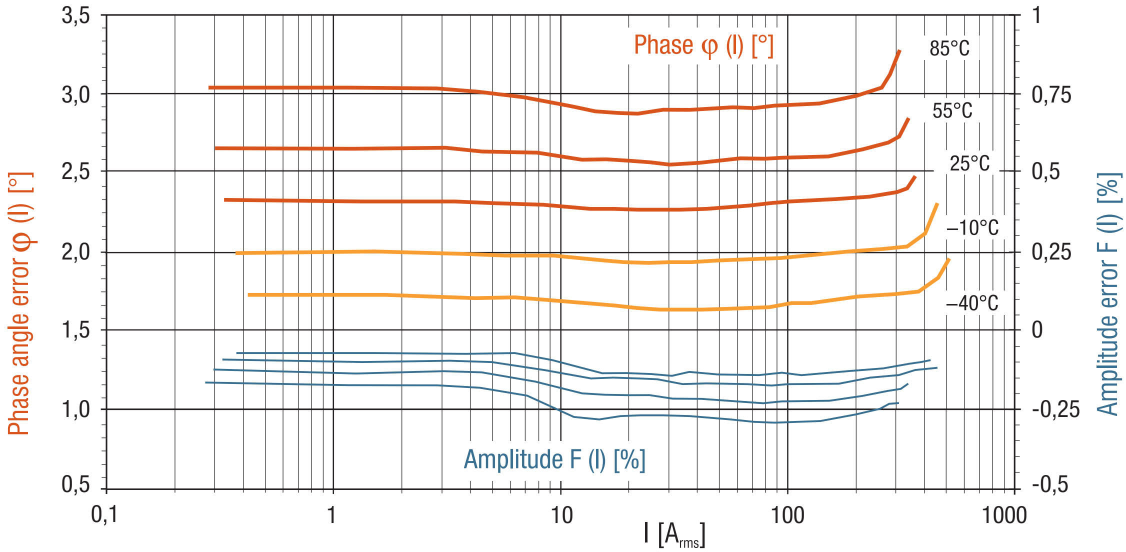


Fig. 10: 60 A with DC Tolerance, T60404-E4624-X131/-X531

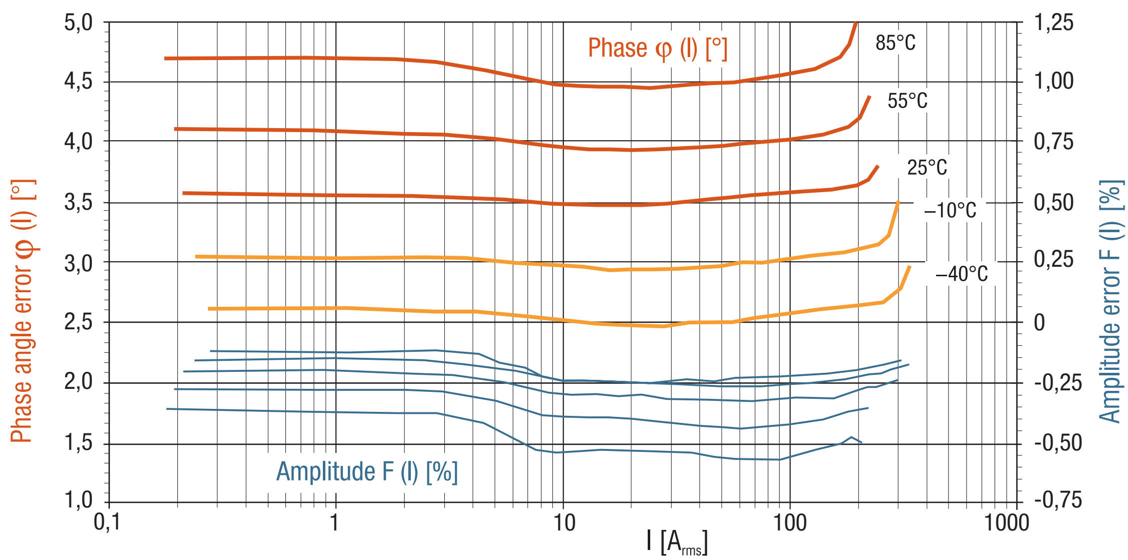


Fig. 11: 80 A with DC Tolerance, T60404-E4625-X121

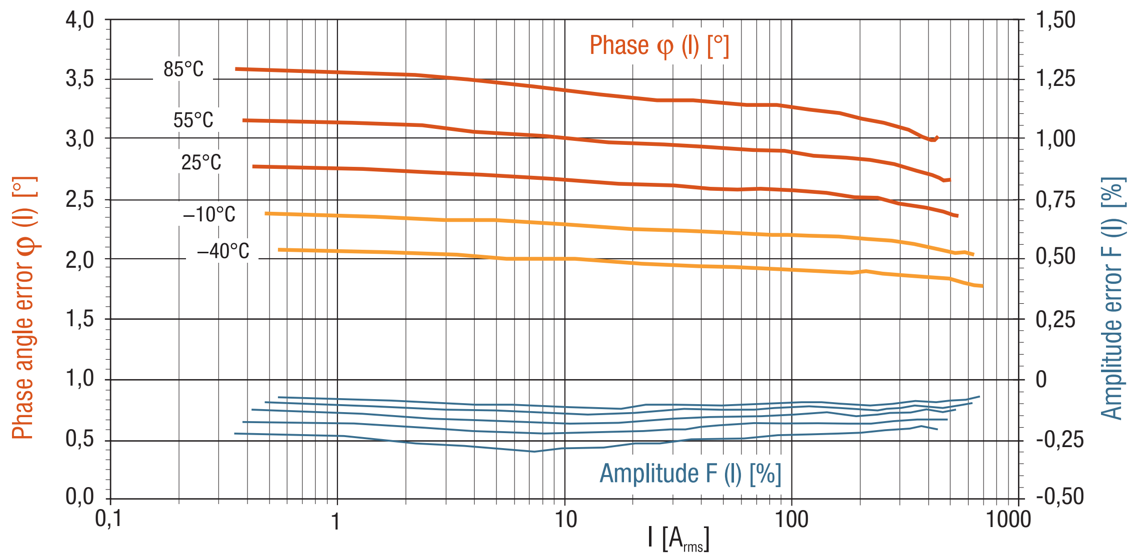


Fig. 12: 80 A with DC Tolerance, T60404-E4625-X131/-X531

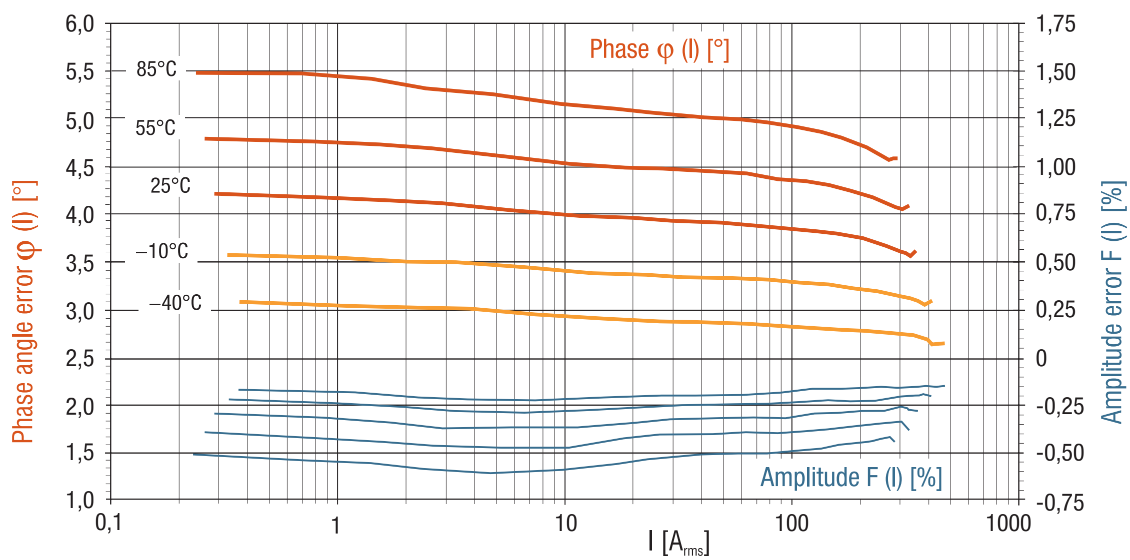


Fig. 13: 100 A with DC Tolerance, T60404-E4626-X121

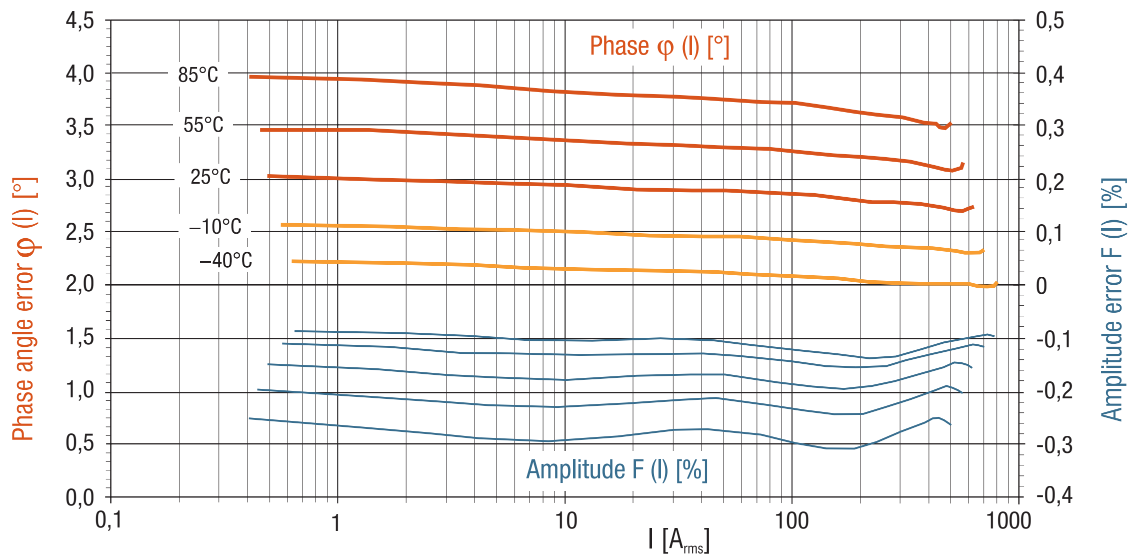


Fig. 14: 100 A with DC Tolerance, T60404-E4626-X131/-X531

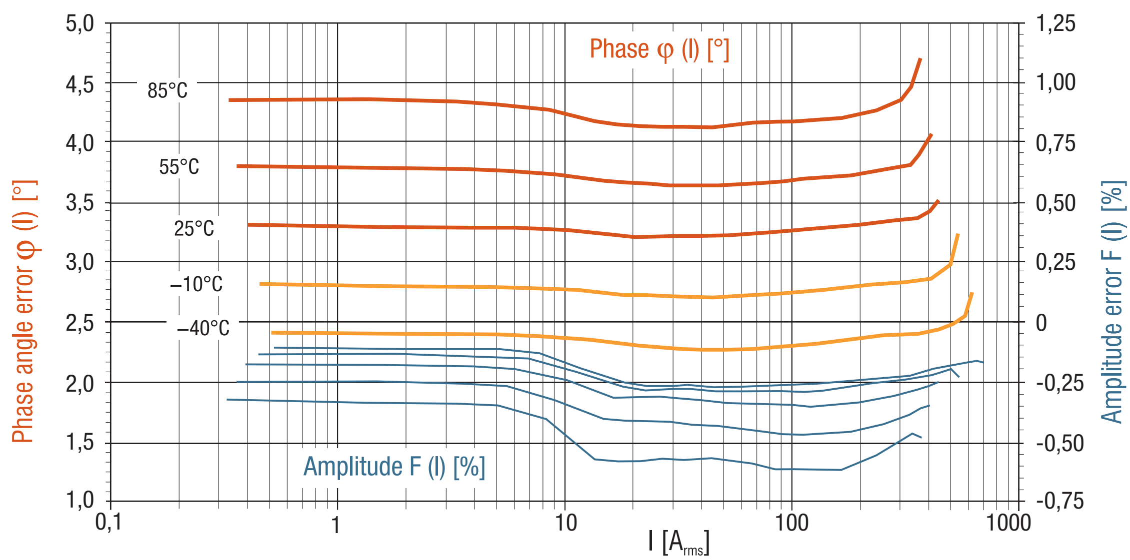


Fig. 15: 120 A with DC Tolerance, T60404-E4627-X121

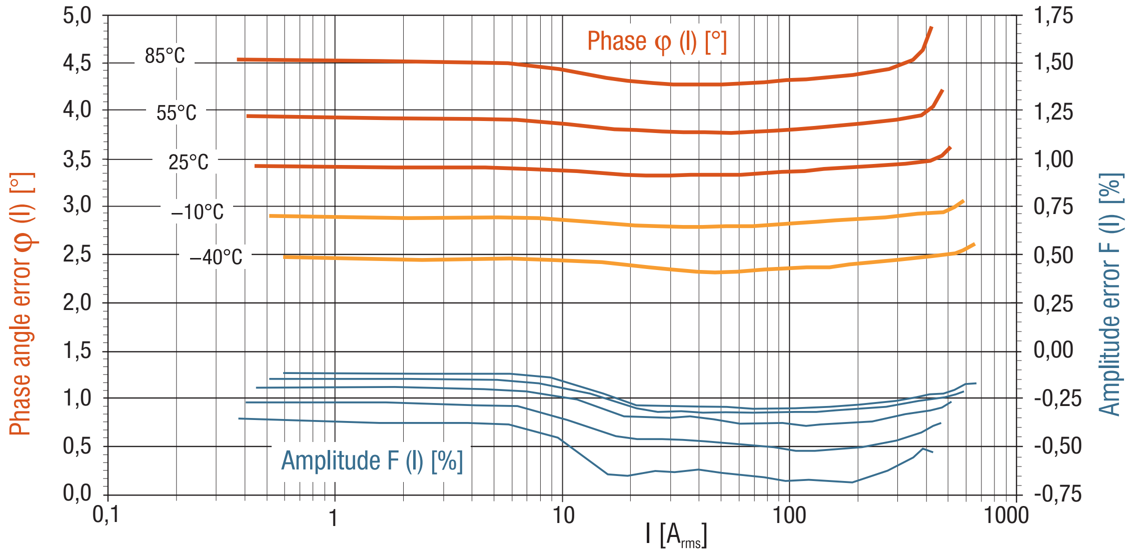


Fig. 16: 20 A, T60404-E4622-X002

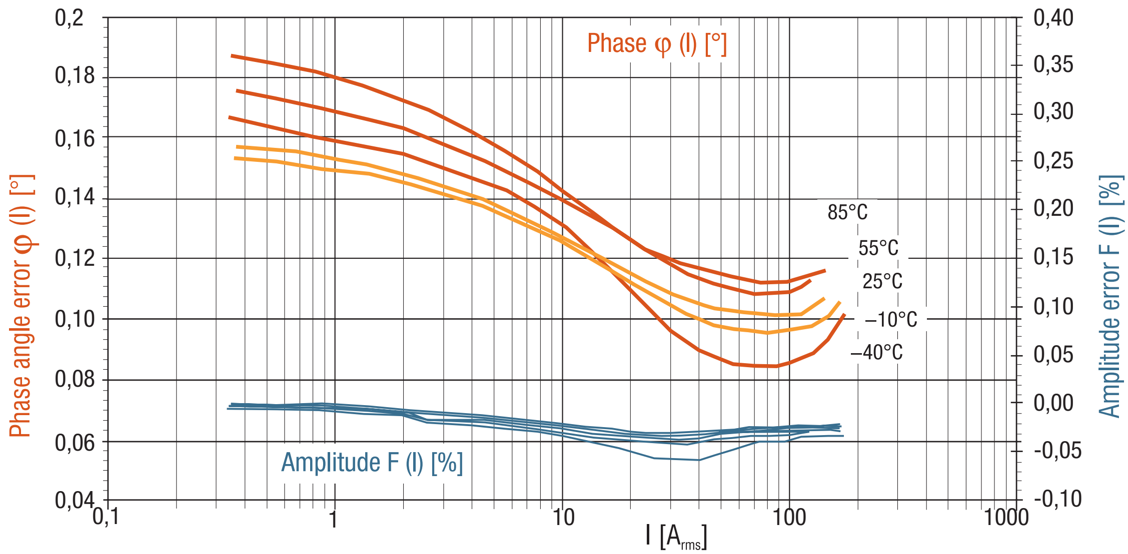


Fig. 17: 40 A, T60404-E4623-X002

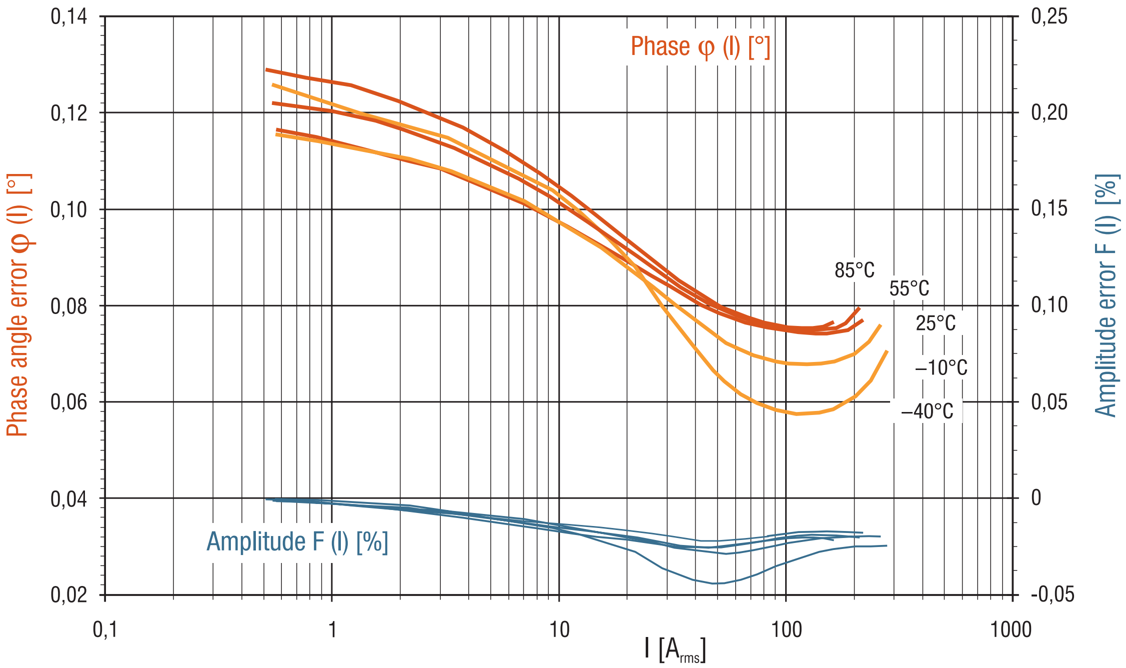


Fig. 18: 60 A, T60404-E4624-X002/-X502

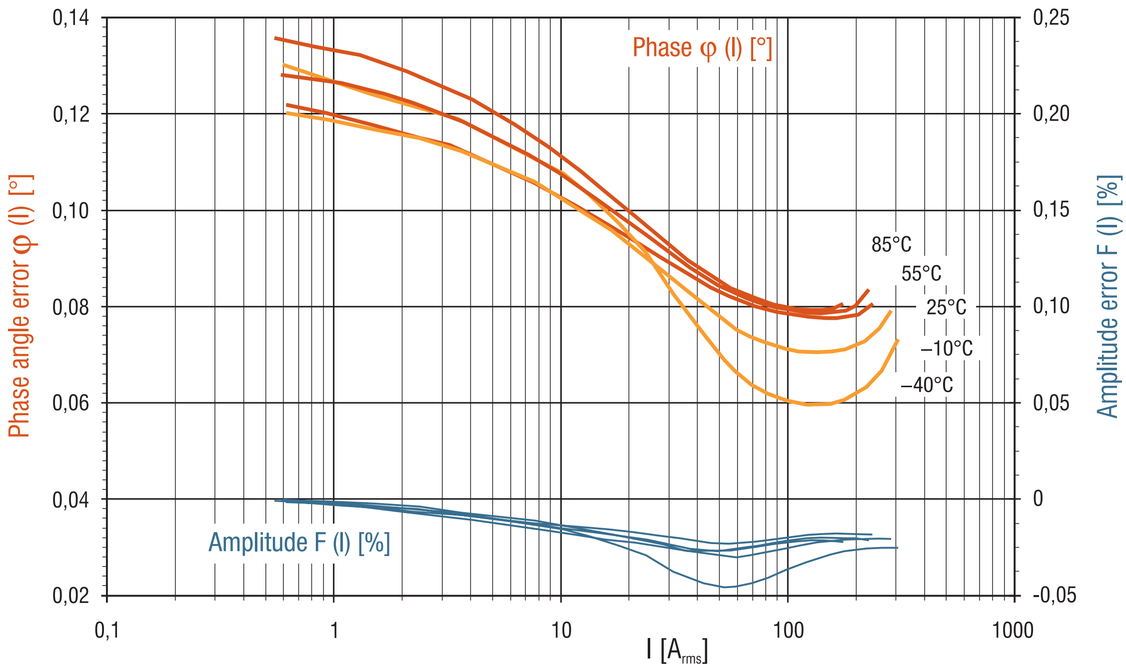


Fig. 19: 100 A, T60404-E4626-X002/-X502

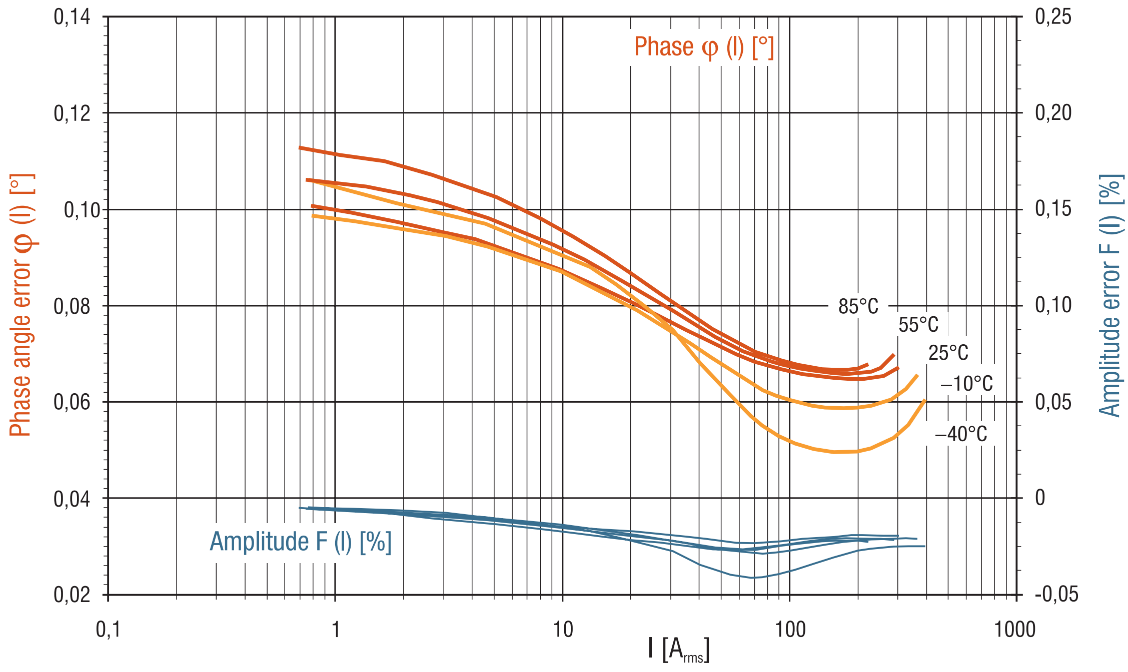


Fig. 20: 6 A, T60404-E4629-X007, 4622-X501, 4622-X011

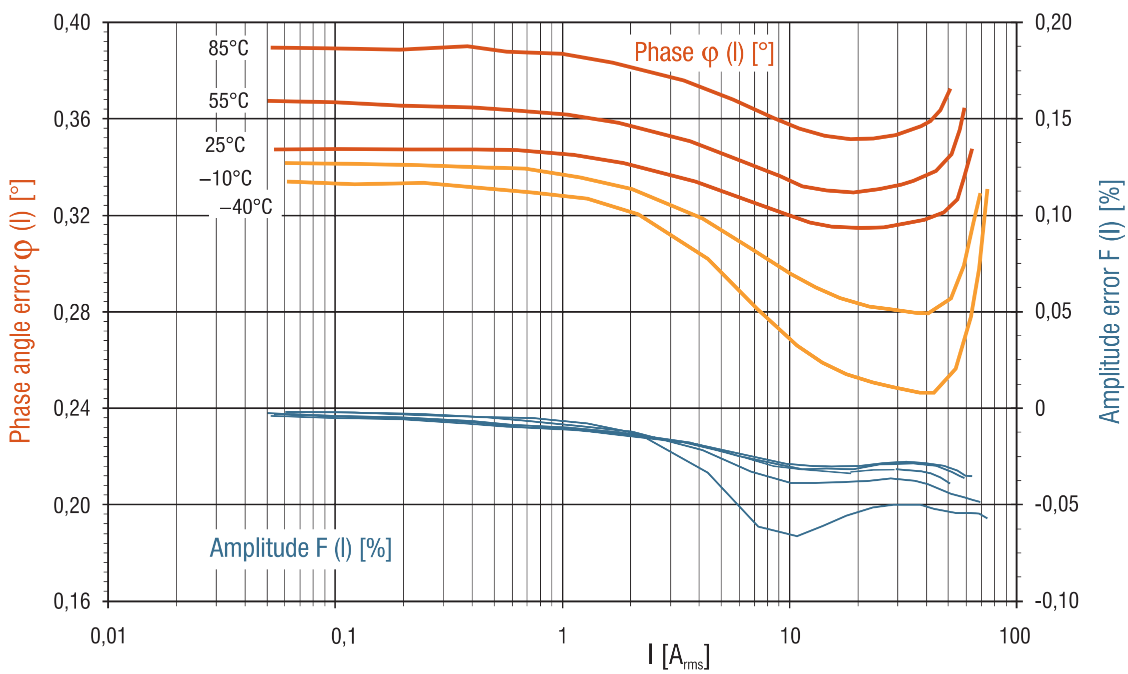


Fig. 21: 6 A, T60404-E4629-X010, 4622-X503, 4622-X012

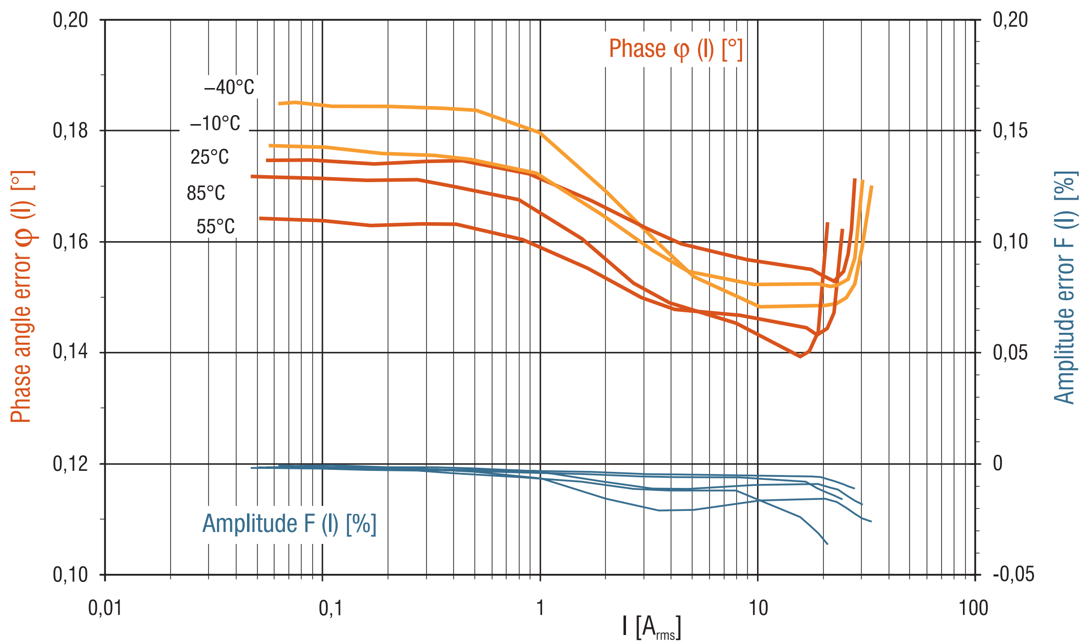


Fig. 22: 6 A, T60404-E4658-X043

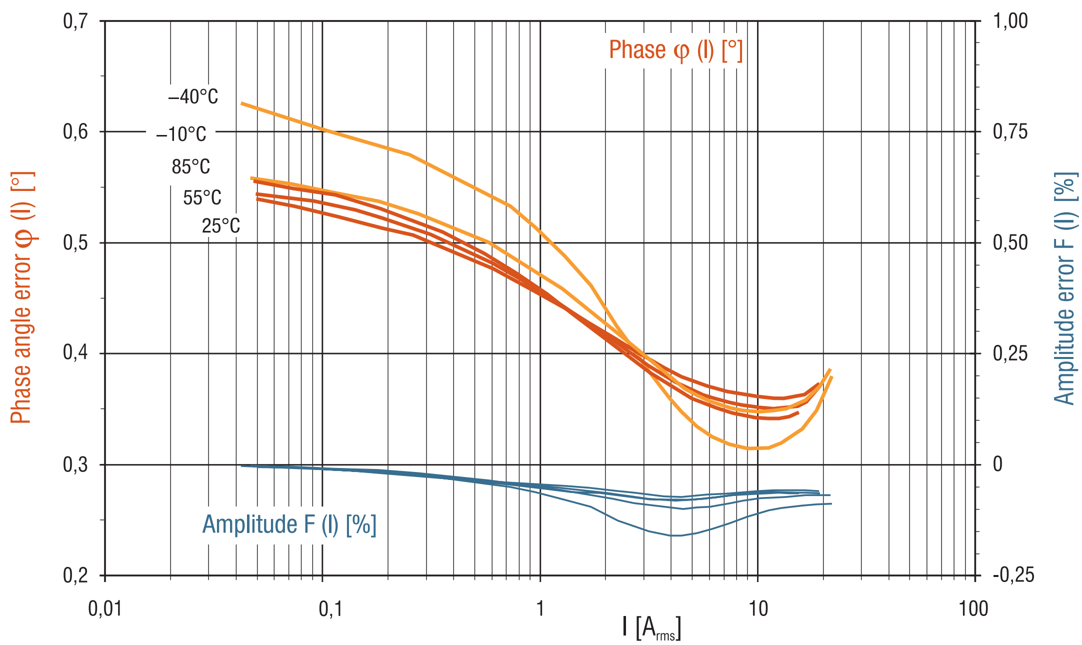


Fig. 23: 20 A, T60404-E4629-X007, 4622-X501

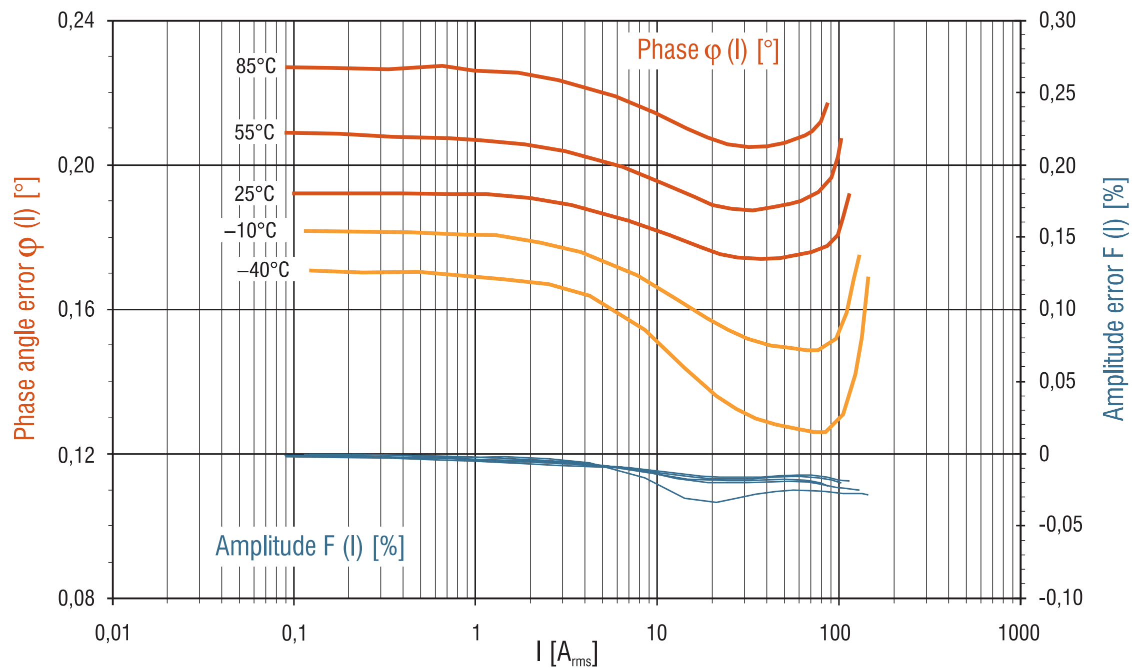


Fig. 24: 20 A, T60404-E4629-X010, 4622-X503

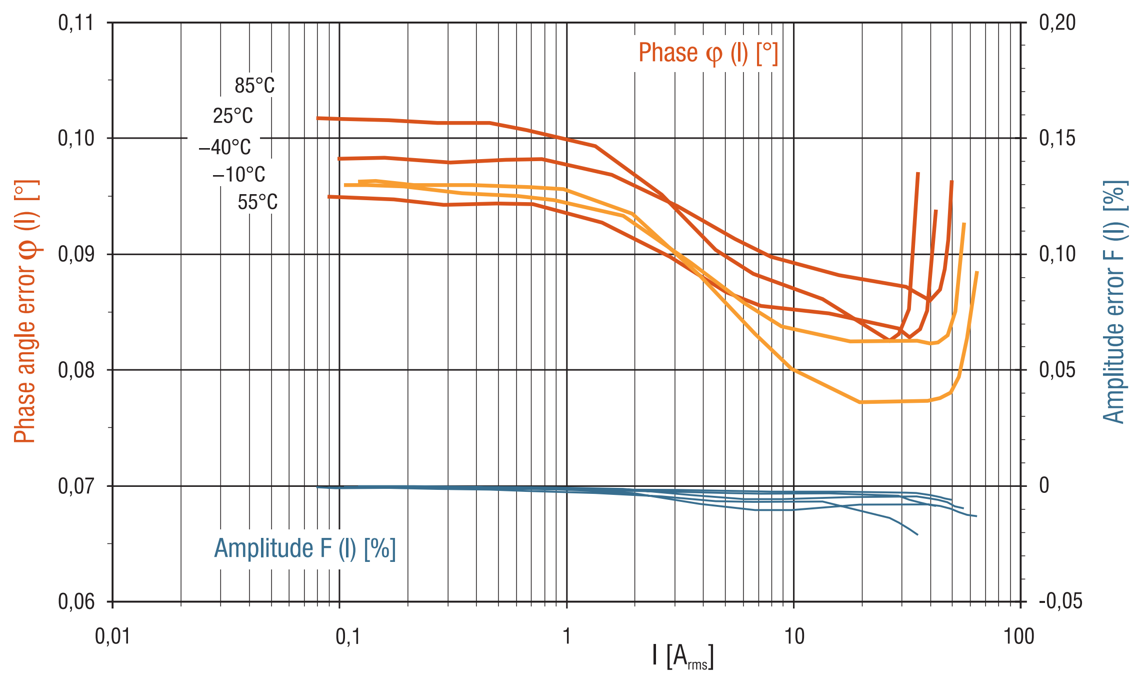


Fig. 25: **200 A, T60404-E4627-X001**

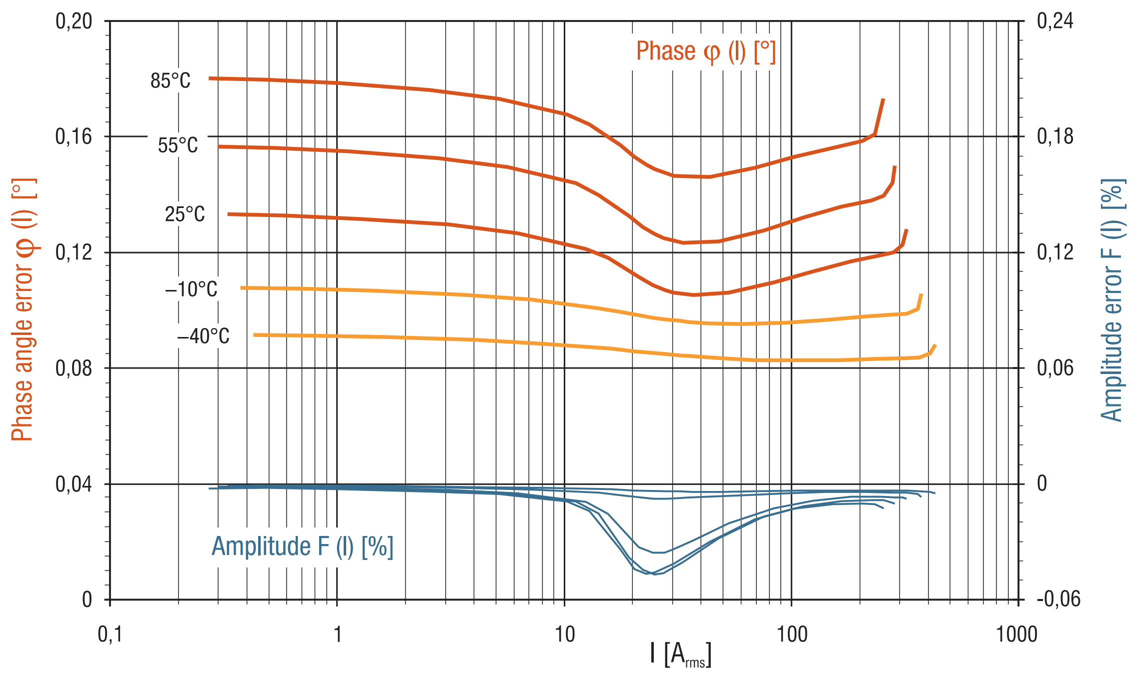
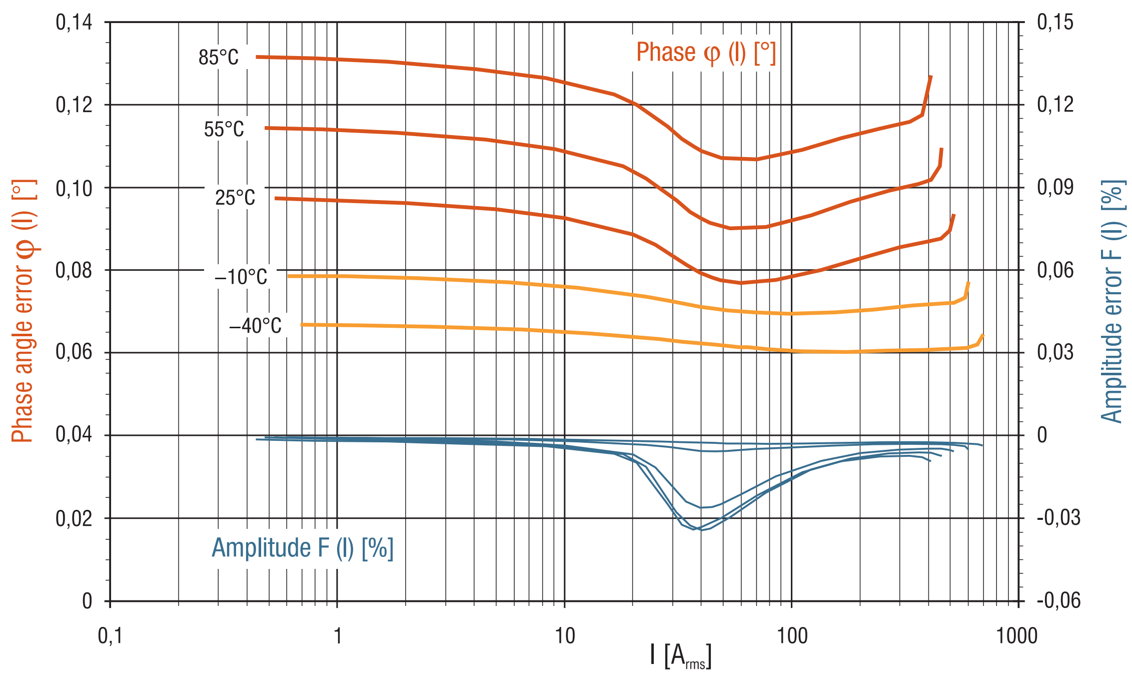
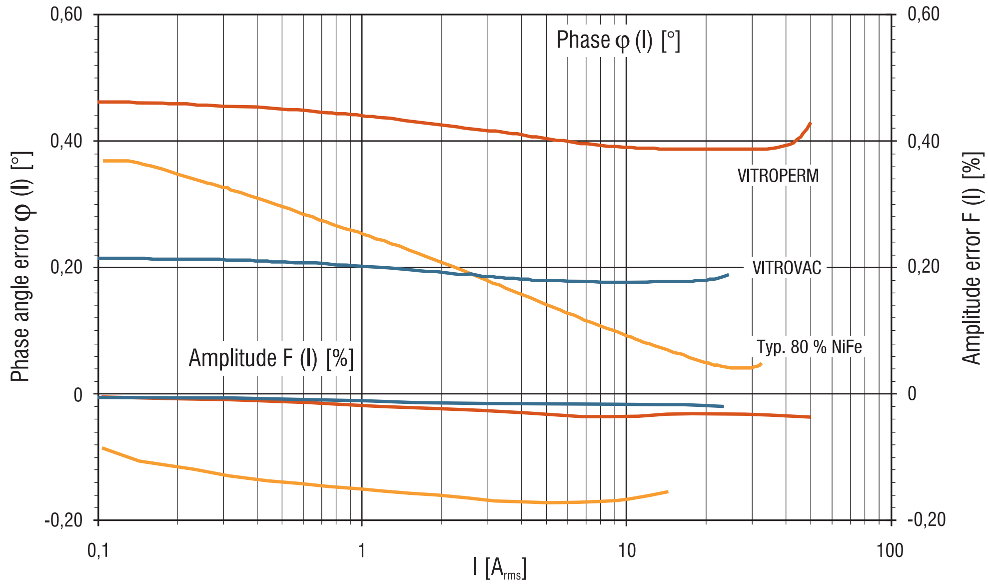


Fig. 26: **320 A, T60404-E4628-X001**



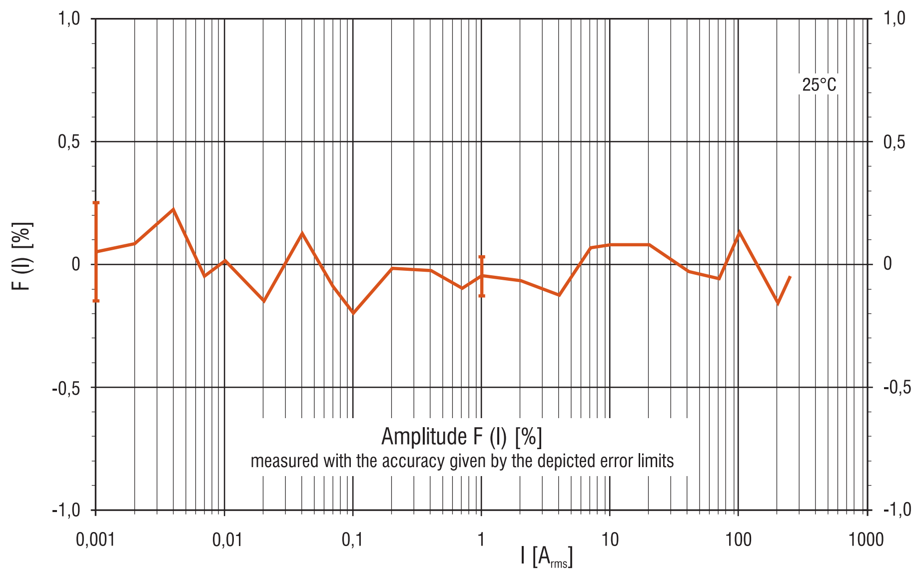
TYPICAL LINEARITY BEHAVIOUR OF DIFFERENT VAC CORE MATERIALS

Classical crystalline 80 % NiFe vs. rapid solified VAC alloys



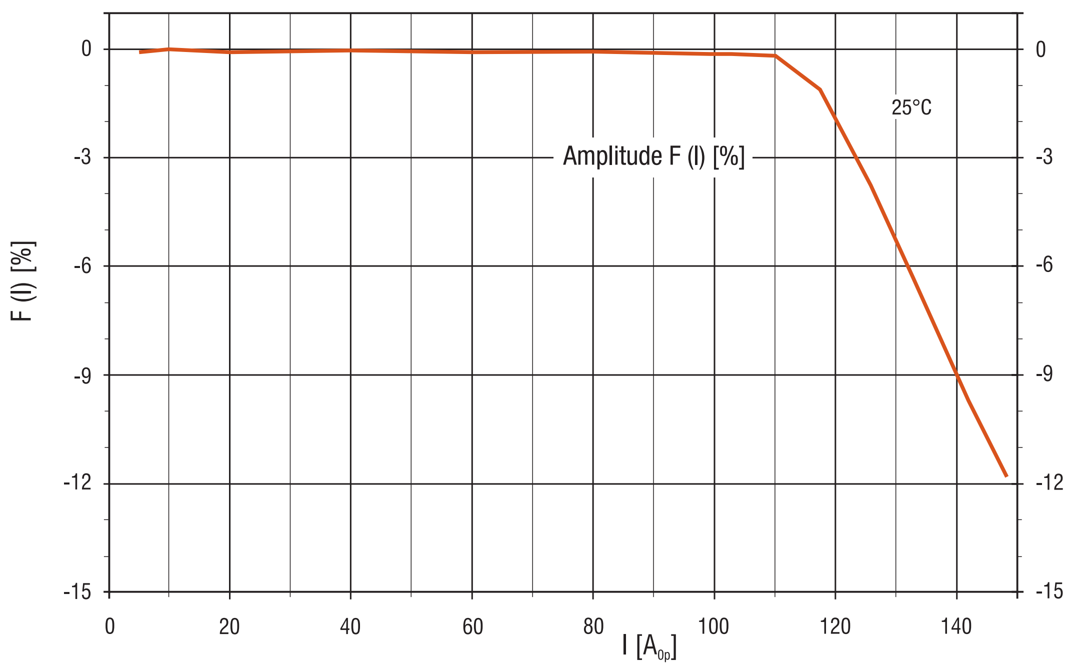
TYPICAL CHARACTERISTIC OF AMPLITUDE ERROR VS. PRIMARY CURRENT

100 A, T60404-E4626-X101/-X501



TYPICAL CHARACTERISTIC OF AMPLITUDE ERROR VS. UNIPOLAR (HALF-WAVE RECTIFIED) PRIMARY CURRENT

100 A, T60404-E4626-X101/-X501



APPENDIX A

RECOMMENDATION: ENSURING THE MEASURING ACCURACY OF ELECTRICITY METERS

1. MEASURING SENSITIVITY FOR LOW LOADS

According to table 6 of IEC 62053-21 the percentage error limits for meters of class 1 (balanced loads) are specified as follows:

Value of current for direct connected meters for meters of class 1	Percentage error limits
$0.05\ I_b <= I <= 0.1\ I_b$	+/-1.5 %
$0.1\ I_b <= I <= I_{max}$	+/-1.0 %

There are no limits specified in the low load range below $0.05\ I_b$ (e.g. for accurate metering of stand-by modus of electronic devices, low energy lamps…).

For specification of meters with I_b=5 A and balanced loads (IEC) we therefore recommend supplementing these requirements by low load conditions as follows:

Current	Value of current for direct connected meters	Percentage error limits for meters of class 1
0.05 A <= I < 0.25 A	$0.01\ I_b <= I <= 0.05\ I_b$	+/-1.5 %
$0.25\ A <= I <= I_{max}$	$0.05\ I_b <= I <= I_{max}$	+/-1.0 %

This condition will ensure fair measuring accuracy in the low load range.

2. DC IN THE AC CURRENT CIRCUIT

According to table 8 of IEC 62053-21 with respect to DC components the limits of variation in percentage error shall be as follows:

Influence quantity	Value of current for direct connected meters	Power Factor	Limits of variation in percentage error for meters of class	
			1	2
DC and even harmonics in the AC current circuit	$\frac{I_{max}}{\sqrt{2}}$	1	3.0	6.0

This condition does not represent realistic loading where very often inductive load condition (power factor <<1) occurs simultaneously with DC-content of the current waveform (e.g. hair-dryers, vacuum cleaners …).

We therefore recommend supplementing the DC tolerance requirements by inductive load conditions as follows:

Influence quantity	Value of current for direct connected meters	Power Factor	Limits of variation in percentage error for meters of class	
			1	2
DC and even harmonics in the AC current circuit	$\frac{I_{max}}{\sqrt{2}}$	1 0.5 inductive	3.0	6.0

This condition will ensure reliable measuring accuracy independently from power factor and DC components.

3. IMMUNITY AGAINST EXTERNAL MAGNETIC FIELDS

According to table 8 of IEC 62053-21 the immunity of meters against external magnetic fields shall be as follows:

Influence quantity	Value of current		Power Factor	Limits of variation in percentage error for meters of class	
	for direct connected meters	for transformer operated meters		1	2
Continuous magnetic induction of external origin	I_b	I_n	1	2.0	3.0
Magnetic induction of external origin 0.5 mT	I_b	I_n	1	2.0	3.0

The conditions specified are adequate for normal environmental conditions.

In recent years requirements concerning much stronger fields have been discussed by metering regulators to also take into account potential tampering with meters. These requirements led to considerable efforts by meter manufacturers, e.g. encapsulation of the meter's susceptible components against strong rare earth magnets using magnetic shielding.

However, it must be realised that not only permanent magnets, but also coils creating AC magnetic fields can potentially be used for tampering and that ultimately any measurement principle including the 'old' Ferraris meter can be manipulated in one way or the other. Of course, counter-measures such as magnetic shielding are also available for each measurement method. In the long run, the competition between factors such as increasing magnet dimensions and increasing shielding efforts cannot be won by any one of the parties involved, but does increase meter costs significantly.

We therefore recommend introducing electronic means to detect tampering attempts and taking corresponding measures inside the meter's electronics and communication system, while retaining the specifications cited above for field immunity requirements.

For example, external magnetic influences of extreme field strength, clearly indicating tampering attempts, could be detected by cost-effective electronic sensors and generate an alarm signal at the front panel. Additionally, the alarm status should be stored within the meter's data memory and, if a data exchange module is installed, communicated via the data interface to the data collection and evaluation site of the energy supplier.

APPENDIX B

DIFFERENCE FROM COMBINED CORE CTS

In recent years CTs based on cores with two parts known as combined cores have appeared on the market. One part of the core is highly permeable while the second one is a low-permeable core for DC tolerance according to IEC 62053 -21, -23.

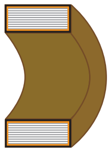
At conditions with power factor cosφ < 1 and appearance of half rectified sinusoidal currents in the electricity grid, errors in measuring power can increase up to 18 %.

The pictures below show the differences between 'Single' and 'Combined' cores.

SINGLE-CORE CT

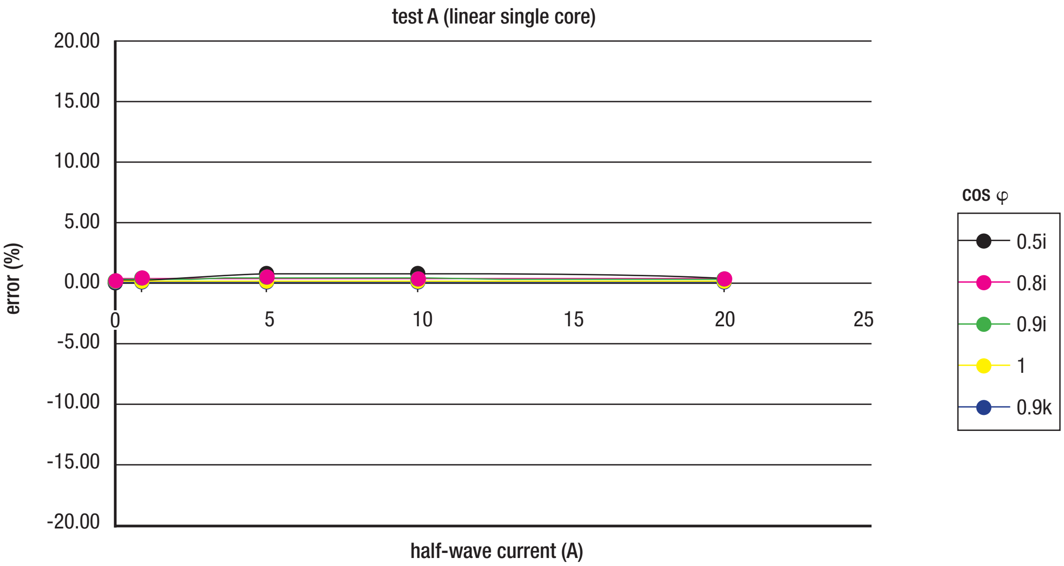
HOMOGENOUS CORE (VAC – TYPE, HIGH LINEARITY):

• best linearity in amplitude and phase



Meter with high-linearity CT measures correctly!

Measurement accuracy: current IEC- test and proposal



• IEC-test cos$\varphi = 1$

fine

• proposal cos$\varphi \neq 1$

Error data between +0.6 % and -0.3 %

Result: Power measurement independently from load and DC components!

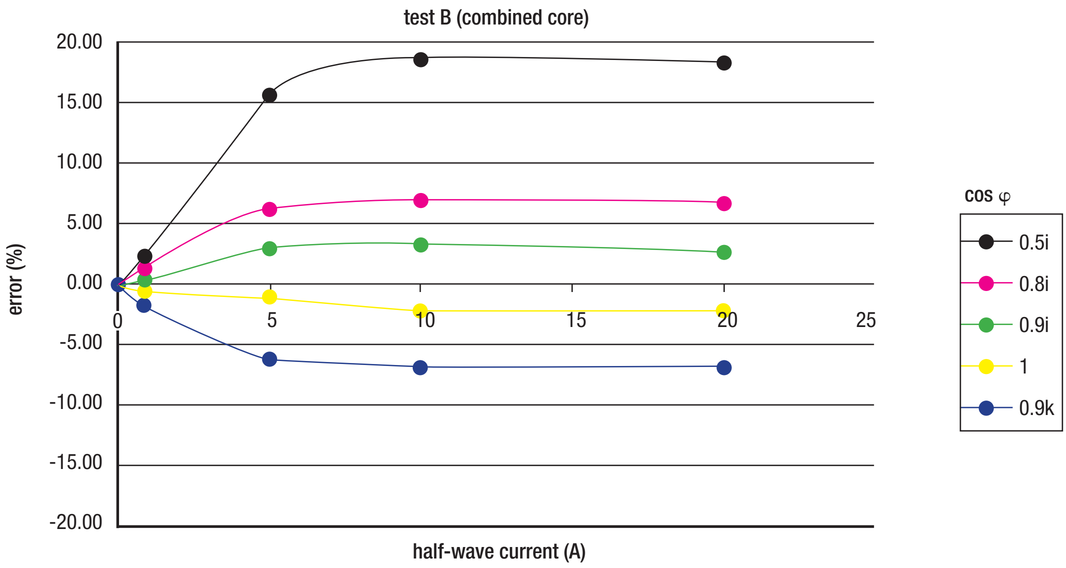
COMBINED CORE CT

COMBINED CORE (2 CORE PARTS):

- one high-permeability core part for AC operation
- one non-linear low permeability core part for operation under DC components

Meter with combined core CT behaves very sensitive.

Measurement accuracy: current IEC-test and proposal



- IEC-test cosφ = 1

satisfactory

- proposal cosφ ≠ 1

Error data between +18 % and -7,5 %

Result: Power measurement depends strongly on load phase and DC components!

VACUUMSCHMELZE GMBH & CO. KG

P.O. BOX 2253
GRÜNER WEG 37
D 63412 HANAU / GERMANY
PHONE +49 6181 38 0
FAX +49 6181 38 2645
INFO@VACUUMSCHMELZE.COM
WWW.VACUUMSCHMELZE.COM

VAC SALES USA LLC

2935 DOLPHIN DRIVE
SUITE 102
ELIZABETHTOWN, KY 42701
PHONE +1270 769 1333
FAX +1270 765 3118
INFO-USA@VACUUMSCHMELZE.COM

VACUUMSCHMELZE
SALES OFFICE SINGAPORE

1 TAMPINES CENTRAL 5, #06-10/11
CPF TAMPINES BUILDING
SINGAPORE 529508
PHONE +65 6391 2600
FAX +65 6391 2601
VACSINGAPORE@VACUUMSCHMELZE.COM

PB-CT EDITION 2012

Published by VACUUMSCHMELZE GmbH & Co. KG, Hanau

ADVANCED MATERIALS – THE KEY TO PROGRESS