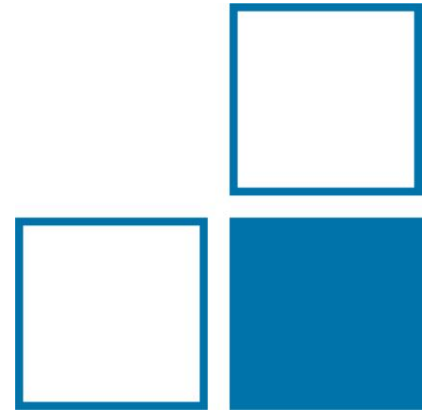
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Ratiometrische Messeinrichtung für Normalspannungswandler

319. PTB-Seminar

Peter Räther, AG 2.31
Enrico Mohns, FB 2.3



Themenschwerpunkte

- Motivation
- Aufbau des Messsystems
- Hybridwandler
- Anwendung
- Zusammenfassung

Motivation (Kalibrierservice)

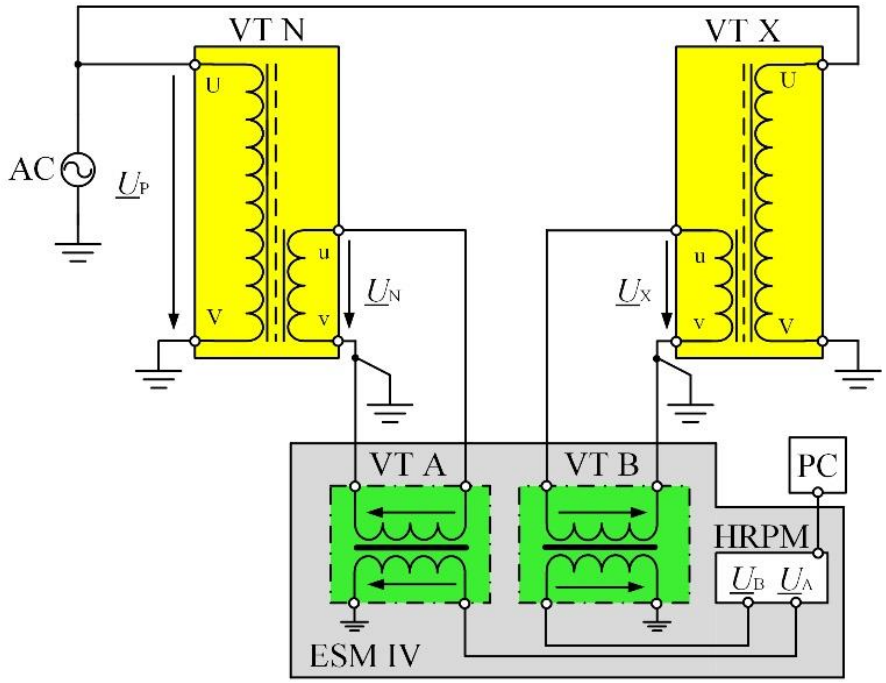
BIPM; CMC PTB (Data copy March 2022)

Quantity	Parameters	Uncertainty	Comments
High AC voltage: voltage transformer ratio error	Voltage : 30 V to 300 kV Frequency : 16.7 Hz, 47 Hz to 63 Hz	[2.0E-6 , 1.0E-4] (dimensionless) (Absolute)	According to IEC 61869 (conventional and non-conventional instrument transformers)

sekundäre Bemessungsspannungen (IEC 61868-3)

Bevorzugte Werte V		Andere (nicht bevorzugte) Werte V
100	110	200
$\frac{100}{\sqrt{3}}$	$\frac{100}{\sqrt{3}}$	$\frac{200}{\sqrt{3}}$
$\frac{100}{3}$	$\frac{100}{3}$	$\frac{200}{3}$

Ratio-based calibration methode for VTs



$$\underline{F_U} = \frac{\underline{U_X}}{\underline{U_P}} = \frac{(1+\varepsilon_u)}{K_n} \cdot e^{j\cdot\delta_u}$$

K_n - Nennübersetzung

Kalibriergrößen:

ε_u - Betragsabweichung

δ_u - Fehlwinkel

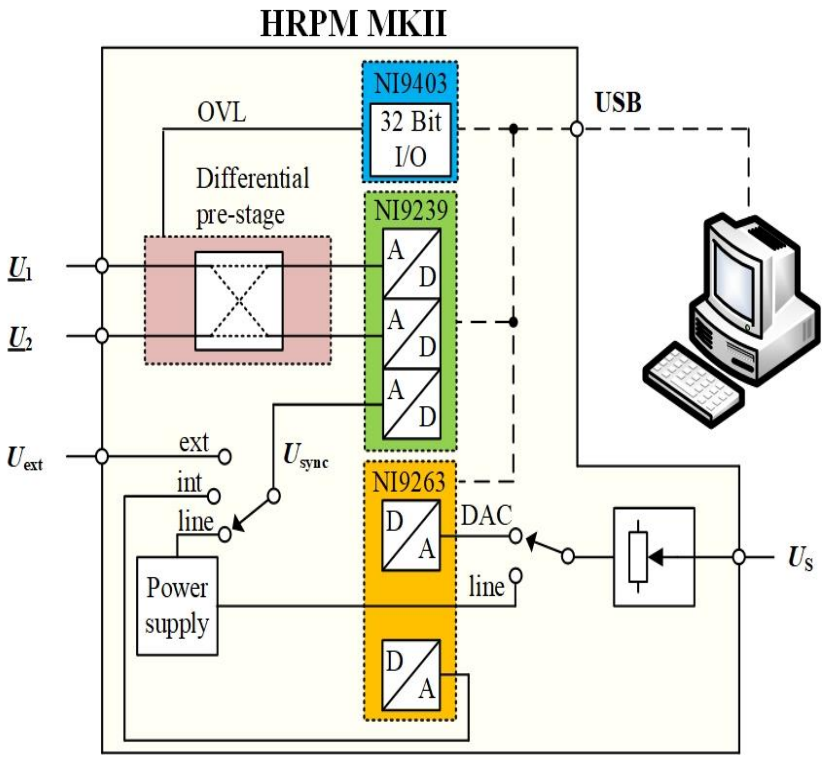
Bestandteile des Messsystems

- (5 Referenzwandler; 30 V -> 300 kV)

- Anpasswandler
  (Ausgangsspannung < 10 V)

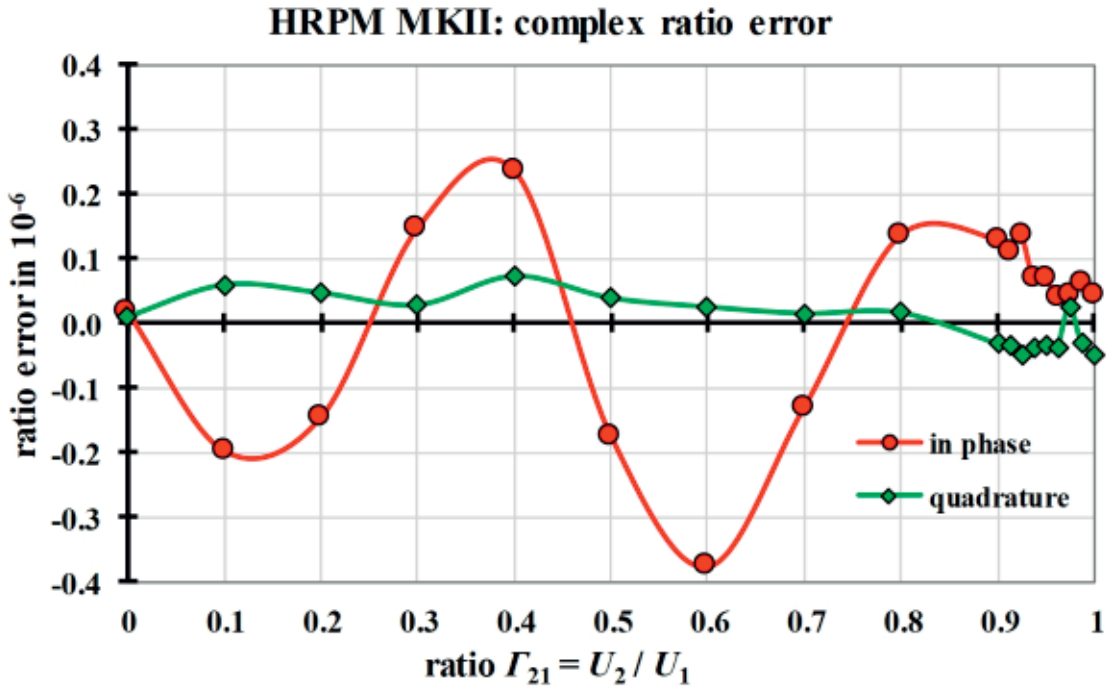
- Komplexes Abtastsystem

2-Channel Sampling System (“HRPM”)

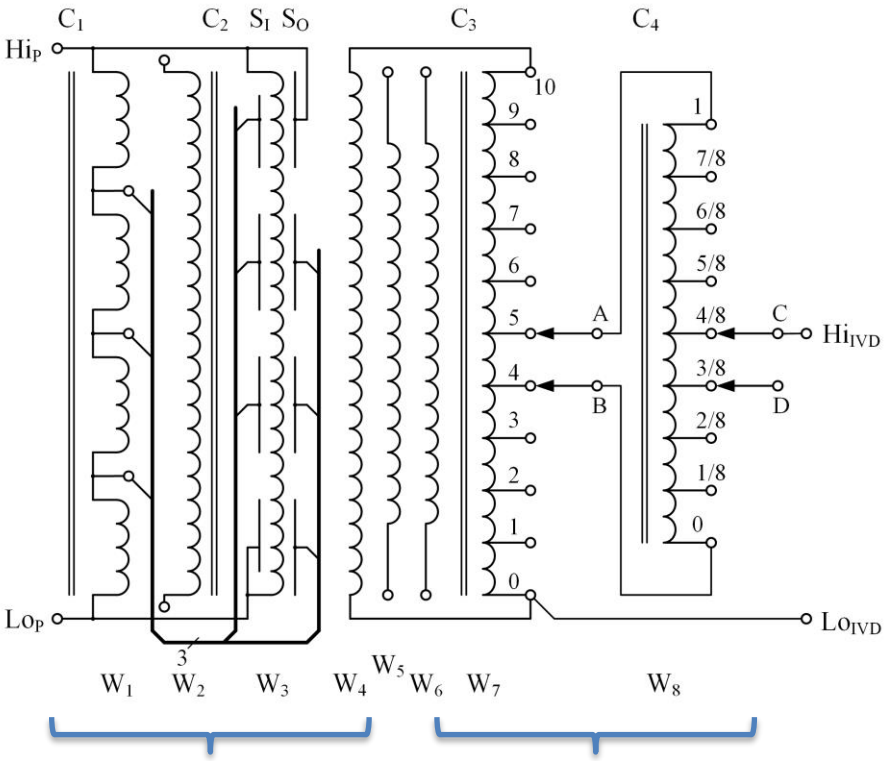


- Voltage range: ±10 V and ±1 V
- Optimized for **complex ratio $\underline{U}_2 / \underline{U}_1$**
- ratio error: < **2×10^{-7}** for **$0.9 \leq (\underline{U}_2 / \underline{U}_1) \leq 1$**

Ergebnisse der Abtastung



Hybrid Voltage Transformer (“ESM IVa”)

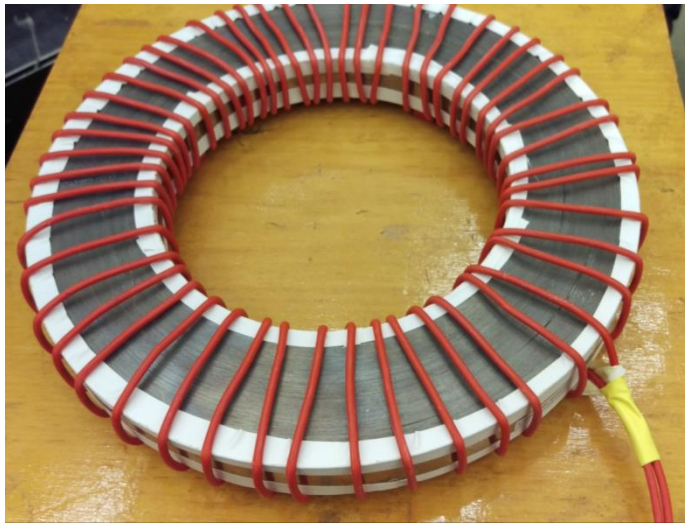


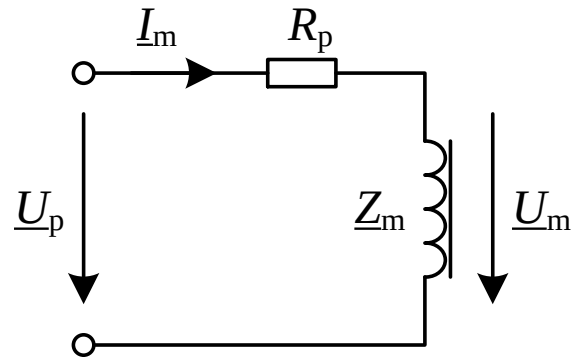
Two-stage VT (K_n = 10) **IVD with 1/80 resolution**

- U_{max} = 320 V / 50 Hz
- D_H = 0.00125 … 0.1
- Divider error: < **1.5×10^{-8}**

Wandler (Einkern Prinzip)

Zunächst 1-Kernwandler





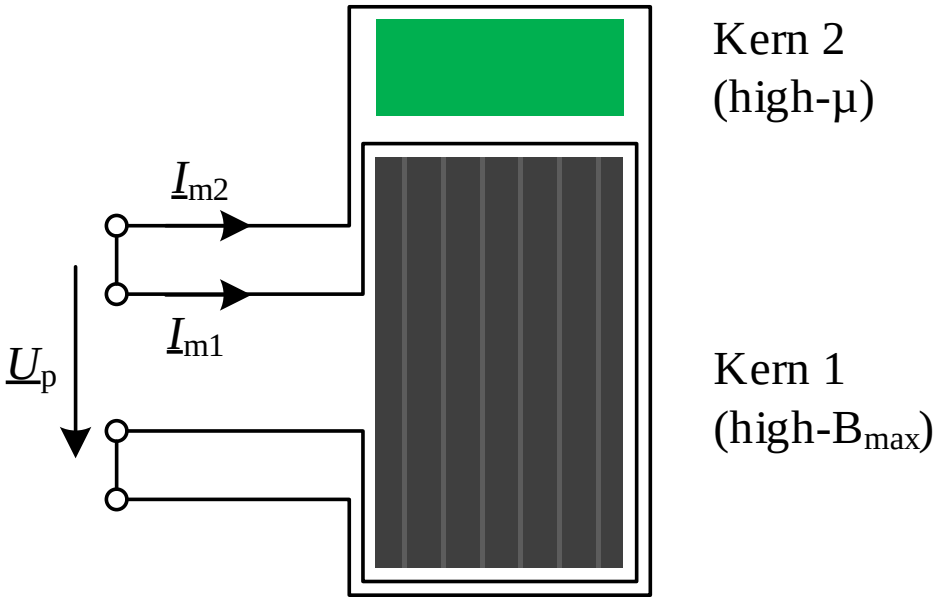
$$\underline{E}_{mag} = -\frac{R_p}{\underline{Z}_m} + \ldots$$

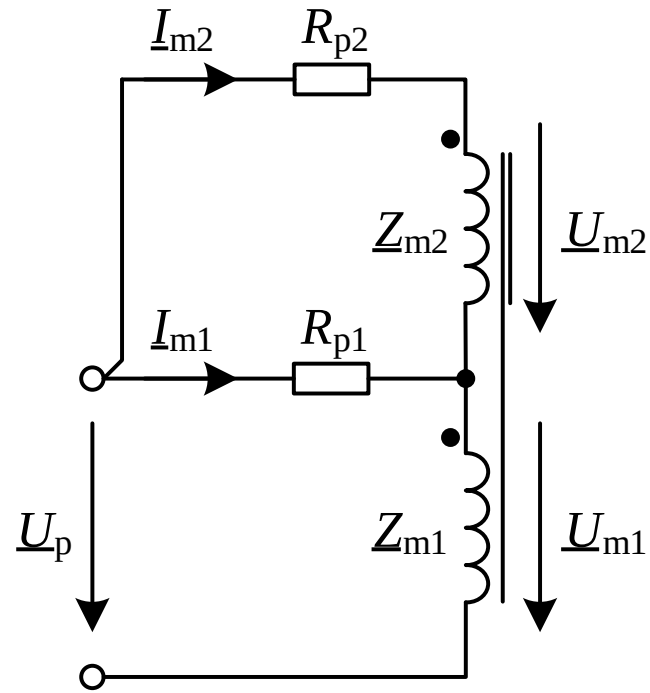
Typ. 10-4 - jedoch f(U)

+ magn. Streuung (Prim→Sek)

+ Wicklungskapazität (Prim)

Wandler (Zweikern Prinzip)





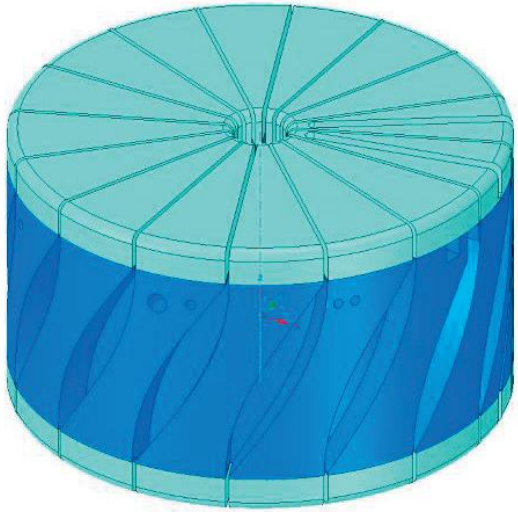
$$\underline{E}_{mag} = -\frac{R_{p1}}{\underline{Z}_{m1}} \cdot \frac{R_{p2}}{\underline{Z}_{m2}} + \ldots$$

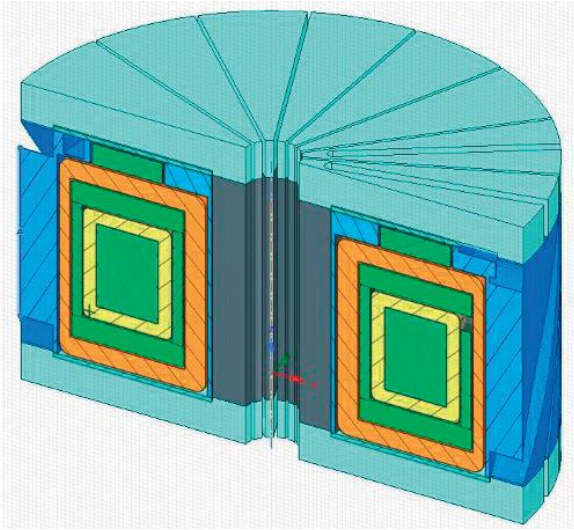
Typ. $10^{-4} \cdot 10^{-3} = 10^{-7}$

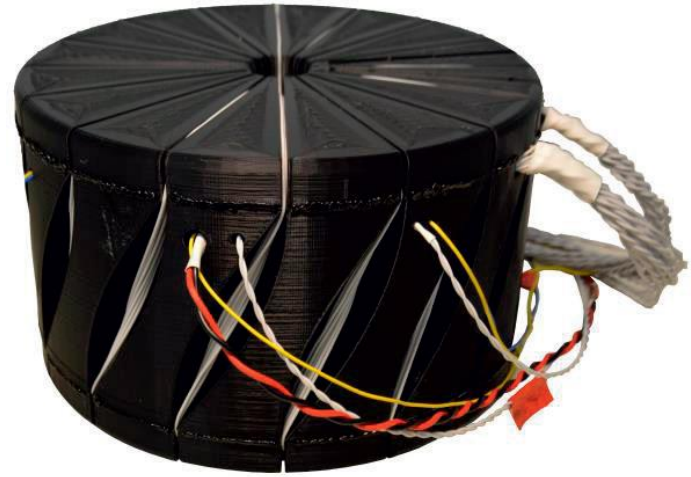
+ magn. Streuung (Prim→Sek) geringer als 1-Kern, da $I_{m,2}$ kleiner

+ Wicklungskapazität (Prim)

Ansicht Hybrid Voltage Transformer







ESM IVa Eigenschaften

- **U_{max}** = 320V / 50Hz
- **Input impedance**: 400kΩ (40V) to 700kΩ (240V)
- **Output impedance**: < 1Ω

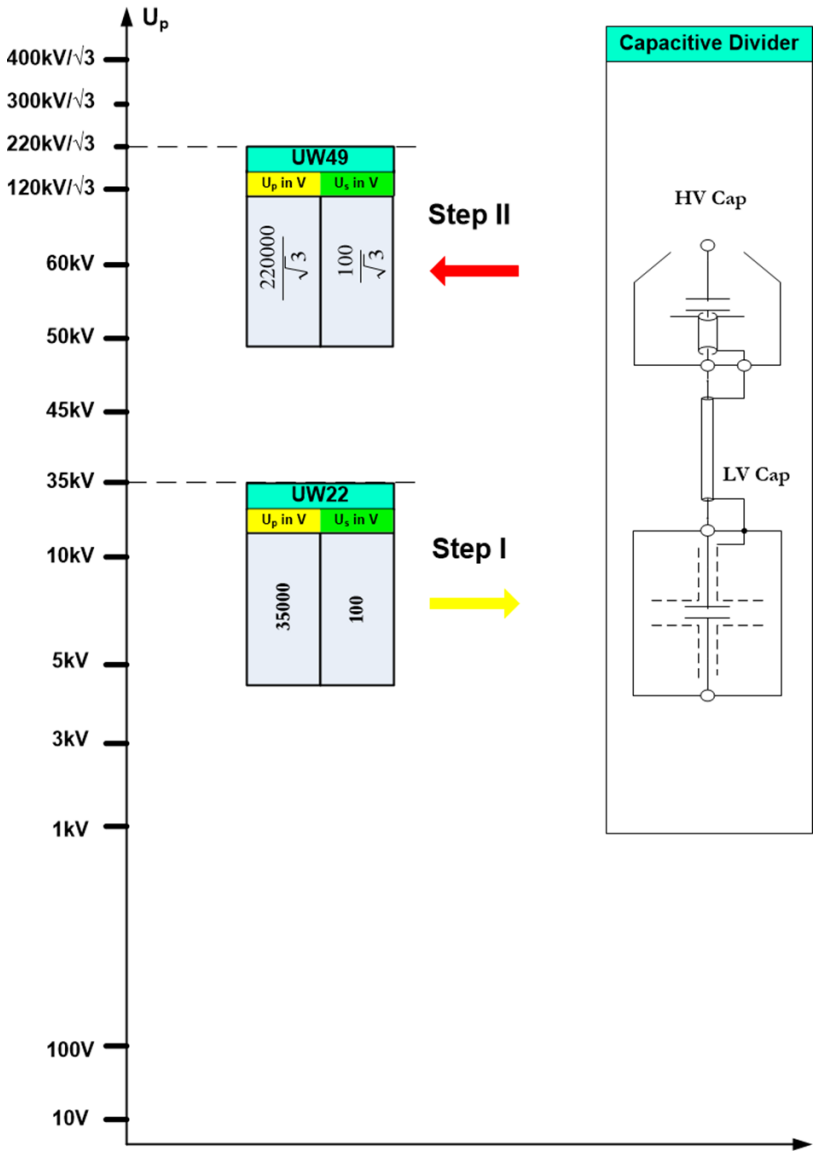
f in Hz	U_{pn} in V	U_p / U_{pn} in %	*Divider* A	*Divider* B	*Output*	ε_u in µV / V	δ_u in µrad
51	100	50	9	8 / 8	T_{out}	-0,4	-0,2
51	100	50			U_{sek}	-0,5	-0,3
		20				-0,3	0,0
		10				-0,4	0,2

Anwendung

PTB hat die Aufgabe zur **Darstellung** und **Weitergabe** der Einheiten (Einheiten und Zeitgesetz)

- Fachbereich Elektrische Energiemesstechnik beinhaltet Spannungswandler -> **Darstellung**
- Dienstleistung **Weitergabe**
  - gesetzlich geregelten Bereich (Prüfstellen)
  - Prüflabore, Kalibrierlabore und Industrie

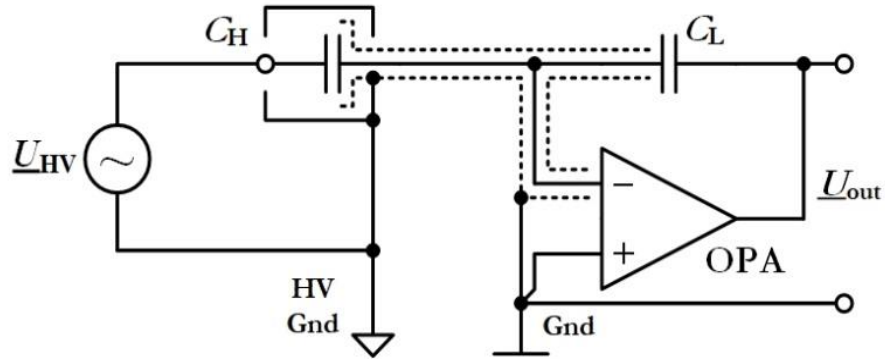
PTB Fundamental step-up method for VT



Calculated expanded uncertainty for UW49 (Step II)

LP	$U(\varepsilon_x)$	$U(\delta_x)$
2,5%... <10%	**13,0 µV / V**	**13,2 µrad**
10%... <20%	**4,0 µV / V**	**4,3 µrad**
≥ 20%	**2,7 µV / V**	**3,3 µrad**

Active low voltage capacitor (principle)



Uncertainty

Model equation (complex)

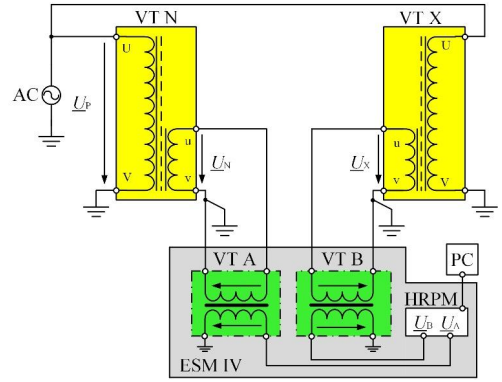
$$\underline{F}_X = \underline{F}_N \cdot \underline{\Gamma}_{21} \cdot \frac{\underline{D}_A}{\underline{D}_B}$$

Uncertainty bridge reading

$$u_r(\underline{E}_B) = \sqrt{u_r(\underline{\Gamma}_{21})^2 + u_r(\underline{D}_A)^2 + u_r(\underline{D}_B)^2}$$

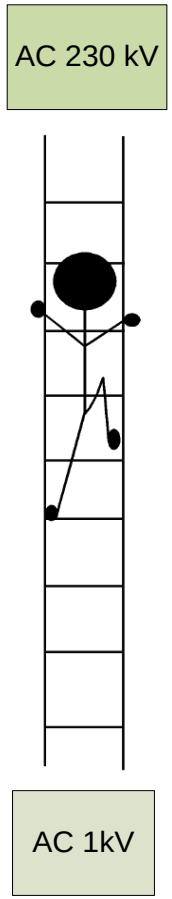
Uncertainty VT X

$$u_r(\underline{F}_X) = \sqrt{u_r(\underline{E}_B)^2 + u_r(\underline{F}_N)^2 + u(\underline{\Delta}_{Load,X})^2}$$



quantity		ratio error ε (k=1)	phase error δ (k=1)
ratio measurement	$\underline{\Gamma}_{21}$	0.10 µV/V	0.10 µrad
divider ratio	$\underline{D}_A$	0.15 µV/V	0.15 µrad
divider ratio	$\underline{D}_B$	0.15 µV/V	0.15 µrad
result bridge	ε_B, δ_B	0.23 µV/V	0.23 µrad
error VT N	ε_N, δ_N	2.0 µV/V	2.0 µrad
burden sensitivity VT X	$\Delta_{Load,X}$	0.25 µV/V	0.25 µrad
result VT X	ε_X, δ_X	2.03 µV/V	2.03 µrad

Zusammenfassung



Erreicht

- Erweiterung der Messsysteme (Differenz- und Ratiometrische Brücke)
- Kalibriersystem für nichtkonventionelle Spannungswandler

aktive EU Projekte

- Digitalwandler
- Kalibriermöglichkeiten für Spannung und - Stromsensoren (50 Hz + Störung)

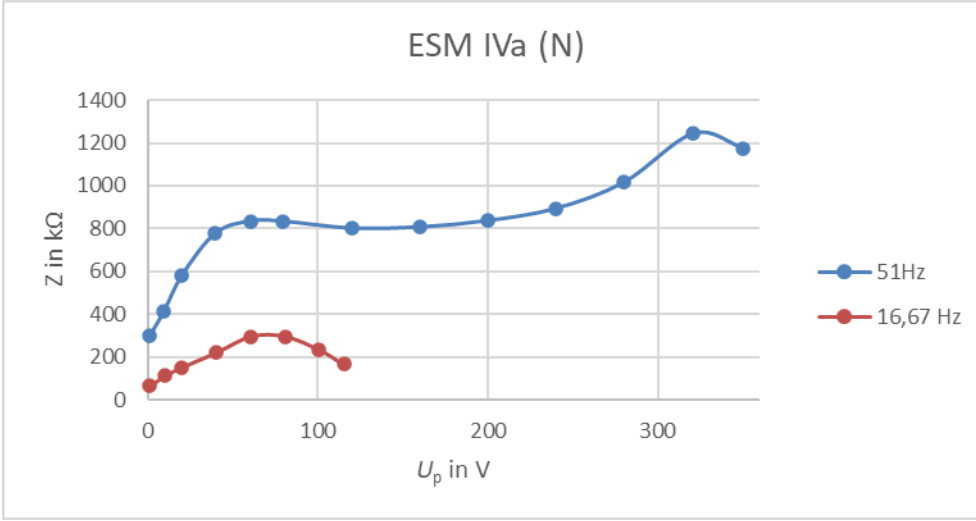
Thanks for your attention !

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Bundesallee 100
38116 Braunschweig

Peter Räther
Telefon: 0531 592-2339
E-Mail: peter.raether@ptb.de
www.ptb.de

2-Channel Sampling System (“HRPM”)

Eingangsimpedanz



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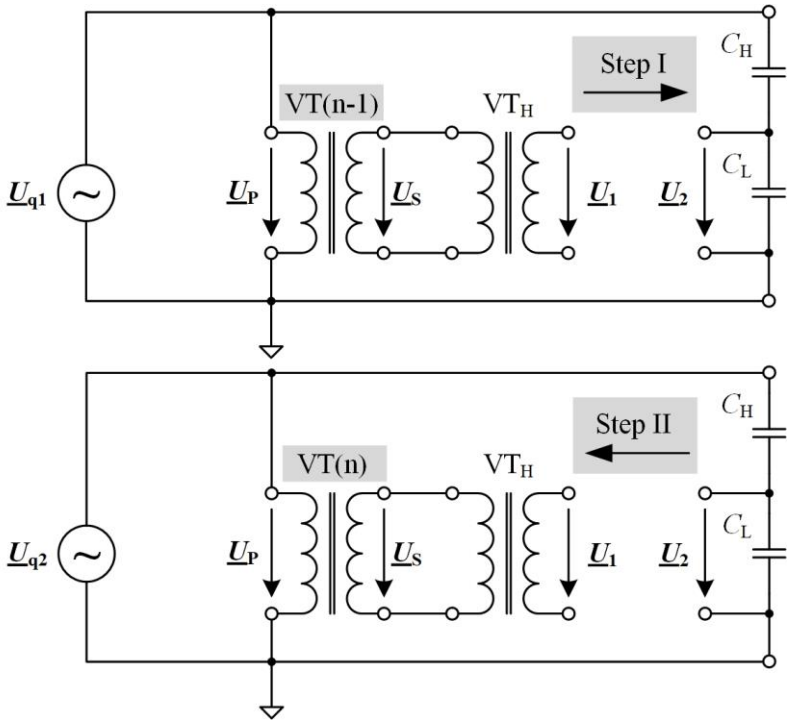


Standard VTs (cl. 0,02)

- 1000V IVD → 6 different standard VTs
- Voltage range of VTs (5 kV - 800 kV / √3)

Required components

- Two-Stage Voltage Transformer with IVD (VT_H) for scaling (e.g. 100 V to 5 V)
- 2-Channel Ratio Sampling Bridge
- Capacitive Voltage Divider (5… 600kV) as transfer divider

HV capacitors available

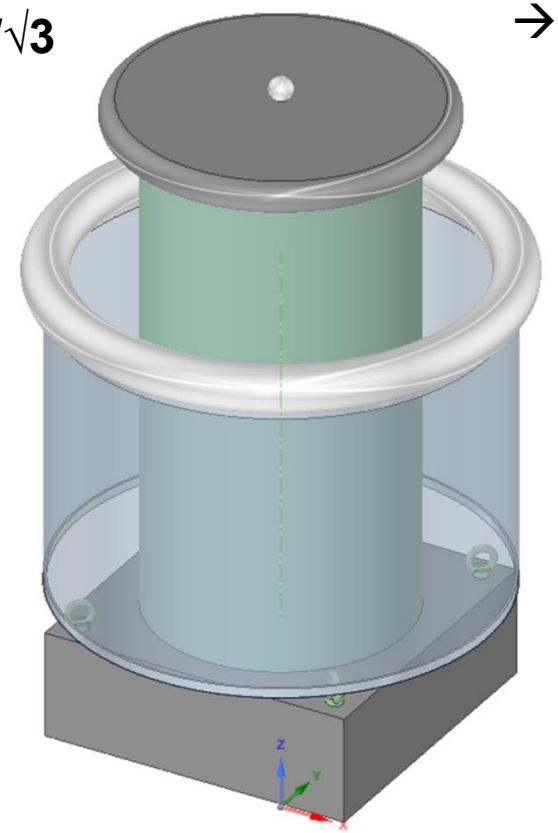
- high-voltage capacitors (C_H): 50 pF … 70 pF

LV capacitors active rebuilding

- low-voltage capacitors (C_L): 100 nF … 7 µF

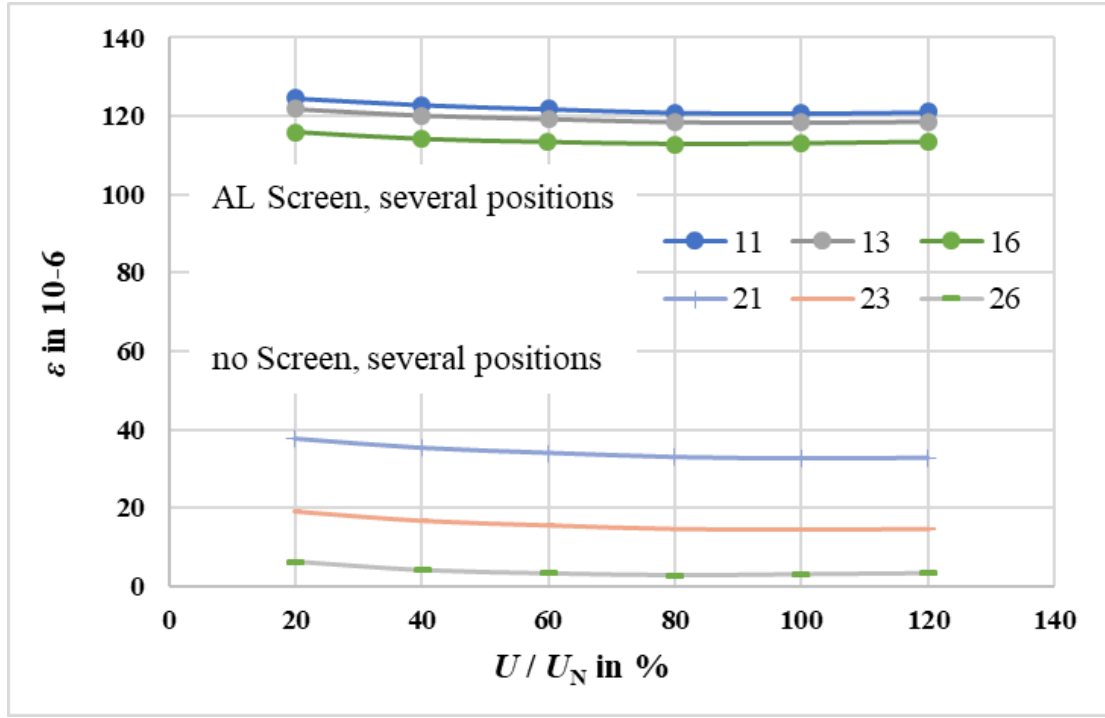
PTB Voltage Transformer improvement

Standard Voltage Transformer for 220kV/√3



→ **Finding:** Ratio and phase error are depending on the position in the cage

→ **Idea:** A screen to fix the electrical and magnetical field will improve the situation and the uncertainties



→ **Result with AL screen:** variation of the ratio error in different positions is reduced by a factor of 4 (uncertainty can be reduced)