Development of 100 kV AC High Voltage Measurement System

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- **Background**
- High Voltage Measurement
- Metrological Traceability
- Design
- Fabrication
- Evaluation
- Conclusion

Background

NIMT has only one national AC high voltage measurement system. This system has been sent periodically for calibration to make an international traceability.

- The systematic verification of AC high voltage measurement system cannot be performed.

- The calibration service for customers has been delayed during the external calibration period.

➡ Additional 100 kV AC high voltage measurement system

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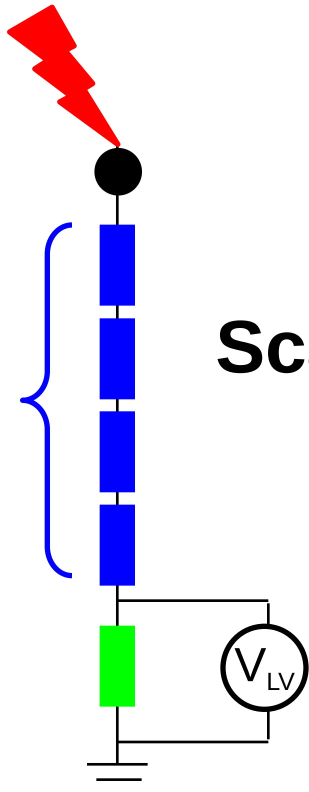
High Voltage Measurement

High Voltage (V_{HV})

HV-side capacitors (C_{HV})

LV-side capacitor (C_{LV})



$$V_{LV}/V_{HV} = C_{HV}/(C_{LV} + C_{HV})$$

$$\text{Scale Factor} = (C_{LV} + C_{HV})/C_{HV}$$

$$= 1 + (C_{LV}/C_{HV})$$

<u>Measuring System (MS)</u>

is used to perform high voltage measurement. It consists of

(1) a converting device

(2) a transmission system and

(3) a measuring instrument

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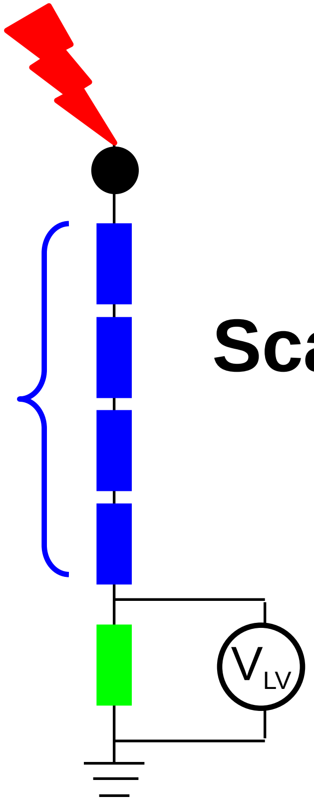
Metrological Traceability (at low voltage)

High Voltage (V_{HV})



HV-side capacitors (C_{HV})

LV-side capacitor (C_{LV})

$$V_{LV}/V_{HV} = C_{HV}/(C_{LV} + C_{HV})$$

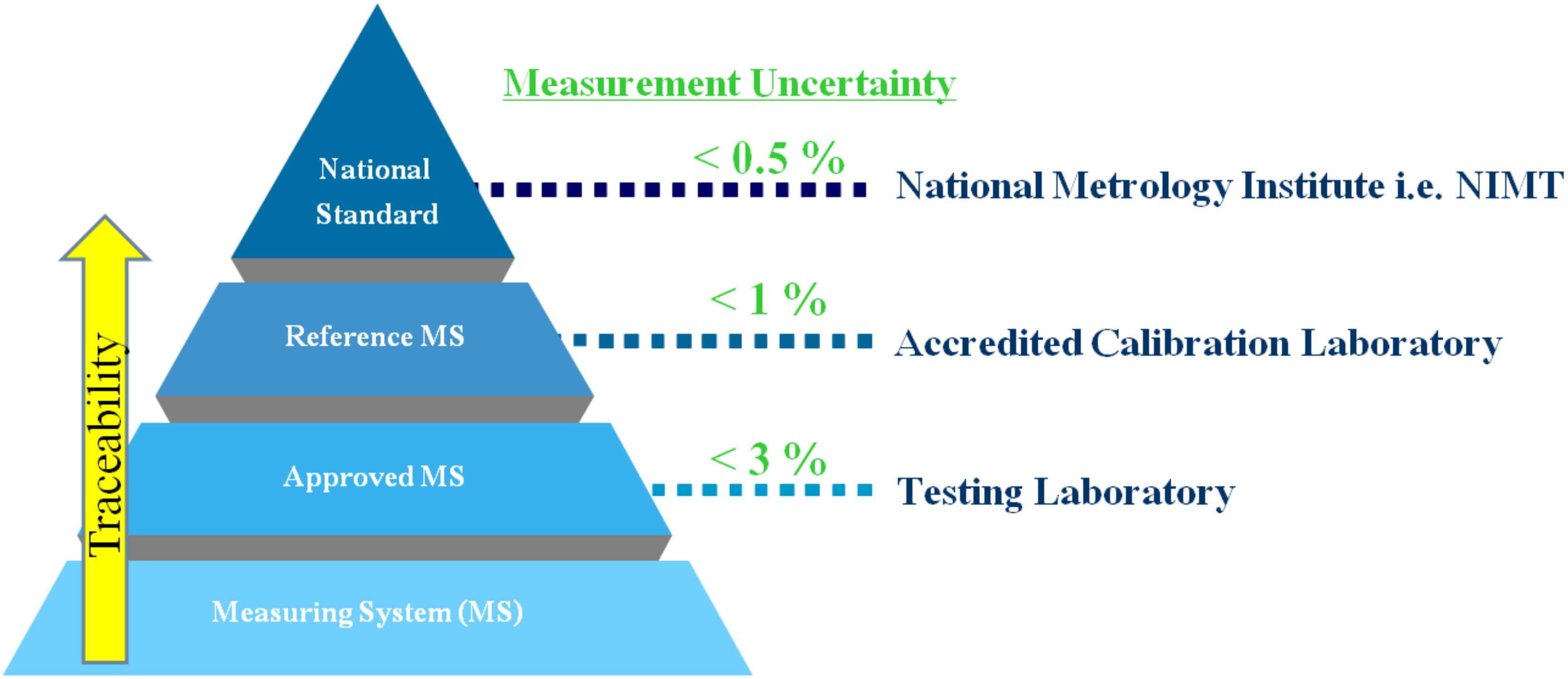
$$\text{Scale Factor} = (C_{LV} + C_{HV})/C_{HV}$$

$$= 1 + (C_{LV}/C_{HV})$$

*without effect of a measuring cable, DVM

➡ Low voltage measurement (Capacitor, DVM)

Metrological Traceability (at high voltage)



IEC 60060-2 : 2010

Due to Voltage Dependence of capacitors, Stray capacitance etc.

- **Inter-comparison**
- **Calibration (Comparison Measurement)**

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Design

(1) Rated Voltage = 100 kV

► National Standard, and UUCs

(2) Type = Capacitive Voltage Divider

► Practical application for AC High Voltage measurement

(3) Construction = Serial-connected Capacitor design

► Simplicity, and Cost

(4) HV-side capacitor = total 400 pF

► Effect of Stray Capacitance

(5) Nominal Scale Factor = 1000 :1

► Dynamic Range of voltage to be measured

(6) Digital multi-meter = 6 ½ digit multi-meter

► Measurement uncertainty less than 0.5%

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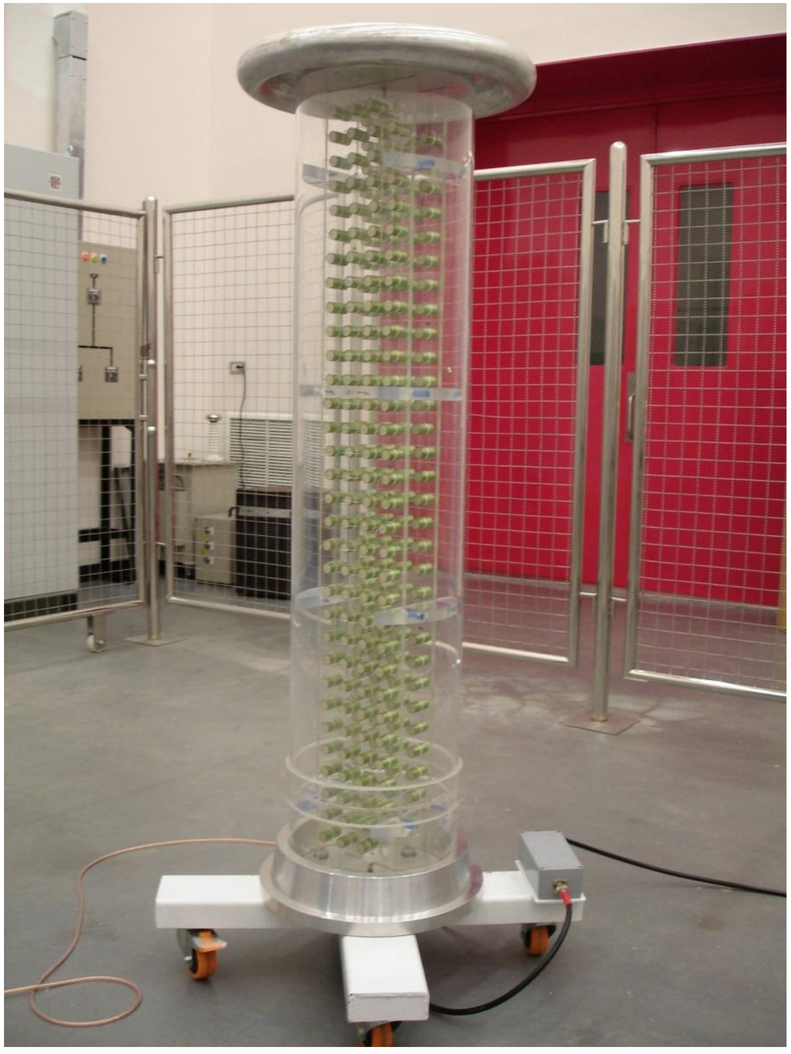
Fabrication (Low Voltage – Side)

► 4 of 0.1 pF are parallel-connected (Total = 0.4 μF)

► Spark gap for protection against breakdown

Fabrication (High Voltage – Side)



► 250 of 0.1 pF are serial-connected (Total = 400 pF)

► VISHAY MKP 1845 : 0.1 pF (700 Vac)

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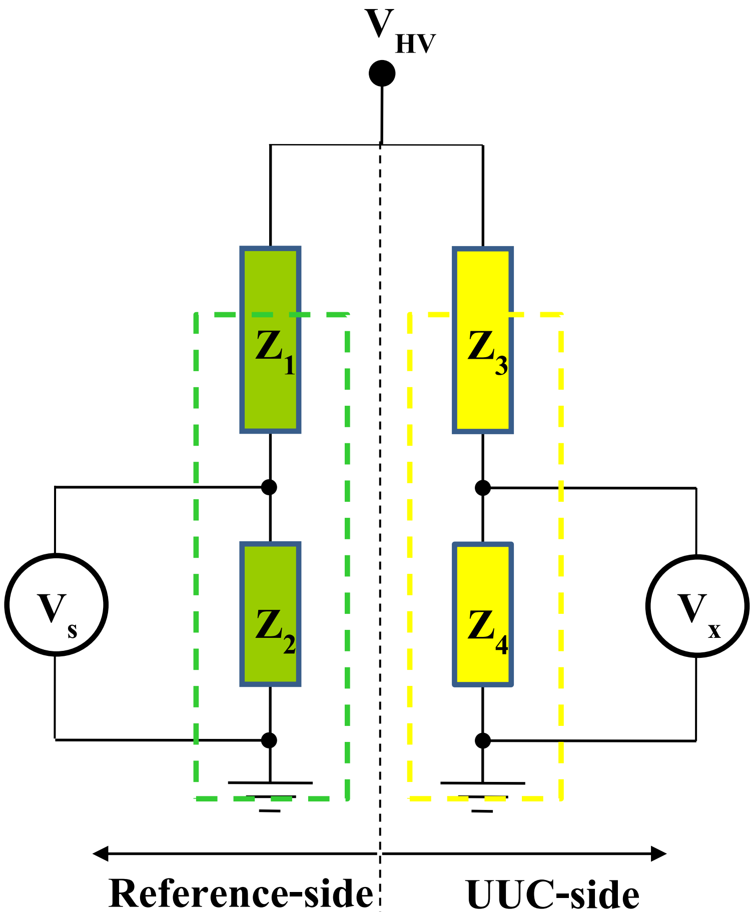
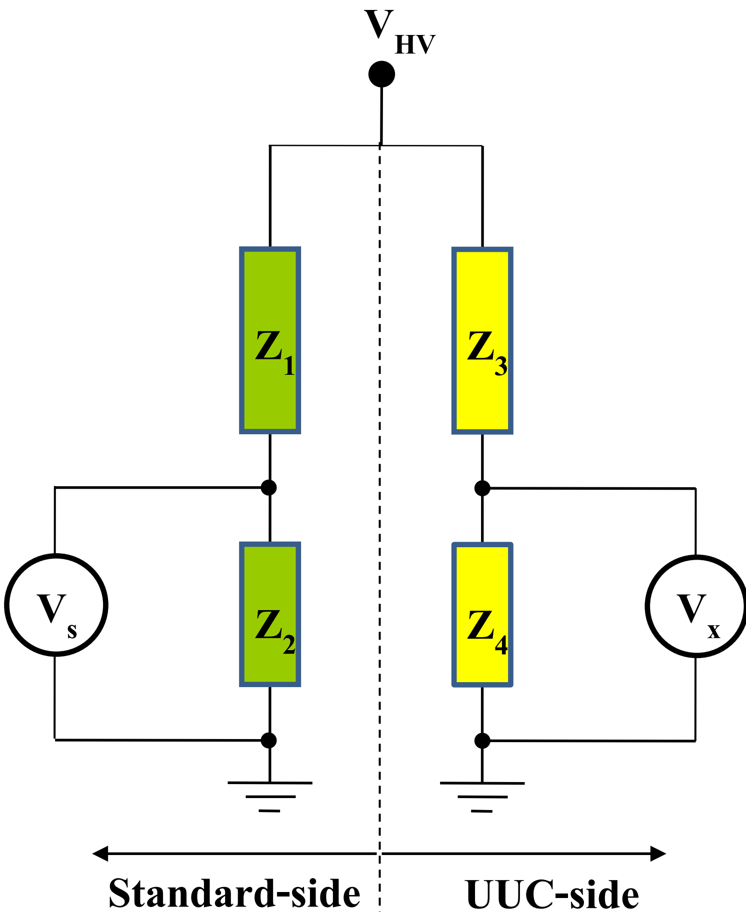
Comparison measurement (Calibration)



High voltage is applied to both, the reference measuring system and the unit under calibration (UUC), while the output of both measuring system are simultaneously measured and compared to scale factor of the UUC.

$$\text{Scale Factor}_{\text{UUC}} = \text{Scale Factor}_{\text{Standard}} \times (V_s/V_x)$$

Scale Factor



Applied Voltage (kV)	Scale Factor
10	1018.0
20	1018.1
30	1018.2
40	1018.2
50	1018.3
60	1018.1
70	1018.1
80	1018.0
90	1018.2
100	1018.0
	1018.1

1010 (Calculated value)

Linearity

Applied Voltage (kV)	Scale Factor
10	1018.0
20	1018.1
30	1018.2
40	1018.2
50	1018.3
60	1018.1
70	1018.1
80	1018.0
90	1018.2
100	1018.0
average	1018.1

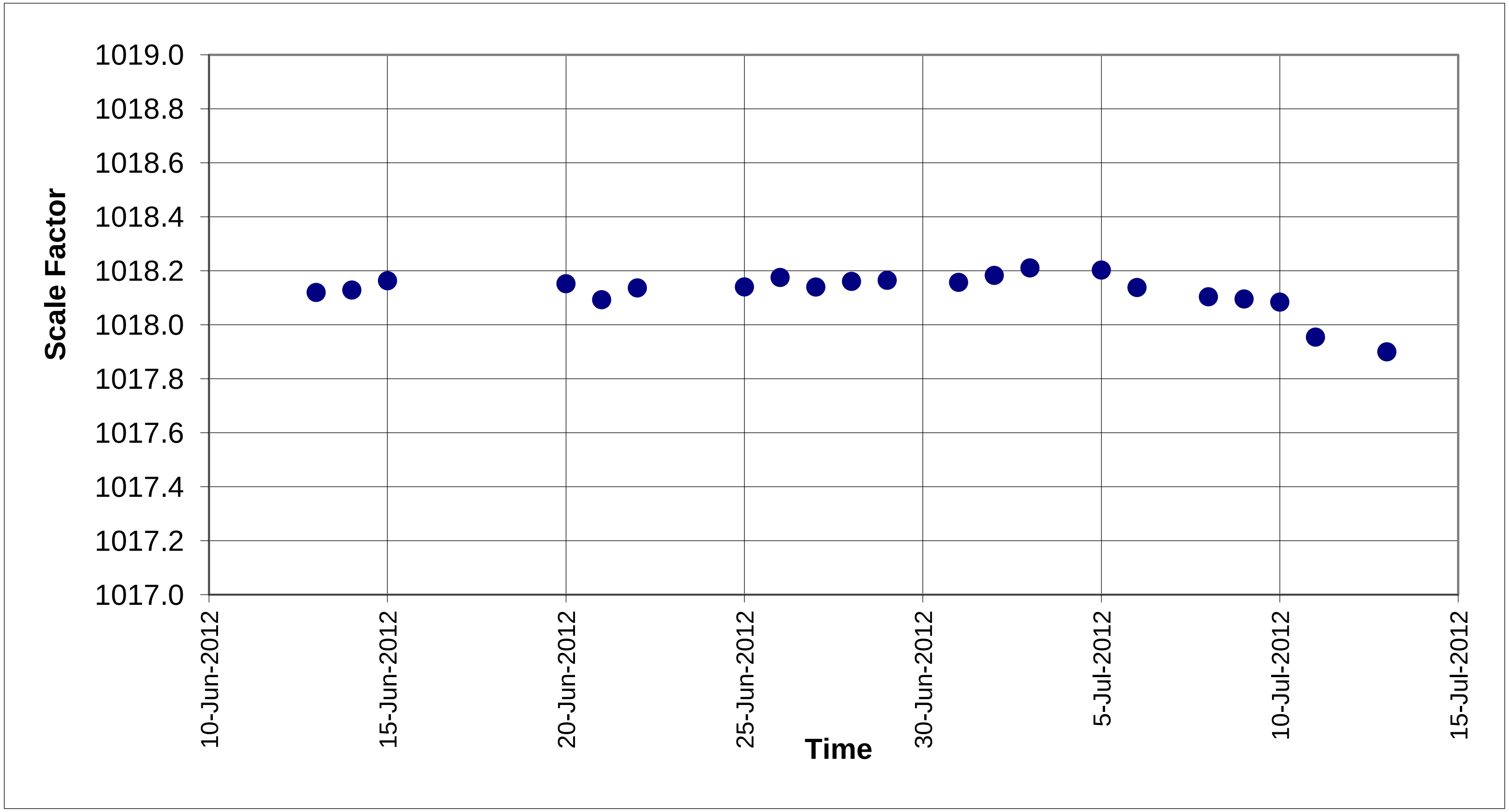
Standard Deviation/Average

= 0.011 %

Stability

► Short-term stability (15 minutes) = 0.02 %

► Long-term stability (1-month) = 0.03 %



Temperature Dependence

Temperature Coefficient of Scale Factor ($\alpha_{Scale\ Factor}$) can be calculated from

$$\alpha_{Scale\ Factor} = \alpha_{LV} - \alpha_{HV}$$

where

Temperature Coefficient of low voltage – side capacitors (α_{LV}), and

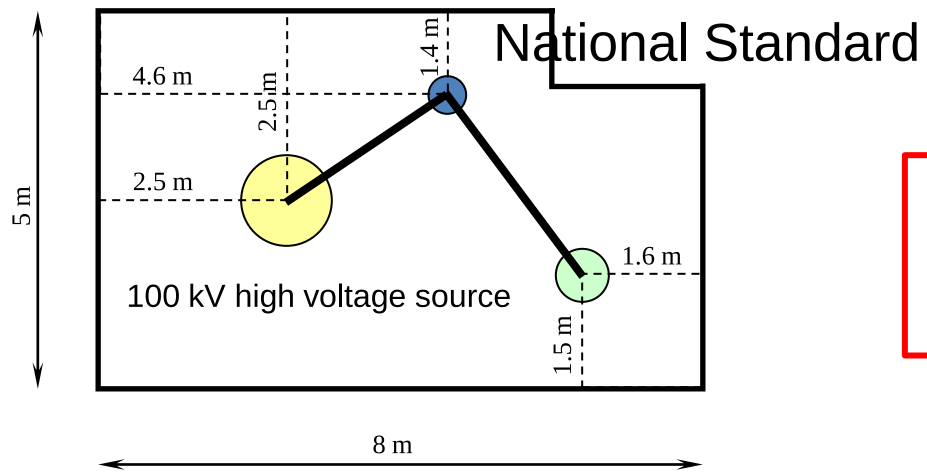
Temperature Coefficient of low voltage – side capacitors (α_{HV})

(246 ppm/^{o}C and 235 ppm/^{o}C respectively)

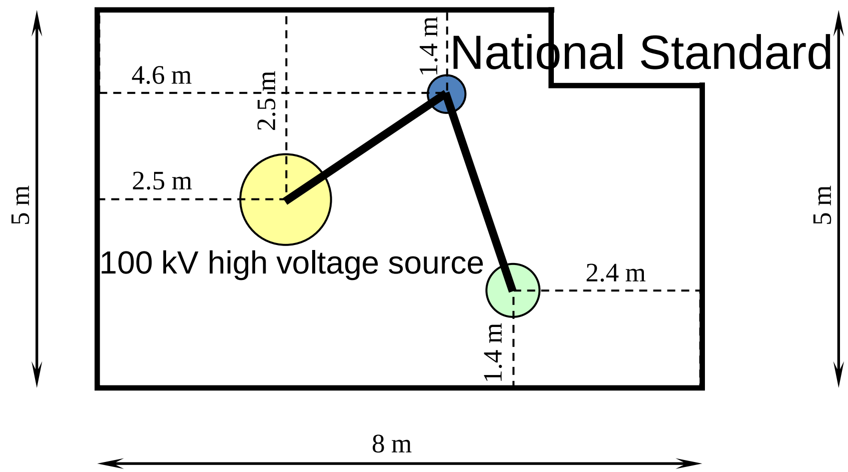
Hence,

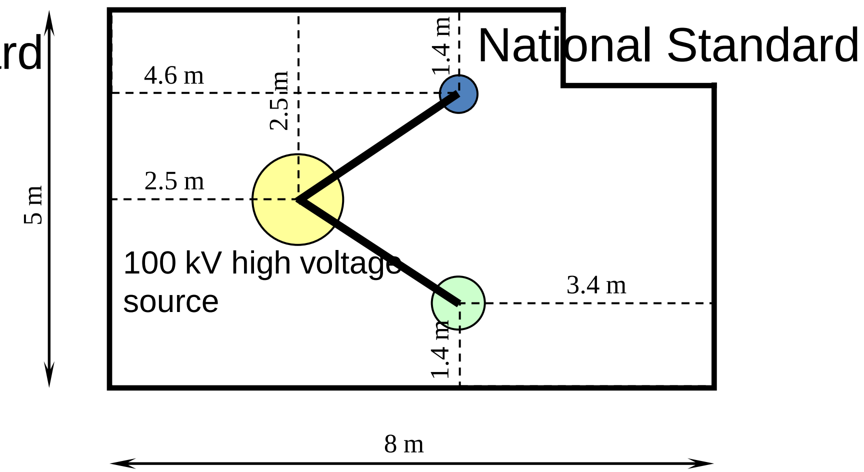
Temperature Coefficient of Scale Factor = 11 ppm/^{o}C

Proximity Effect



Max – Min = 0.5
= 0.05 %





Uncertainty Budget

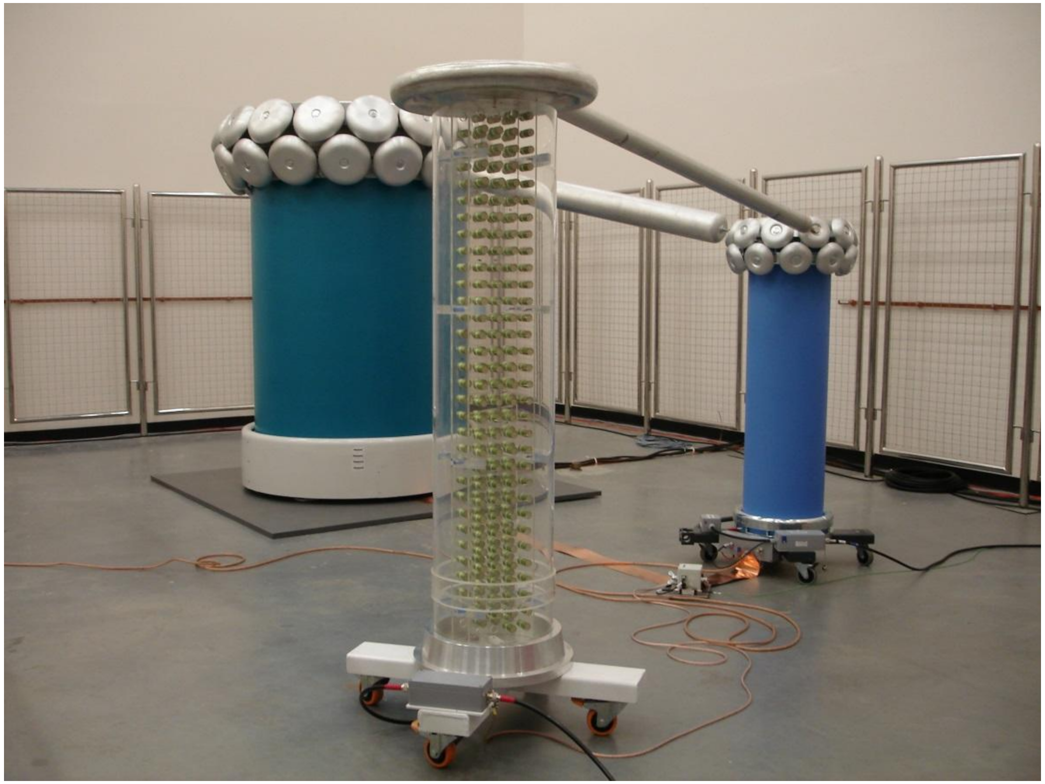
Source of Uncertainty (k = 1)	%
Uncertainty from Standard	0.150
Uncertainty from Long-term stability of Standard	0.020
Uncertainty from Temperature of Standard	0.001
Uncertainty from Linearity of UUC	0.011
Uncertainty from Short-term stability of UUC	0.012
Uncertainty from Resolution of UUC	0.001
Uncertainty from Proximity Effect of UUC	0.029
Uncertainty from Repeatability of UUC	0.010
Expanded Uncertainty (k = 2)	0.32

Conclusion

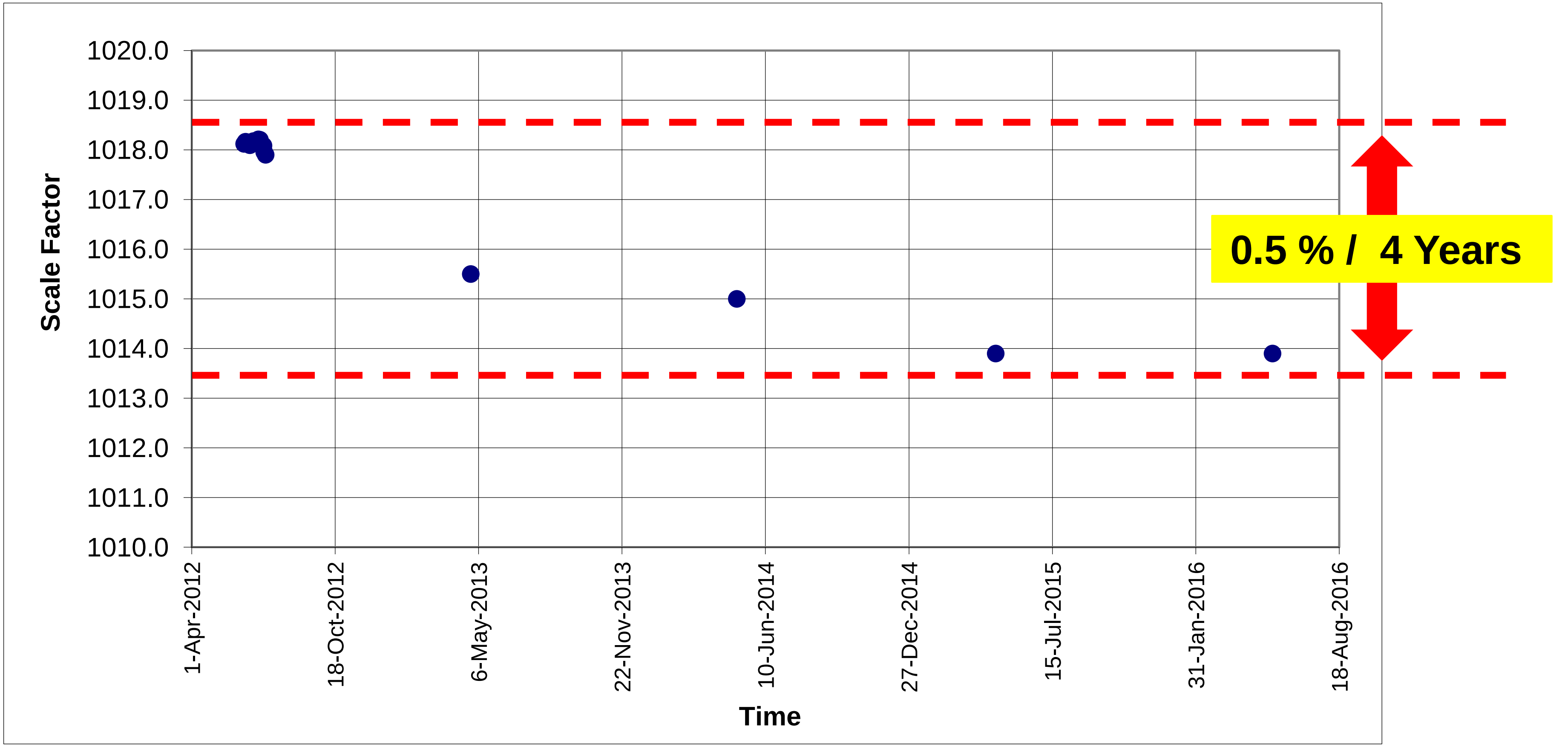
The 100 kV AC high voltage measurement system consists of a capacitive voltage divider with a 6 ½ digit multi-meter. 250 capacitor are serial-connected to form a high voltage arm of 400 pF. The low voltage arm consists of 4 of 0.1 pF connected in parallel. The calculated scale factor is 1010.

The fabricated measurement system was characterized by a comparison measurement. The scale factor is 1018, which agrees well with the calculated value. The measurement system was evaluated according to IEC 60060-2:2010 standard. The expanded uncertainty of 0.32 % was obtained.

Thank you for your attention



Stability


1020.0
1019.0
1018.0
1017.0
1016.0
1015.0
1014.0
1013.0
1012.0
1011.0
1010.0
Scale Factor
1-Apr-2012
18-Oct-2012
6-May-2013
22-Nov-2013
10-Jun-2014
27-Dec-2014
15-Jul-2015
31-Jan-2016
18-Aug-2016
Time
0.5 % / 4 Years