Paris Session 2022

Requirements on the design and testing of RC voltage dividers for application in HVDC GIS

SC D1 – Materials and emerging test techniques

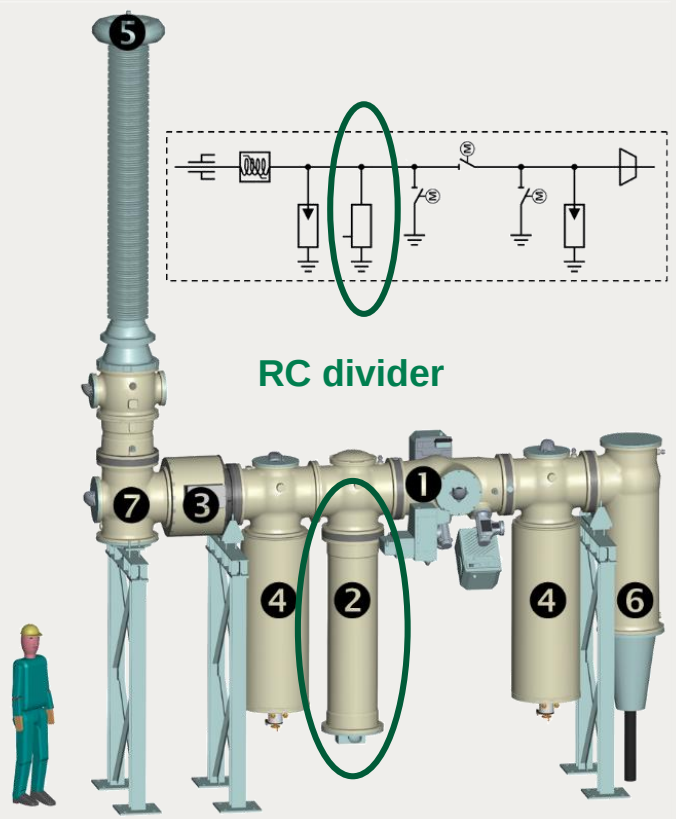
PS 1 – Testing, monitoring and diagnostics

Question 1.03 – Gas-insulated voltage dividers for HVDC application

Maria KOSSE, Dr.-Ing. (Germany), Erik SPERLNG, Dr.-Ing. (Switzerland)

Requirements on the design and testing of RC voltage dividers for application in HVDC GIS

- Worldwide development activities on HVDC GIS with products available up to U_r = ±550 kV DC
- Standardization for HVDC GIS prepared with CIGRE TB 842
  - Additional thermo-electric tests to consider DC specifics in terms of electric field distribution of insulators, influenced by the accumulation of electrical charge carriers and the inhomogeneous temperature distribution
  - High importance: composite voltage testing (DC + impulse) after long DC pre-stress (reaching DC steady-state) with maximum temperature gradient
- Standardization for low-power instrument transformers within IEC 61869 series



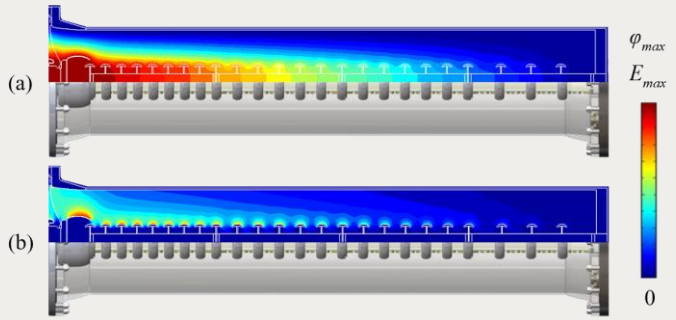
Analysis of existing CIGRE recommendations and IEC standards

- Requirements for AC and DC withstand voltage tests are comparable
- Requirements for LI voltage tests are the same. SI voltage test acc. IEC 61869-15 only with positive voltage, while acc. CIGRE TB 842 for both polarities
- Composite voltage tests not existing acc. IEC 61869-15. According to TB 842, composite voltage tests ensure appropriate insulation performance under transient overvoltages during operation

Equipment $U_r = U_m = \pm 550$ kV		DC GIS	RC divider
Standard		CIGRE TB 842	IEC 61869-15
DC withstand voltage test	U_{DC} / kV	$1.5 \times U_r = \pm 825$ kV	
	t_{DC} / min	1	60
AC withstand voltage test	u_{AC} / kV	$1.5 \times U_r/\sqrt{2} = 583$ kV	
	t_{AC} / min	1	
Impulse voltage test (not mandatory for DC GIS)	$\hat{U}_{LI}$ / kV	±1550	
	$\hat{U}_{SI}$ / kV	±1175	+1175
	# impulse	15 per polarity	
	I_n / A	0	0
Superimposed impulse voltage test (“Uncharged” di-electric interfaces)	U_{DC} / kV	±550	Not existing
	t_{DC} / h	2	
	$\hat{U}_{LI}$ / kV	±1550	
	$\hat{U}_{SI}$ / kV	±1175	
	# impulse	15 per quadrant	
	I_n / A	0	
Insulation system test (Superimposed im-pulse voltage test with “charged” di-electric interfaces)	U_{DC} / kV	±550	Not existing
	t_{DC} / h	$> t_{90} = 120$	
	$\hat{U}_{LI}$ / kV	±1550	
	$\hat{U}_{SI}$ / kV	±1175	
	# impulse	3 per quadrant	
	I_n / A	5000	

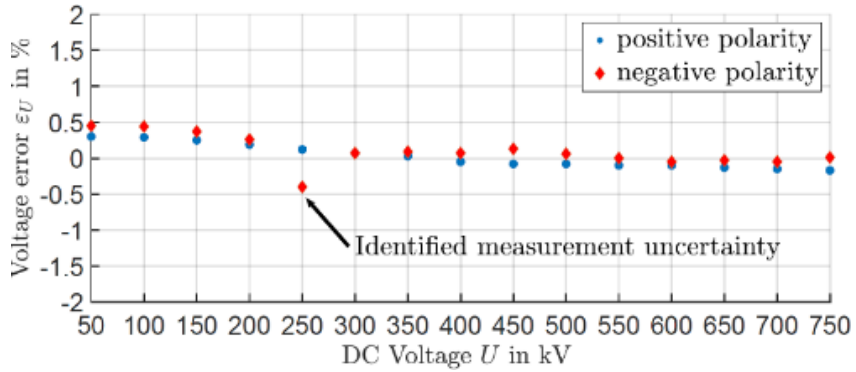
Design and performance verification

- Linear voltage distribution over complete length

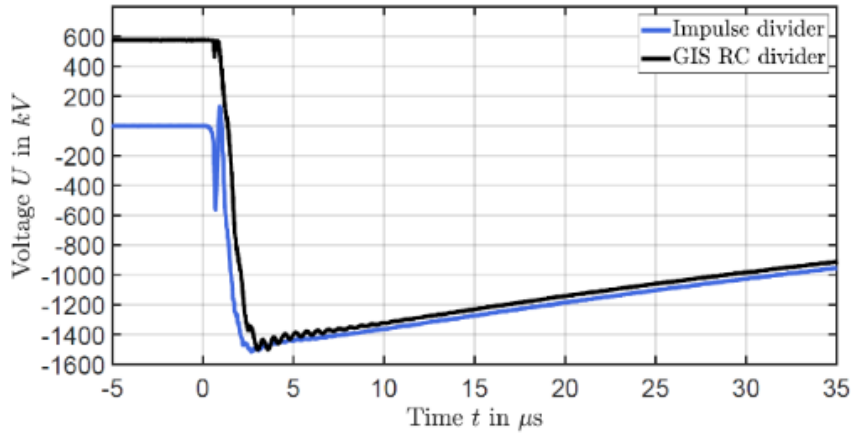


Distribution of
(a) Voltage potential
(b) Electric field

- Identical transformation ratios of the resistance part and the capacitance part to reach a flat frequency response curve
- Low-inductance capacitor design to prevent any transient overvoltage phenomena
- Divider internal insulation material must prevent charge accumulation, otherwise surface discharge can occur during impulse superposition



DC accuracy performance results



Composite voltage test of +550 kV DC and -1550 kV LI after more than 120 hours of DC pre-stress

Required frequency ranges

following the new upcoming standard CDV IEC 61869-1, Edition 2.0

Basic application

- Rated DC application: requires precise measurements from DC to 3kHz – Permanent
  (Metering, measuring, control applications – accuracy from ±0.1% up to ±3%)

Extended application

- Voltage monitoring application: up to 20kHz – Permanent
  (Power quality, ripple detection – accuracy from ±0,5% up to ±5%)

Advanced application

- Transient voltage monitoring: - up to 500kHz for travelling wave detection application
  - up to 1MHz or higher for switching impulse, lightning impulse detection

  (Transient voltage detection – accuracy from ±3% up to ±20%)

Experience in Diagnostic and Monitoring application

DC RC dividers in AIS application are in operation for more than ***50 years***

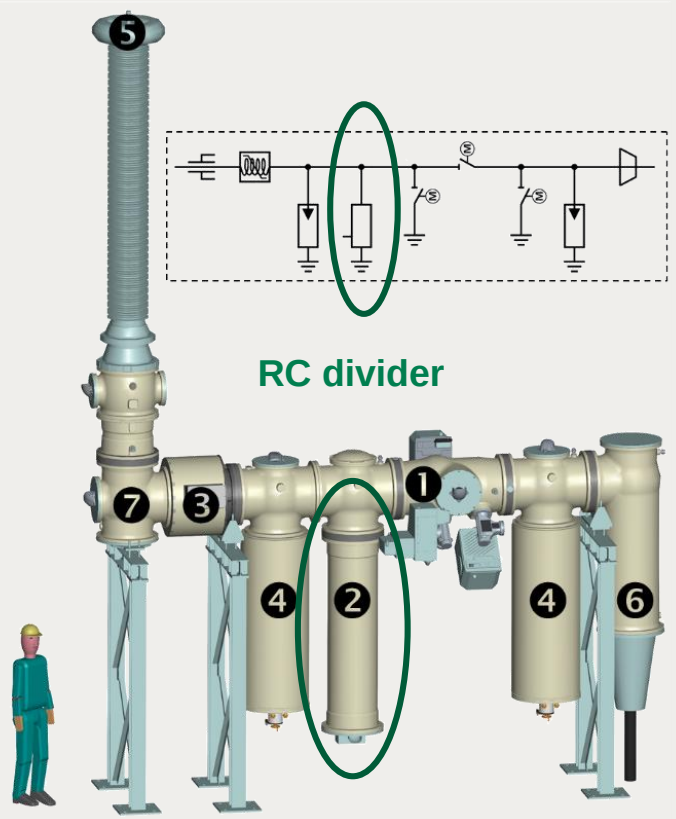
AC RC dividers in AIS application are in operation for at least ***25 years***

Some examples of experience:

- Measurements of PQ parameters in many countries world-wide
- Measurements of transient voltages in DC substations
- Measurements of the ripple level in DC applications
- Measuring DC and AC voltages between power transformer and AC/DC converter (hybrid application)
- Measurements of superimposed DC voltages in AC grids f.e. in back-to-back substations
- First tests on Travelling wave detection by using voltage dividers

Conclusion

- Dimensioning GIS RC dividers acc. to IEC 61869-15 results in an insufficient design for the expected dielectric requirements during operation
- Considering composite voltages as described by CIGRE TB 842 has a significant impact on electrical & mechanical design principles of RC dividers
- Performance of the developed RC divider design has been proven by accuracy measurements, frequency response and composite voltage testing
- Although accuracy in amplitude and waveshape is limited, the designed RC divider can be used to even measure DC+LI composite voltages



RC divider