KEMA Labs

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Testing extruded cable systems up to 525 kV DC: laboratory experiences and late requests from the market

CESI

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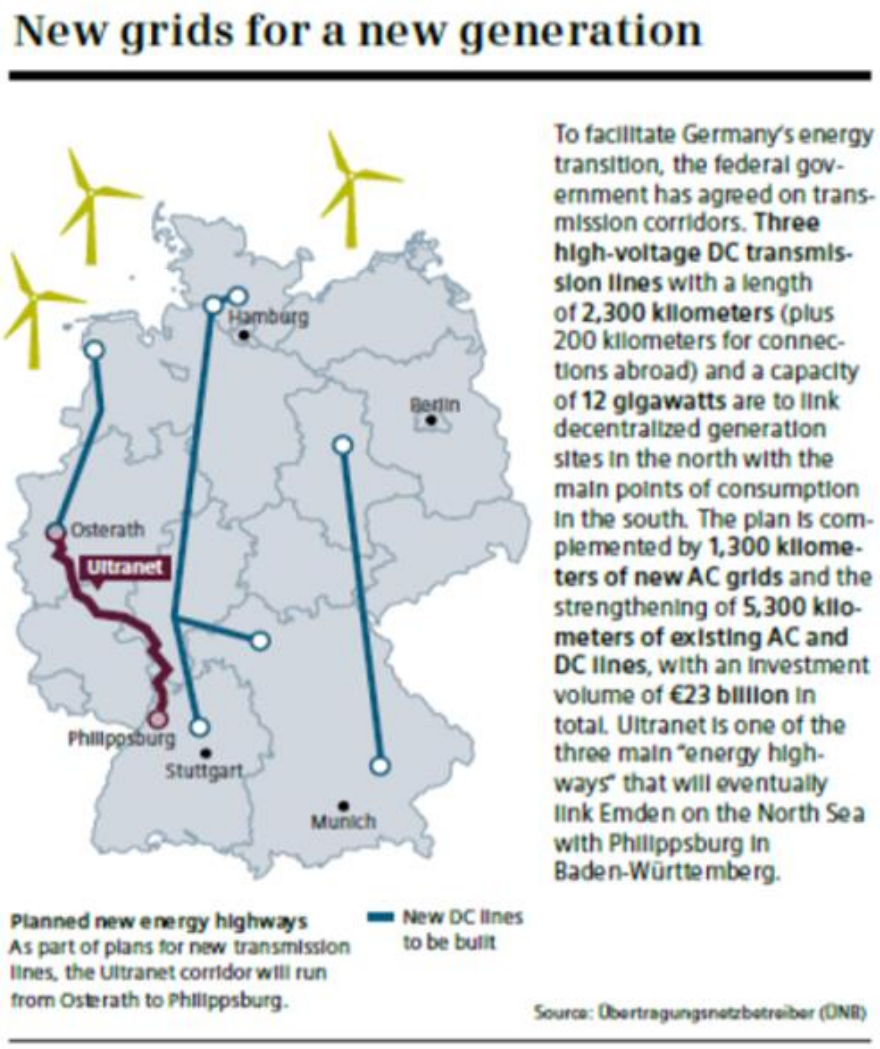
Growing grid with extruded HVDC cables



- The use of polymer insulated HVDC cables is strongly increasing
- SuedLink and SuedostLink are key projects for the introduction of 525 kV HVDC transmission in Germany
- Wind energy from North Sea offshore platforms is transported to the industrial areas in the South
- Simulations of the behavior of the grid revealed that in case of failures overvoltages may occur
- It is not clear, if the tests according to the standards cover this type of dielectric stress
- TSOs and cable manufacturers were asking for the feasibility of a test with such wave shapes

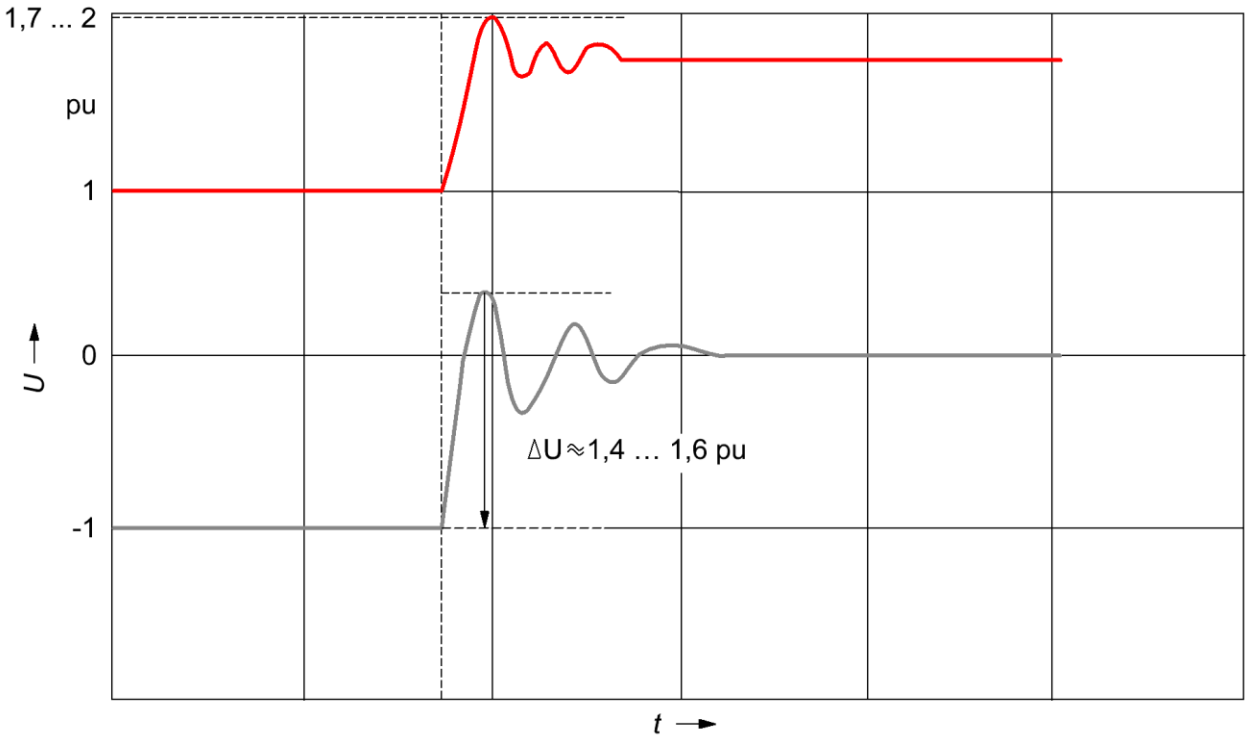
HVDC Test Laboratory Mannheim

- Built 2013/2014
- Total area approx. 60 m x 25 m, height 21 m
- 3 test bays are possible in parallel
- 3 DC voltage sources rated up to 1.600 kV
- Impulse generator rated 3000 kV / 300 kJ
- 2 cranes, 10 tons each
- Laying cables through pipes into the outdoor test area is possible with loop length up to 240 m
- Outdoor area provides duct and tunnel area and laying in natural soil

Testing standards for extruded HVDC cables

- **CIGRÉ TB 496:** Recommendations for Testing DC Extruded Cable Systems for Power Transmission at a Rated Voltage up to 500 kV (2012-04)
- **IEC 62895 Ed. 1.0:** High voltage direct current (HVDC) power transmission – Cables with extruded insulation and their accessories for rated voltages up to 320 kV for land applications – Test methods and requirements (2017-05)
- **IEC 60230:** Impulse tests on cables and their accessories (2018-01)
- **CIGRÉ TB 852:** Recommendations for testing DC extruded cable systems for power transmission at a rated voltage up to and including 800 kV (2021-11)
- Clients' instructions/Client's specifications

New waveshapes to be provided for tests

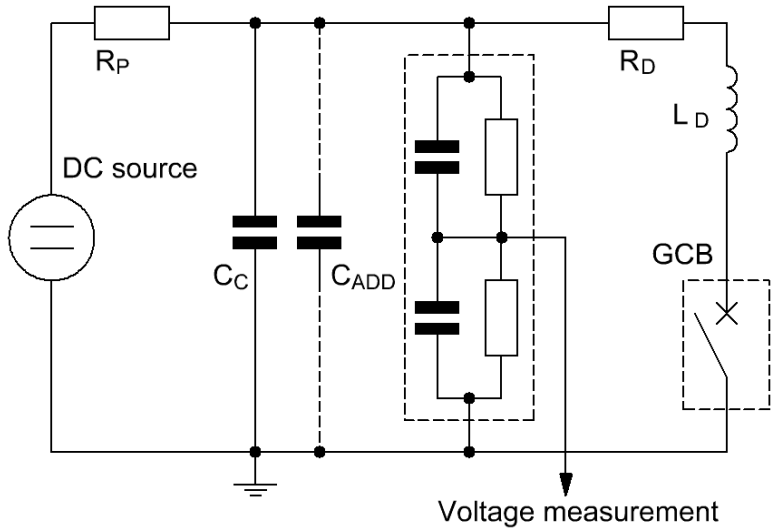


- The simulations revealed that a transient overvoltage stress to the cable can occur
- In case of an earth fault in one pole the voltage in the other pole may rise up to a value of 1.7 to 2 p.u. and is over the regular voltage for a time such as 200 ms or longer (red curve)
- If the polarity of the impulse is opposite the peak will be in the range of -0,6 p.u.
- The faulted pole is meanwhile discharged with an oscillating waveform (grey curve)

A. D. Shakib, H. Hartel, A. Krontiris, A. Menze, T. Rendel, J. Reisbeck, S. Beckler, 2020, „HVDC Cable Connections in a symmetrical monopolar configuration – Influence of single pole faults to the transient voltage behavior", ew Magazin für die Energiewirtschaft, pp. 26-30 (in German)

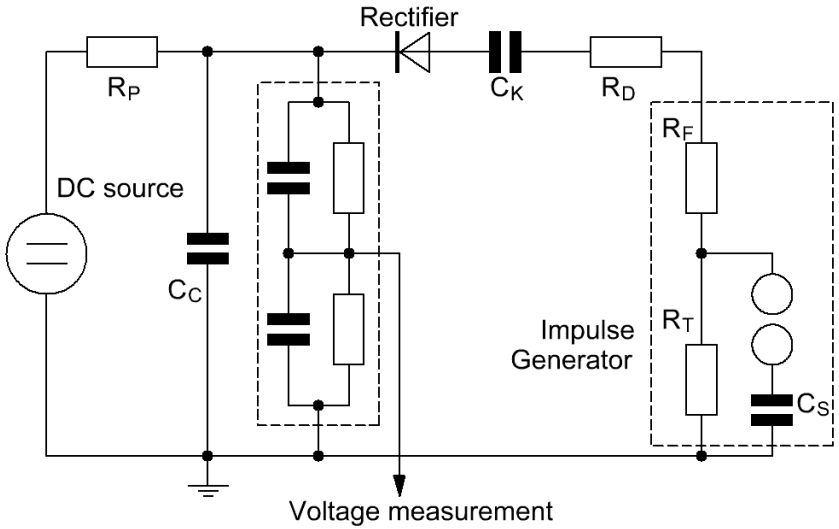
Test set-ups

Set-up for oscillating discharges



- DC source pre-charges the cable
- R_P protects DC generator from over current trip-out
- Cable C_C is discharged through R_D and L_D, switched by a GCB or a triggered spark-gap
- The oscillating frequency can by influenced by the choice of L_D and parallel circuit of an additional capacitor C_{ADD}
- Damping can be increased by increasing R_D
- Measurement shall be done by a universal divider

Set-up for transient overvoltages with long time constants



- Simple set-up as for superimposed impulse test fails to deliver extreme high time constants
- Rectifier is of low impedance only in one direction
- R_P protects DC generator from over current trip-out
- Very high time constants can be reached with acceptable efficiency
- Time to peak can be adjusted by adjusting R_D
- Measurement shall be done by a universal divider

Test set-ups

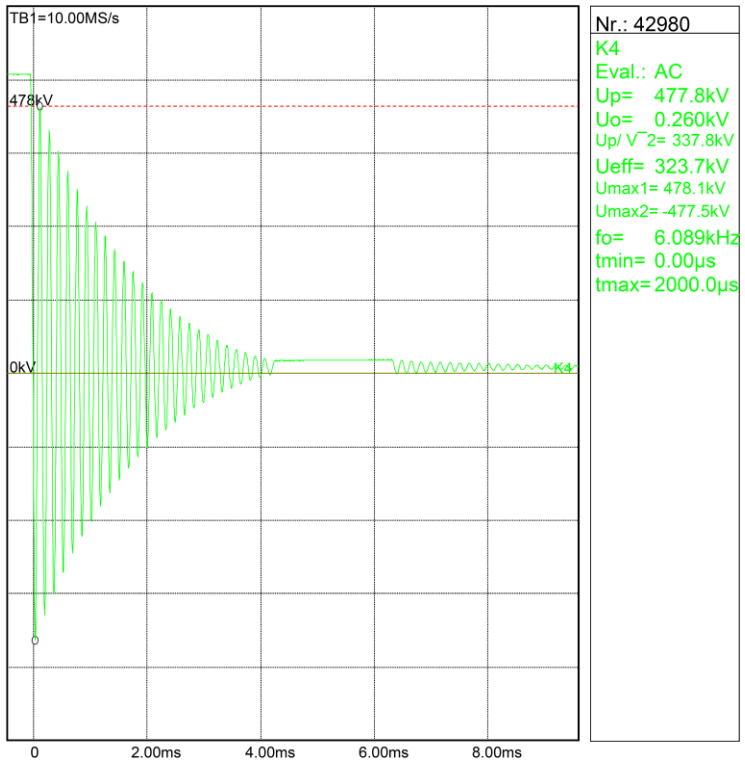
Test on a 525 kV extruded HVDC cable, type test loop, installed by Prysmian Group

Set-up for oscillating discharges

Set-up for transient overvoltages with long time constants

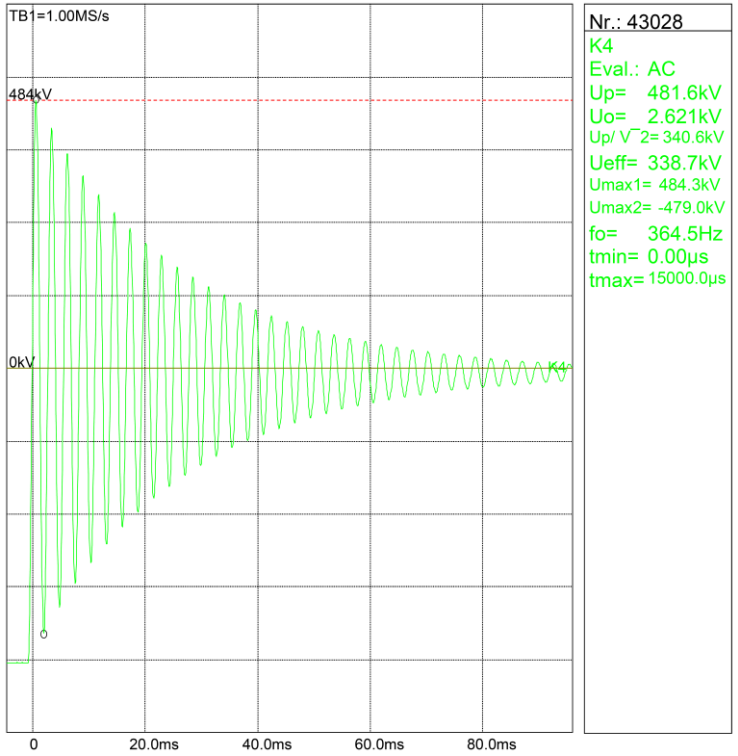
Measured waveshapes – oscillating discharge

High-frequency test



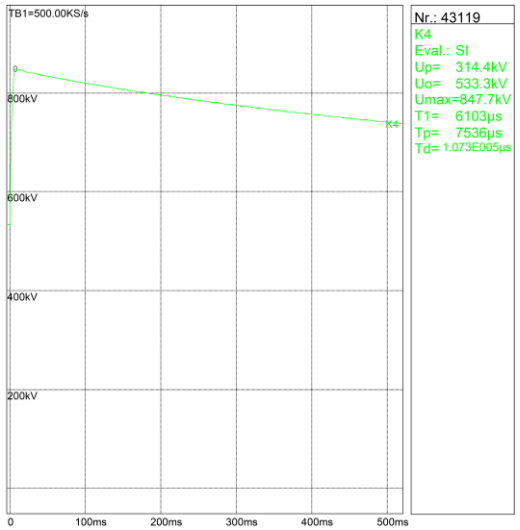
- DC-pre-charge: +525 kV (U_0)
- Discharge frequency: 6089 Hz
- No. of full waves: > 25

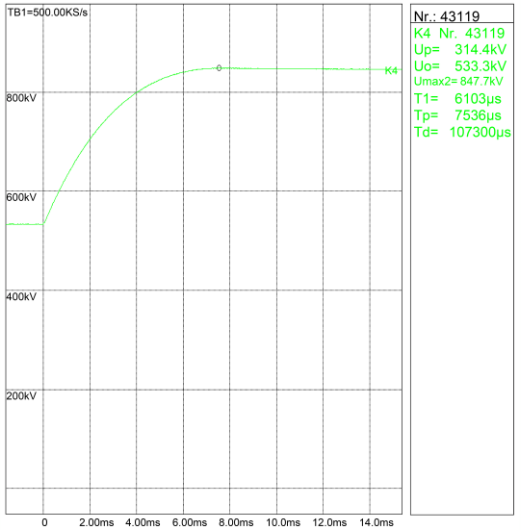
Low-frequency test

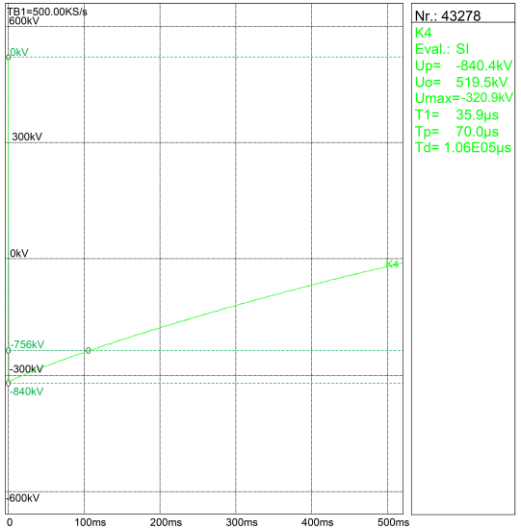


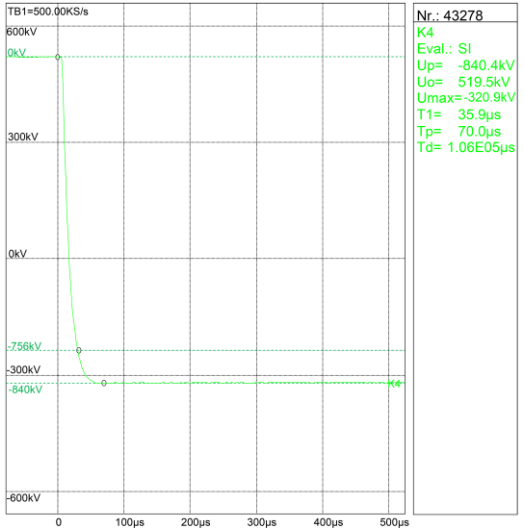
- DC pre-charge: -525 kV ($-U_0$)
- Discharge frequency: 364 Hz
- No. of full waves: > 25

Measured waveshapes – slow front impulse tests









Same polarity tests

- DC-pre-charge: +525 kV (U_0)
- Time to peak: 7536 µs
- Peak voltage: 847.7 kV (1.6 U_0)

Opposite polarity tests

- DC-pre-charge: +525 kV (U_0)
- Time to peak: 70 µs
- Peak voltage: -320.9 kV (-0.6 U_0)

Summary and conclusions

- Increasing installation of HVDC grids basing on extruded cables requires new test procedures to cover all possible stresses
- New waveforms are introduced in CIGRÉ TB 852 clause 12 as special temporary overvoltage tests
- A test set-up for a 525 kV full-size test on an extruded cable type test loop was installed and successfully tested with parameters defined by the client
- The introduction of a high-voltage rectifier allows very high discharge times compared to regular superimposed impulse tests with SI/LI waveshape


Many thanks for your
kind attention