



*High Voltage Testing and Engineering Commission*  
*Fachkommission für Hochspannungsfragen*  
**Cable testing**

Proof of proper assembly and installation of the cable systems is the primary consideration when carrying out on-site voltage testing of high-voltage cable connections.

The on-site AC voltage testing technology for high-voltage cables that is now used throughout the world was developed jointly by the Swiss Federal Institute of Technology Zurich (ETH) and FKH, and was introduced by FKH in the 1980s. It is based on the series resonance principle with a tuneable frequency. Various other diagnostic methods, including partial discharge (PD) measurements in particular, are offered in addition to voltage testing.

### High-voltage series-resonant testing of cable systems

Prior to commissioning a new cable system, or after the completion of major conversion work on an existing system, voltage testing is recommended before starting to operate the system. The aim is to exclude the following faults in particular:

- ⇒ Assembly errors in cable terminations or joints
- ⇒ Damage to the cable sheath or the semiconducting screen

In compliance with CENELEC HD 632 and in divergence from IEC 60840 and/or 62067, FKH recommends that a higher test voltage should be applied to cables, but for a reduced testing duration. This recommendation is based on FKH's lengthy experience of testing.

$U / U_0$	$U_{test}$	$U_{test} / U_0$	Test duration
45 / 26 kV	57 kV	2.2	15 min
60 / 36 kV	80 kV	2.2	15 min
110 / 64 kV	140 kV	2.2	15 min
132 / 76 kV	167 kV	2.2	15 min
150 / 87 kV	190 kV	2.2	15 min
220 / 127 kV	254 kV	2	15 min
275 / 160 kV	320 kV	2	15 min
400 / 230 kV	400 kV	1.8	15 min

Recommended test procedure depending on the system voltage

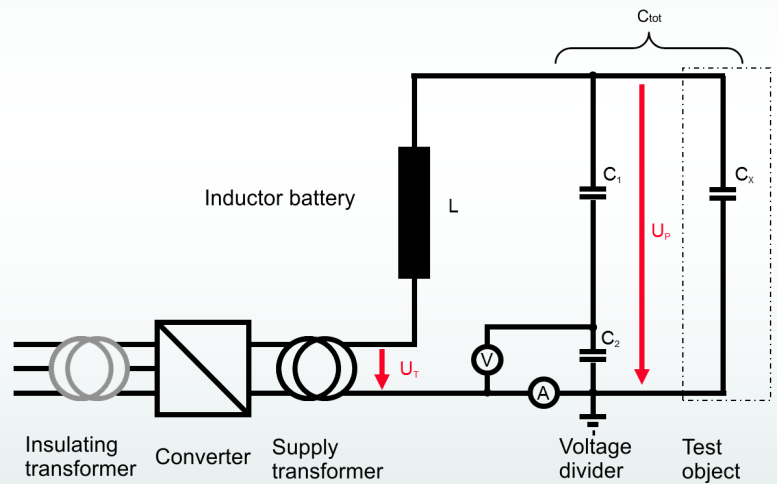


Diagram of a series-resonant system

In the test circuit, an inductance  $L$  with a high quality factor is connected in series to the test capacitance  $C_x$  of the object. Under resonance conditions, a voltage  $U_P$  builds up over the test object that is considerably greater than the voltage  $U_T$  of the supply transformer. The test frequency is obtained with the following formula:

$$f = \frac{1}{2\pi\sqrt{L \cdot C_{tot}}}$$

Thanks to its modular inductances, the test system can be configured for a sufficiently high test frequency to ensure that voltage transformers do not reach magnetic saturation; this eliminates the need to remove them for the test.

Series-resonant systems are virtually the only possible high-voltage sources for AC voltage tests on lengthy XLPE- and EPR-insulated cable sections with typical capacitance values (conductor / to screen) of 0.1 to 0.5  $\mu\text{F}$  per km. This restriction is due to the high charging current  $I_C$  and/or the high reactive power  $Q$ . Oil cable systems can also be tested according to this principle.

### Advantages over other methods

- ⇒ Power supply required is low
- ⇒ Voltage at the test object is sinusoidal and free of harmonics
- ⇒ Minimal energy release at the fault location in case of test object breakdown
- ⇒ If the inductances are connected in parallel, the frequency can be increased so that voltage transformers can be included in the testing
- ⇒ Additional cable connections and other equipment connected via switchgear can also be included in the testing

➔ Concept for integral testing of complete systems



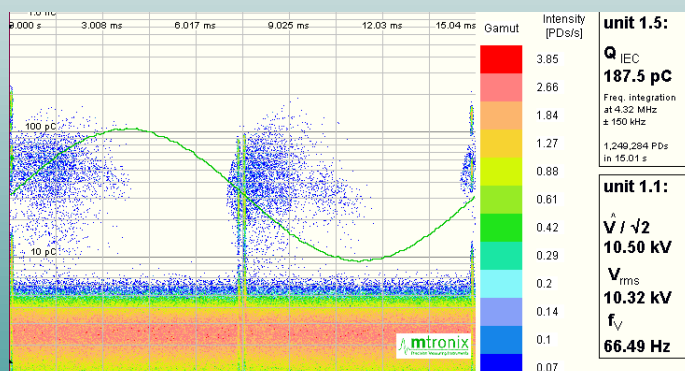
High-voltage resonance test on a 275 kV cable connection

### Partial discharge measurement and other diagnostic methods

A partial discharge measurement is recommended as an additional measure for important cable sections and higher voltage levels. This involves specific inspections of the cable terminations and joints in order to identify insulation faults. In this way, it is possible to detect flaws that have not yet caused an immediate breakdown, but which harbour the risk of an unexpected insulation failure.

FKH uses the following partial discharge test methods and coupling types:

- ⇒ Conventional, via a coupling capacitor
- ⇒ With partial discharge sensors integrated into the fittings (joints, terminations)
- ⇒ Via current sensors on the cable shielding
- ⇒ With acoustic emission sensors

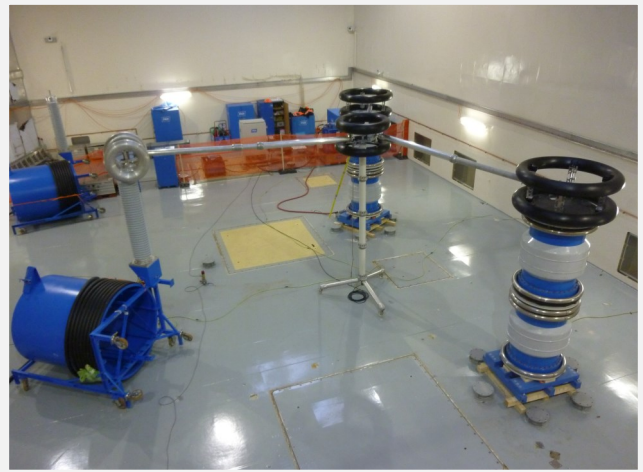


Partial discharge level during a voltage test

The modern partial discharge measurement instruments used by FKH allow synchronous measurements at different points. To capture all partial discharges simultaneously, fibre-optic (OWG) connections must be installed between all the sensors in advance.

For oil-insulated cables and in the medium-voltage grid, FKH also performs  $C\text{-tg}\delta$  measurements as well as measurements of the polarisation and depolarisation currents (PDC).

**Series resonance system on an offshore wind power converter platform with test cable adapters**



**Cable testing system in outdoor switchgear**

**Complete experimental setup for cable testing with partial discharge measurement in the gallery of a hydroelectric power plant**



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