PRYSMIAN
CABLES & SYSTEMS

Diagnostic & Testing Services

Diagnostic & Testing Services

Prysmian Cables & System B.V., based in Delft, the Netherlands, provides a full spectrum of pre and post sales services for its customers, including diagnostic and testing services.

HV Site Acceptance Testing (SAT) with resonance system

Prysmian has a fleet of mobile test systems to provide SAT of high-voltage and extra high-voltage (EHV) cable systems.

On-site dielectric diagnostics of MV, HV and EHV cable systems

Prysmian can perform a number of diagnostic tests on cable systems on-site, including the Partial Discharge (PD) measurements and dielectric loss angle (tanδ) measurement.

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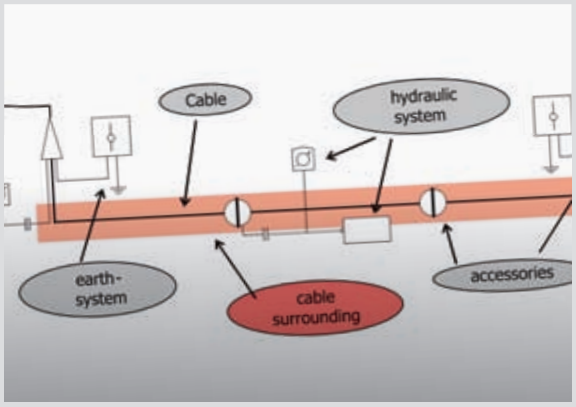
Condition assessment and maintenance on cable systems

Condition assessment of service aged cable systems is an important aspect of preventive maintenance planning and in making asset management decisions. In this context, our customers can count on our knowledge of both XLPE and paper-insulated cable systems.



On-site testing and diagnosis with Damped AC (DAC) 150kV systems

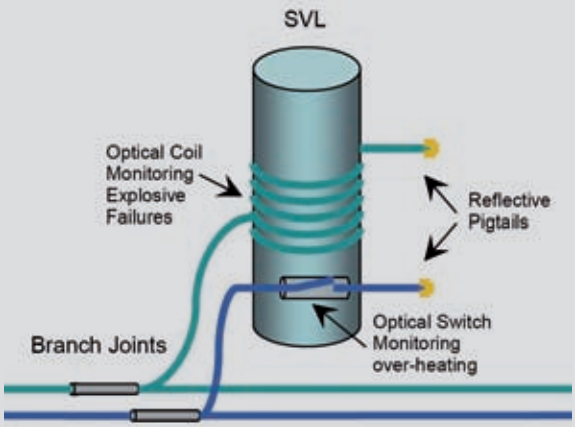
Prysmian can provide PD and tanδ measurements on-site with a DAC150kV system, in cooperation with the Delft University of Technology.

High Voltage Research Laboratory (HRL)

The HRL is a Prysmian laboratory that specialises in the testing of HV components (particularly cable systems) up to the highest voltage levels and is capable of testing the largest conductor cross-sections. Prysmian can offer a complete testing service, including engineering, jointing work for the cable accessories and arrange third-party witnessing and test reports if required.
With the HRL, Prysmian can also offer supervision and coordination of complex testing and qualification projects, even where multiple test locations need to be involved.

Monitoring systems

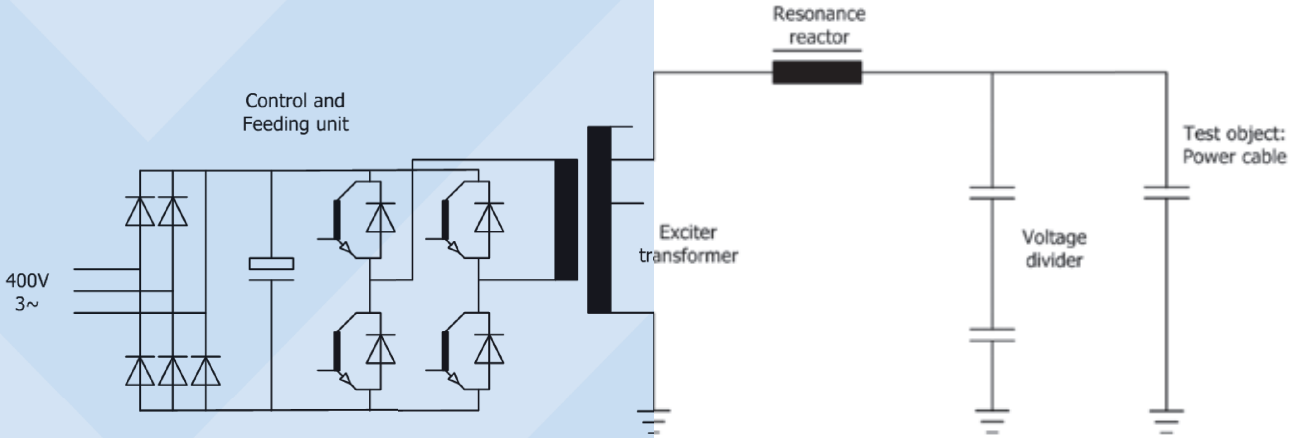
The Cable Load Prediction System (CLPS) is a Prysmian tool for monitoring cable systems and their environment and for providing a safe optimisation of cable loading.
The Sheath Voltage Limiter (SVL) monitoring system is another Prysmian tool for monitoring the status of the SVLs present in the cable circuit. In case of a partial or total failure of one of the SVLs, the system alerts the user and gives the location of the faulty SVL.



HV Site Acceptance Test (SAT) with resonance test system

Prysmian has a fleet of mobile resonant test sets to enable testing of even the longest cable circuits under power frequencies of 20 Hz to 300 Hz. With the test set's own inductance ("L") and the cable system's capacitance ("C") a LC resonance loop is created, where only the relatively low losses need to be compensated for. A variable frequency feeder is used to tune the frequency to the resonance frequency, being:

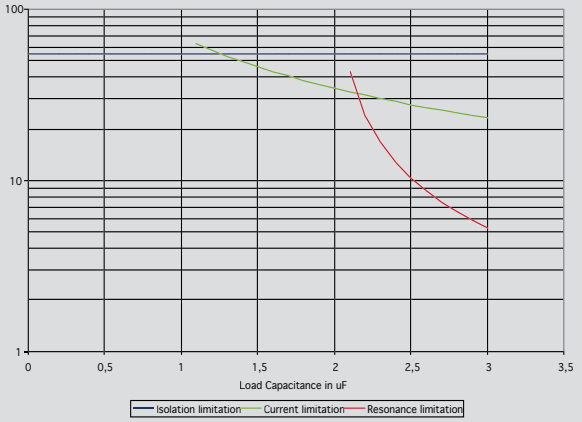
$$f = \frac{1}{2\pi\sqrt{LC}}$$



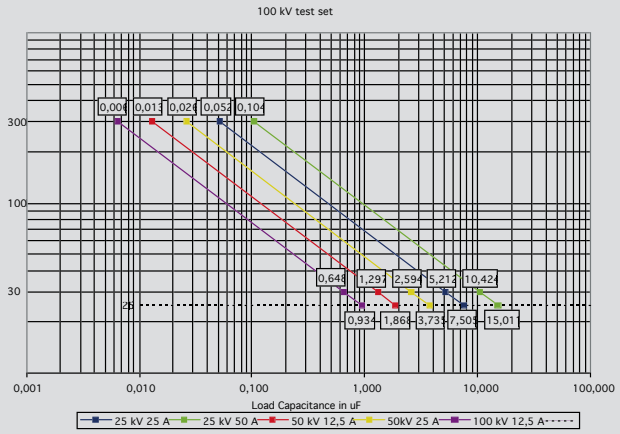
	Rated voltage [kV]	Uo [kV]	Variant 1 Utest [kV]	n x Uo	Variant 2	Test freq. [Hz]	Duration [min]	Soak test 24hrs Utest [kV]
NEN 3620	6	3.6	9	2.5		25 - 200	10	
	10	6	15	2.5		25 - 200	10	
	15	8.7	22	2.5		25 - 200	10	
	20	12	30	2.5		25 - 200	10	
	30	18	45	2.5		25 - 200	10	
NEN 3630	45 . . 47	26	65	2.5		25 - 200	10	26
	60 . . 69	36	90	2.5		25 - 200	10	36
	110 . . 115	64	160	2.5		25 - 200	10	64
	132 . . 138	76	190	2.5		25 - 200	10	76
	150 . . 161	87	217	2.5		25 - 200	10	87
IEC 60840	45 . . 47	26	52	2		20 - 300	60	26
	60 . . 69	36	72	2		20 - 300	60	36
	110 . . 115	64	128	2		20 - 300	60	64
	132 . . 138	76	132	1.73		20 - 300	60	76
	150 . . 161	87	150	1.73		20 - 300	60	87
IEC 62067	220 . . 230	127	180	1.42	216	20 - 300	60	127
	275 . . 287	160	210	1.31	272	20 - 300	60	160
	330 . . 345	190	250	1.32	323	20 - 300	60	190
	380 . . 400	220	260	1.18	374	20 - 300	60	220
	500	290	320	1.1	493	20 - 300	60	290

Power frequency testing is effective and recommended under most international standards

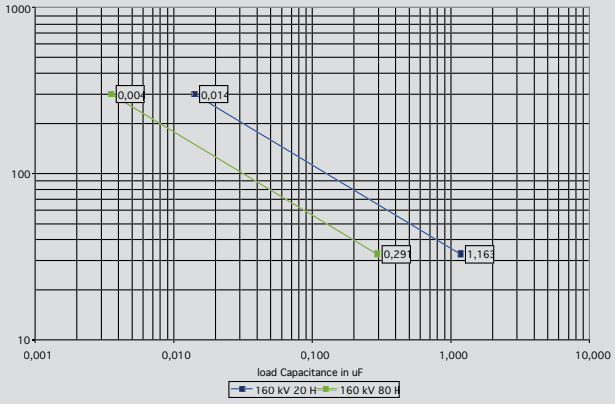
55kV 50Hz Hypotronics
(variable inductance, fixed frequency)



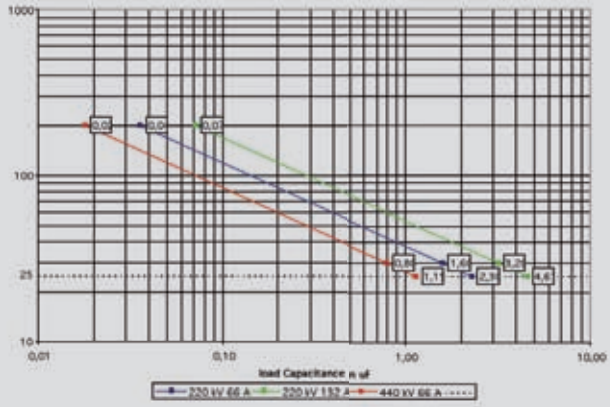
100kV Highvolt resonance test set
(variable frequency, 25Hz – 300Hz)



160kV Highvolt resonance test set
(variable frequency, 33Hz – 300Hz)



220kV/440kV Highvolt/Haefely resonance test set
(variable frequency, 25Hz – 200Hz)



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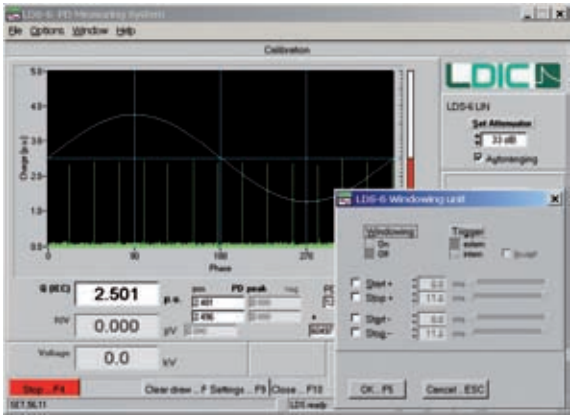
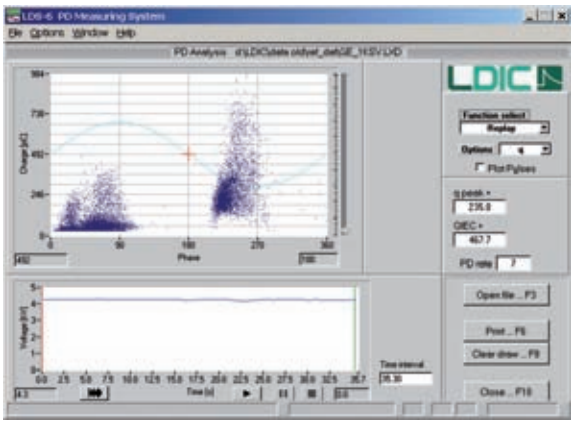
On-site dielectric diagnostics of MV, HV and EHV cable systems

Prysmian can perform a number of diagnostic tests on cable systems on-site. The dielectric loss angle (tanδ) measurement and the Partial Discharge (PD) measurement are among the most reliable indicators of the conditions of a cable system. Tanδ measurement provides a clear indication of the condition of the overall cable system's insulation. In addition, PD measurement allows for a precise location and identification of contained defects which may be detrimental to the cable system.

Benefits

Dielectric diagnostics allow for an assessment of the cable system conditions within a very short time. This provides the asset manager with reliable details regarding possible changes in the condition of the cable system. Such information is vital to the asset manager in the decision-making process and when planning preventive or corrective maintenance actions and load plans.
The periodical monitoring of the cable system conditions increases the reliability of the link and allows for postponement of the cable system replacement.





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Services

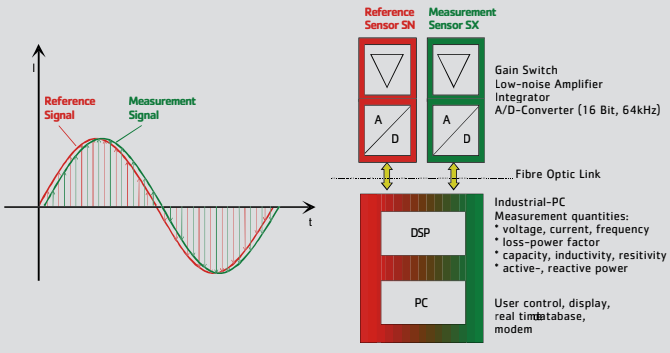
The loss factor (tanδ) and the capacitance of a cable are important quantities for assessment purposes. These quantities are used to detect aging processes and can be used for (re)calculating the maximum load capacity. The tanδ value of a cable is influenced by, among other things, the layout of the connection and the deviations in joints so the actual measurement is mainly applicable as a trend measurement. For HV paper insulated cables the tanδ as a function of the voltage can be an important indicator for possible thermal breakdowns.
These measurements can be and normally are performed in combination with PD measurements.

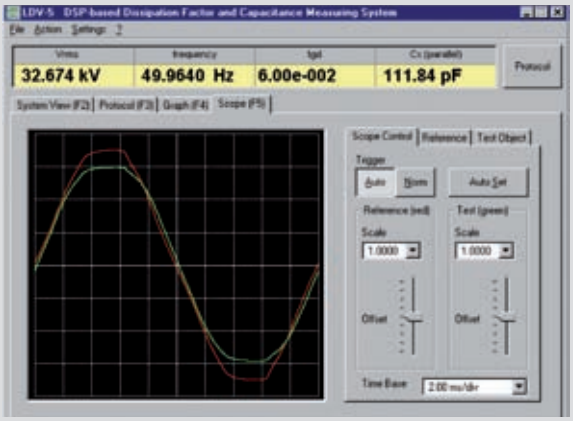
Prysmian can use several PD measuring techniques, depending on the type of cable system. PD measurements on MV cable systems can be executed by classic PD detection (procedure recommended under the IEC60270 standard) in combination with an external voltage using the grid voltage or a mobile resonance test set.

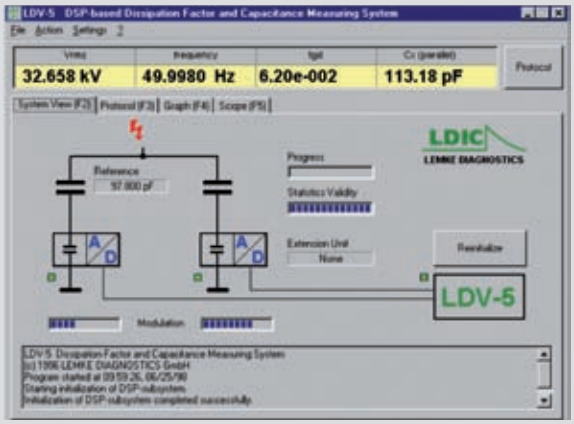
The benefits of this type of system is that the PD source can be located in the complete cable system.

PD measurements on HV and EHV XLPE cable systems require a different approach, because a more sensitive PD level is required and the presence of noise may disturb the measurements.

Prysmian has developed an unconventional UHF PD measuring system in cooperation with the Delft University of Technology. This system is based on the technique of measuring the frequency domain using a spectrum analyser. The advantage with this technique is that very low noise levels can be obtained (<5pC) on-site.







This technique is usually applied on the cable accessories (joints and terminations) in order to check correct installation. During the PD measurement, the cable system can be energised either with a mobile HV test set (off-line measurement) or using the grid voltage (on-line measurement).

A Dutch record: Prysmian successfully performed the PD measurement as a part of the Site Acceptance Testing of the longest 400 kV cable system in The Netherlands (12.5 km).

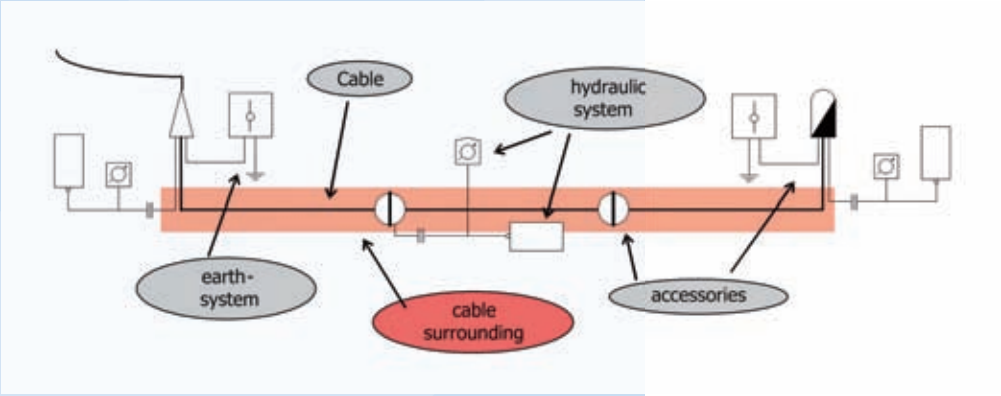
PRYSMIAN CABLES & SYSTEMS

Condition assessment and maintenance of cable systems

Condition assessment of service aged cable systems is an important factor in planning preventive maintenance and making asset management decisions. In this context, our customers can count on our knowledge of both XLPE and paper-insulated cable systems.

Preventive maintenance

Preventive maintenance helps to keep a healthy cable system in a reliable condition and should be executed before function loss of the cable system occurs.
In determining a program for preventive maintenance, it is important to identify the current condition of the system. Hence the diagnostic measurements and inspections. The choice of the specific diagnostics/inspections will depend, among other things, on the cable type, age, history of the cable system and the surrounding conditions. Also important are the specific aims of the maintenance. Do they concern the condition assessment and the short term expectations? Or do they relate to long term expectations based on a coordinated approach to maintenance and management? In the latter case, the diagnostic services are mostly combined with extra research of e.g. load calculations and studies on the aging mechanisms of the cable system.



Overview cable system with possible components.

Corrective maintenance

Corrective maintenance will apply when a dangerous situation has been identified and prompt action needs to be taken. This occurs, for instance, when normal functioning of the cable system is absent (e.g. breakdown) or where an environmental hazard has occurred (e.g. oil leaks).
Prysmian's emergency service is available 24/7. It is the customer who determines the urgency of the situation. A short response time and correct organisation will contribute to a minimum out-of-service time.
Prysmian works closely with suppliers and contractors and can provide full turnkey solutions in the event of emergency situations. Our clear arrangements and task planning help to achieve a fast and successful solution to the emergency with optimum regard for health and safety and the environment.

The following table shows the possible diagnostic services per component of a cable system.

System-component		Diagnostic service	Outcome
Cable insulation	General	- Partial discharge measurements	Detection of local defects
		- Loss-factor measurements	Indication for the overall condition of the cable insulation
		- Capacitance measurements	
		- AC voltage test	Eliminate weak spots
		- Fault localization	Localize insulation faults in case of a breakdown
		- DTS (distributed temperature sensing)	Determine temperature along the cable system
		- DAC (Damped AC voltage) test	AC test with partial discharge and loss-factor measurements
	Oil	- Oil analyses (dielectric and DGA)	Overview of aging and degradation processes
	Paper	- Magenta test	Overview of electrical degradation by discharges
		- Moisture test	Determine moisture content
		- Visual inspection	General condition of the paper layers
	Plastic	- Visual inspection	General condition
		- Water treeing test	Presence of water treeing
Sheath		- DC sheath test and fault localization	Condition of outer sheath
		- Lead research	Condition and expected life time of lead sheath
Accessories		- Visual inspection	Overview and repair of anomalies
		- Resistance measurements	Quality of contacts
		- Röntgen research	Condition of surge arrestors
		- Partial discharge measurements	Condition and correct connection of the cross-bonding
Hydraulic system		- Visual inspection	Condition of system and small repairs
		- Inspection manometer	Condition manometer and check on warning signals
		- Impregnation coefficient	Determination of free gasses
		- Inspection cathode protection	Check correct working
Surroundings		- Determine thermal resistance ground	Thermal resistance ground
		- Soil research	Condition of soil (density, moisture, grain - distribution)
		- DTS temperature measurements	Temperature of surroundings
Cable route		- Route measurements	Determine length, height profile and possible hotspots

The following table shows the possible (diagnostic) services to be performed in the Prysmian High Voltage Research

Description	Outcome
- Special test on cable sample	- Condition of the cable with an indication of the remaining life time
- Loss-factor measurements	- Loss-factor as a function of temperature and voltage
- Partial discharge measurements	- Partial discharges as a function of temperature and voltage
- AC voltage test	- Voltage test
- DC voltage test	- Voltage test
- Lightning impulse test	- Lightning impulse test
- Degradation test	- Long-time degradation tests on cables and components
- Type testing	- Full type test according to standards and witnessed by external bureau
- Special R&D test	

The following table shows the possible engineering services

Description	Outcome
- Grid survey	Database setup of existing circuits for fast and complete overview of the grid
- Load calculations	Maximum load of system
- Cable consultancy	Solving cable questions
- (Re-) engineering	Complete approach for rerouting and adjustments in cable systems
- Specialties	Design of specials (accessories and special situations)
- Failure analyses	Failure analyses after breakdown
- Remaining life time research	Complete research to determine remaining lifetime

On-site Testing and Diagnostics using the DAC 150kV system

Accessible solutions means for maintenance and emergencies

Our customers can count on:
- A 24/7 emergency service;
- qualified personnel and proper equipment for jointing and maintenance of all existing HV cable circuits, including transport of cable and accessories on-site;
- qualified personnel and means for fault localisation and on-site diagnostics;
- knowledge and expertise in fault analyses and in identifying consequences for the rest of the grid;
- methods for the location of oil leaks (freezing);
- two mobile oil units (500 litre) for filling oil pressurised cable systems;
- oil degassing tank with a capacitance of 30 ton;
- training and upskilling of all people in the assessment and maintenance of cable systems;
- contracts with suppliers and (civil) contractors for services outside office hours in case of emergencies;
- extensive stocks of emergency cable and cable accessories;
- full expertise of XLPE and paper-insulated cable systems;
- technical knowledge of existing cable circuits and of the Dutch grid;
- qualified personnel and means for testing in the Prysmian's HV laboratory HRL in Delft (NL);
- material laboratory and laboratory for oil analysis;
- close cooperation with the Delft University of Technology, where Prysmian has access to the requisite personnel and equipment.

On-site testing and diagnostics of HV power cables using sinusoidal Damped AC (DAC) voltages

Prysmian can perform partial discharge and dielectric loss angle measurements using the DAC150kV system. For several years, DAC testing has been an accepted method for on-site PD measurements and diagnosis of both polymeric and paper-insulated MV and HV power cables. Prysmian can perform DAC 150kV system measurements on-site, in cooperation with the Delft University of Technology.

Applications:
- Detection and localisation of partial discharges
- Dielectric losses measurement (tanδ)
- DAC voltage withstand testing and diagnosis

To perform PD and tanδ measurements, the cable section must be disconnected from the network at both ends and it is then energised on-site via the DAC system. Each cable phase is energised separately. After charging the cable section to the selected voltage level (max. 150kV peak), the LC circuit as obtained from the cable capacitance ("C") and the system inductance ("L") produce damped AC voltages ranging from 20Hz to 300Hz, depending on the cable capacitance. During this period, which is representative for operational AC stresses, PD inception may occur.

The PD measurements are performed in two ways:
1) In accordance with the IEC 60270 standard, where the PD inception and presences is evaluated in [pC].
2) Using the VHF method where the PD pulses are evaluated in the time domain (TDR) to estimate the location of the PD site in the cable section.

Based on the voltage decay, the dielectric losses of the cable section may be estimated for a particular voltage level.

Benefits:
- The DAC 150kV system can be applied as a diagnostic tool (regular or incidental) or as a site acceptance test-set.
- The system consists of a number of components and can be transported by air or by midsize van.
- Depending on the specific situation, measurements on a 3-phase cable circuit can be performed in a relatively short time (max. 1 day).
- The DAC 150kV system is operated by one engineer who can also set up the measuring system.

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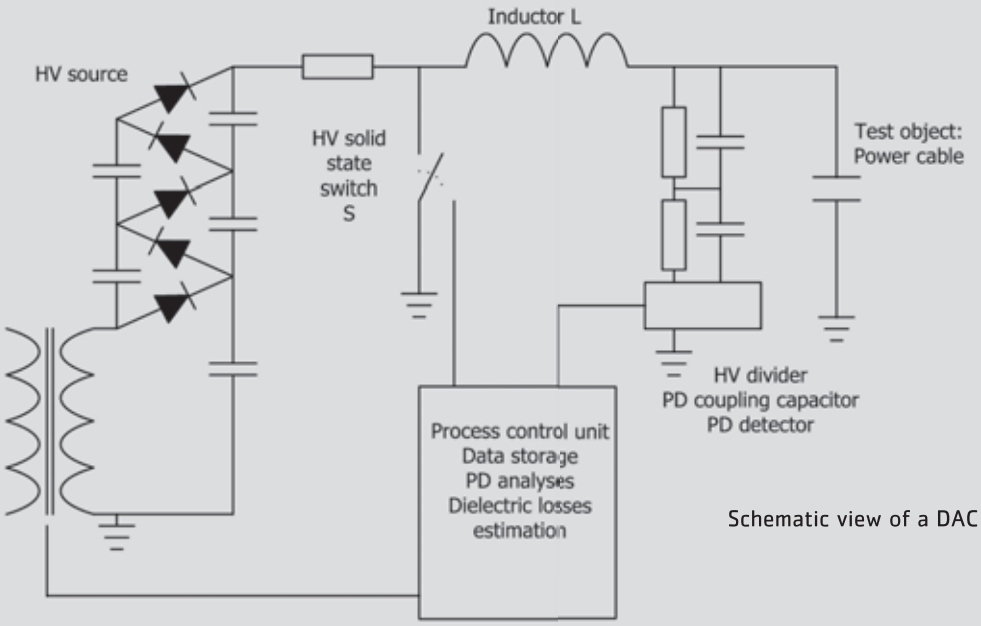


Schematic view of a DAC measuring circuit.

- The noiseless 150kV HV source of the DAC system allows for a PD measurement with an extremely high sensitivity.
- No high power feed unit is required. A 10kW/230V power supply is sufficient.

Working principle

For the generation of DAC voltages, a capacitive test object is connected in series to the system's air core inductor. The test object is charged with a continuously increasing ramp voltage having a low current ranging from 10 mA to 30 mA. Linear charging ensures that no "steady state" DC conditions occur in the test object. Within approximately 1 µs, a HV solid state switch closes the L C loop and a sinusoidal damped AC voltage with a frequency between 20Hz and 300 Hz is produced. The DAC voltage frequency equals approximately the resonant frequency of the circuit $f = 1/ 2\pi\sqrt{(L \bullet C)}$.

Applicable standards:

- IEC 60060-3: High Voltage test techniques – Part 3: Definitions and requirements for on-site testing
- IEEE 400: Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems
- IEC 60840: Power Cables with extruded insulation and their accessories for rated voltages above 30kV - Test methods and requirements
- IEEE 400.3: Guide for PD Testing of Shielded Power Cable Systems in a Field Environment
- IEC 60270: Partial Discharge Measurements
- IEC 885-3: Test methods for Partial Discharges measurements on lengths of extruded power cable

Maximum test voltages DAC 150kV system

Network voltage [kV]	DAC 150kV [xUo]
50	3,6
66	2,7
110	1,6
132	1,4
150	1,2

Technical Data DAC 150kV System

Max. DAC output voltage	150 kVpeak / 106 kVrms
DAC frequency range	20 Hz ... 500 Hz
Capacitance range	0,025 F ... 13 F
HV charging current	10 mA
PD measuring range	1 pC ... 100 nC
PD level detection	acc. to IEC 60270
Bandwidth for PD-localisation	150 kHz ... 45 MHz
Dissipation factor tanδ	0,1 % ... 10 %
Power supply	115 / 230 V 50 / 60 Hz

Set-up of the DAC 150kV system during a test on-site

High Voltage Research Laboratory

The High Voltage Research Laboratory (HRL)

HRL is a high-voltage laboratory specialized in testing of HV components, in particular cable systems. HRL is located at Prysmian Cables & Systems B.V. in Delft, The Netherlands.
In HRL we can test cable systems up to the highest voltage levels and up to the largest conductor cross-sections. We qualify new products adopting state of the art measuring techniques, to comply with the most severe standards and test requirements.
HRL can offer a complete testing service, including engineering, jointing work for the cable accessories and eventual third part witnessing and test reports.
Thanks to the excellent contact network with international test institutions, HRL can offer supervision and coordination of complex testing & qualification projects, even when multiple test locations need to be involved.

Facilities

HRL's facilities include an indoor testing and preparation area of over 2000 m2 and an outdoor testing area of approximately 1000 m2. Even the largest objects can be tested in our facilities and different tests can be performed in parallel.

We can perform:
- AC and DC voltage tests up to 900 kV
- Impulse voltage tests up to 2.5 MV
- Partial discharge measurements
- Dielectric loss angle measurements
- Material tests
- Thermal and mechanical tests for cable systems
- Taylor-made tests for a specific cable system
- ...and many kinds of special tests for cable and accessories

HV cascade transformers up to 900 kV, HRL Delft.

Services

In addition to testing, HRL can provide complete preparation of the test and of the test object, for tests to be performed at Prysmian Delft or at a different location.
If the test needs to be performed at an external institution, HRL can prepare, coordinate and supervise the test, to ensure correctness and completeness of the service.

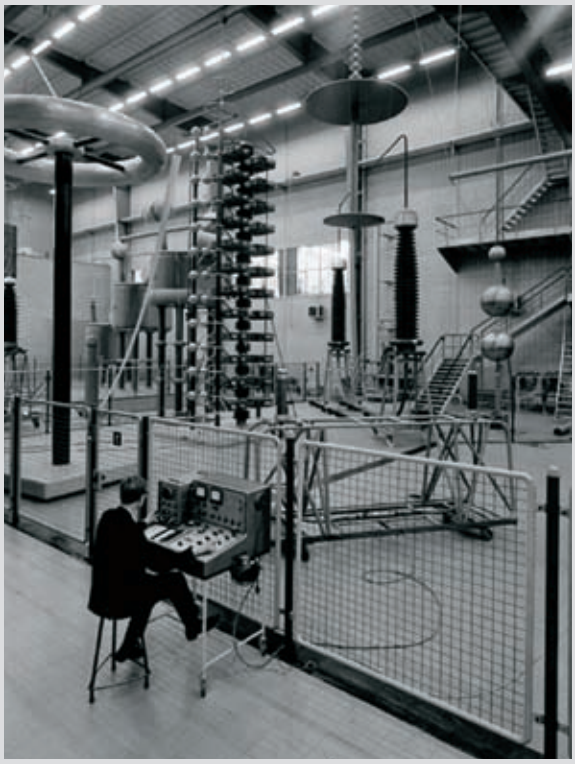
400 kV prequalification test, external laboratory.

Type Test on a 2500 mm2 400 kV cable system, HRL Delft.

Experience

HRL can count on over 50 years of experience: we have been testing HV components and cable systems in our research laboratory since 1958.

Nowadays, approximately 20 test engineers and technicians work at Prysmian in Delft in the quality control & development field. In addition to the research laboratory, three (3) HV quality-control laboratories, one (1) material laboratory for extruded systems and one (1) material laboratory for oil-paper systems are operational at Prysmian Cables & System B.V. Furthermore, a number of mobile installations are present for performing various tests on-site.



High Voltage Research Laboratory during the 1960's, Delft.

Cable Load Prediction System (CLPS)

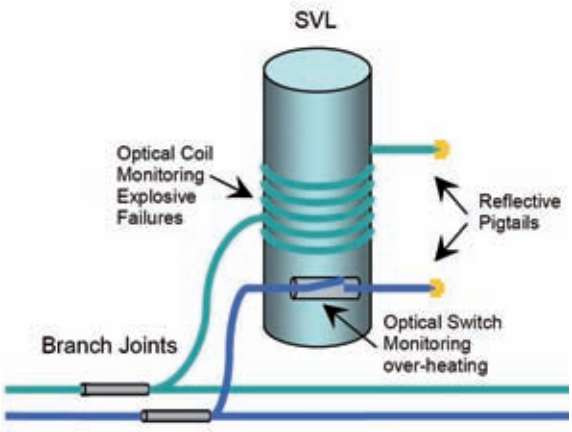
CLPS is a Prysmian tool for monitoring the cable system and its environment which provides for safe optimisation of cable loading. The system is based on a Distributed Temperature Sensing (DTS) technology. It allows for thermal measuring along the entire cable system via the use of optical fibres.
This information enables the maximum (over) load to be determined. Maximum performance can now be obtained from the cable system, without exceeding the safety limits.
The methods used to determine the current ratings of high voltage power cables are based on IEC standards for continuous rating, emergency rating and cyclic ratings. The mathematical models are fully integrated in the Control & Acquisition software and hardware, which also collects and elaborates all measured data from the cable system and its environment.
The software provides a user friendly graphical interface that allows access to a number of indicators for the circuit(s). Alarm information is displayed and all relevant data are automatically filed for historical system analysis. The system is integrated into a stand-alone unit and can be accessed remotely.

Sheath Voltage Limiter (SVL) Monitoring System

Sheath voltages limiters (SVLs) are used to protect the sheath sectionalizing insulators of joints or terminations for specially-bonded cable systems. The purpose of SVLs is to minimise the transient voltage that is generated across during switching surges or lightning strikes and to reduce the risk of flashover of the sectionalizing insulators. In the event of SVL failure, the sectionalizing insulators remain unprotected.
The SVL monitoring system developed by Prysmian checks the SVL for failure. The system is based on a optical coil and on a separate optical switch.

- The coil is wrapped around the SVL and provided with a reflective mirror at the remote end, to reflect the optical signal. If an explosive failure of the SVL occurs, the optical coil is interrupted and no signal is reflected. In this way the failure is detected.
- The purpose of the optical switch is to show when the SVL is at elevated temperatures. The switch is normally open, preventing the transmission of light. If the temperature is above 80 °C approx., the switch closes, allowing light to pass through. The hot SVL is then immediately located. During normal operation, the SVL may be at high temperatures but for short periods only (10-15 minutes). Prolonged periods at high temperature indicate a partial failure of the SVL.

The system is supported by a user friendly graphical interface. Alarm information is displayed and all relevant data are automatically filed for historical system analysis.



For more information, please contact the Diagnostic & Testing department of:

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The Diagnostic & Testing department, part of the Customer Service Group, can offer assistance with:

On-Site:
- After-Installation HVAC tests, up to 440kV
- DAC150kV tests
- Additional on-site tests (e.g. DC sheath testing, Distributed temperature measurements, Partial discharge measurements, loss-factor measurements)
- Condition assessment (on-site inspection, DGA analyses and electrical condition of oil)
- Emergency service 24/7 (on-site fault-localization)

High voltage laboratory in Delft:
- Type testing of cable systems
- Sample testing
- Special testing
- Remaining life time determination on cables

The Customer Service Group, can offer assistance with:

- Installation of XLPE cable systems from 50KV up to 400KV.
- Installation of paper insulated cable systems from 50KV up to 400KV.
- Supervision of cable installation and jointing.
- Training programs for jointing of (EHV) cables.
- Servicing of (old) cable systems.
- Emergency service 24/7

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