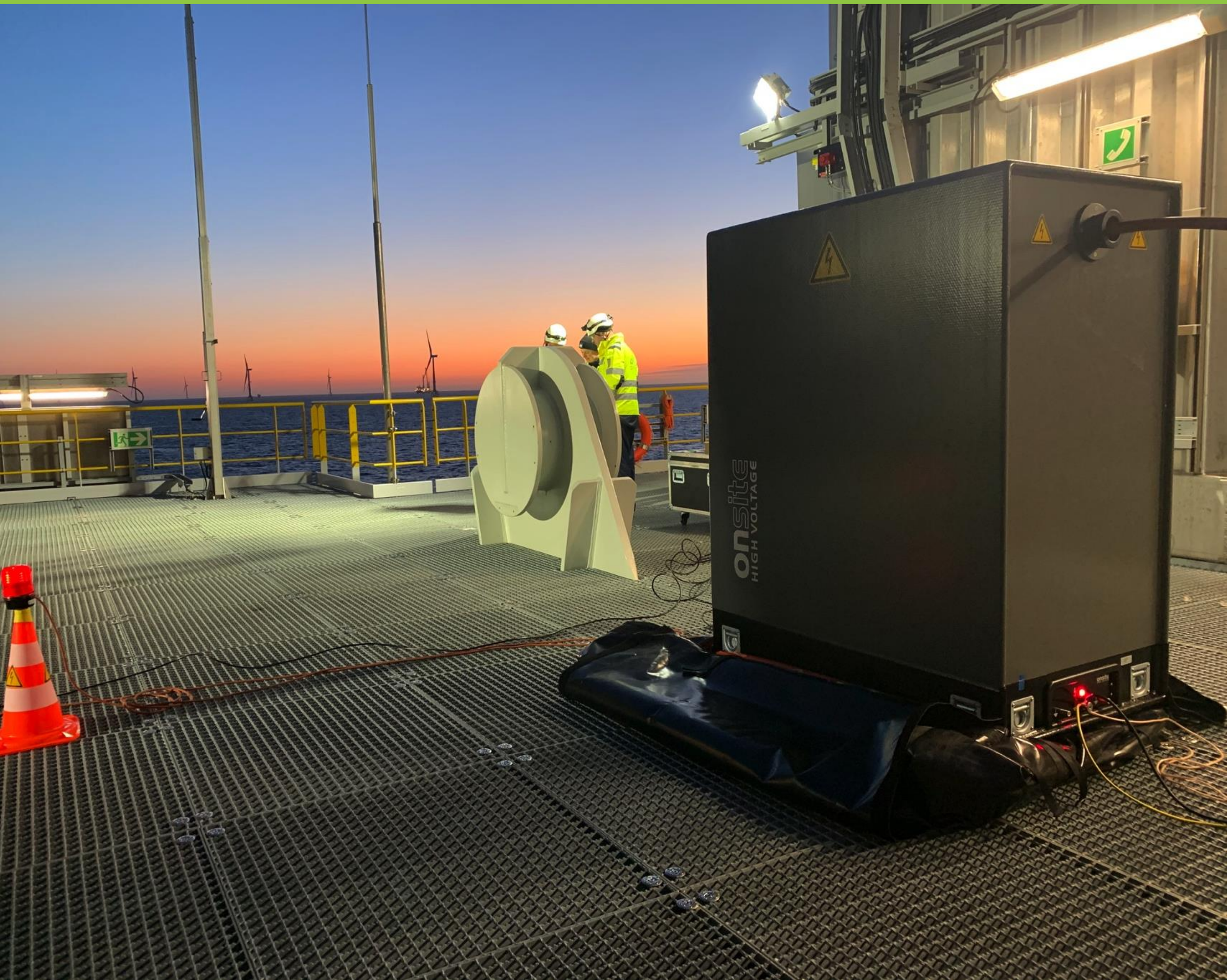
onsite
HV SOLUTIONS

OFFSHORE WIND FARMS

After-laying testing and diagnosis of electrical infrastructures with an emphasis on export and inter-array cable systems



About us

onsite hv solutions, headquartered in Switzerland, is an international organization of independent companies with a team of highly qualified specialists, providing world-wide support in testing and maintenance of electrical infrastructures like inter-array and export power cable systems, power transformers and GIS of offshore wind farms.

onsite hv solutions possesses extensive scientific knowledge combined with years of field experience, long and close cooperation with world renowned universities, leading manufacturers power companies and developer around the world.

onsite hv solutions has over 20 years of experience in world-wide after-laying testing and on-site condition assessment with damped AC (DAC) voltages monitored by partial discharges and dissipation factor of all types of on-shore and off-shore power cables up to 275 kV.

onsite hv solutions is actively working in organizations like CIGRE, IEEE, IEC and ACP, which allows us to understand the needs of electric power utilities, and to develop and offer effective asset management and asset optimization solutions accordingly.

Export and inter-array power cables	On- and off-shore power transformers	On- and off-shore gas insulated switchgear (GIS)
After-laying (SAT)	SAT Provided by the manufacturer	SAT Provided by the manufacturer
Condition assessment	Condition assessment	Condition assessment

Content

Overview of Goods and Services

Our Competences

Offshore wind farms (OWF) electrical infrastructures, like export cables, inter-array cables, power transformers and gas insulated switchgear play a vital role in bringing generated power to offshore substations and to shore.
Our offshore trained test engineers are vital in supporting customers with their installation testing, service life maintenance and asset management.

- **Offshore export and inter-array cable systems** tests - types, scope of tests, test procedures, criteria for evaluation of measurement results with e.g. mechanical-, electrical- and non-electrical tests such as:
    - Pre-qualification tests of the cable system consisting of: offshore- and onshore- cables, factory joint offshore joint, transition joint, land joint and cable terminations
    - Cable system type and routine tests
    - Inspection and factory acceptance tests (FAT)
    - Tests before laying the cable (verifying that the cable has not been damaged during loading onto a vessel or during transport)
    - Inter-operational tests (connections subsequent cable sections, after other works)
    - Site acceptance tests (SAT) after building the cable lines
    - Maintenance test during cable line operation lifetime
    - Test in case of a failure during operation
- **Power transformers** condition assessment of insulation systems by dissolved gas analysis (DGA), oil analysis and insulation resistance test, of on load tap-changers (OLTC) by dynamic resistance measurement (DRM) and transformers winding condition
- **Gas insulated switchgear** (GIS) condition assessment by SF6 gas analysis and PD on-line monitoring (if equipped with PD sensors)

Technical competences

- OTDR of fibre optic cable testing
- TDR test on cable cores
- Insulation resistance test
- Sheath integrity test
- Phase Verification test
- Function test of bonding/earthing system
- Damped AC (DAC) after-installation- and diagnostic testing including partial discharge and dissipation factor estimation of inter-array cable strings (up to 66 kV) and export cable circuits (up to 275 kV)

Man-power competences

- Highly qualified specialists with over 15 years of field-testing experiences
- Offshore trained test engineers with GWO certificate (Sea Survival, First Aid, Working at Heights, Manual Handling, Fire Awareness) and HUET with CAEBS with a minimum of 1 year of field-testing experience

Expertise competences

- Measurement data evaluation and analysis
- Measurement results interpretation
- Data reporting including recommendation
- Data storage and evaluation for condition-based maintenance

Follow-up competences

- Risk impact estimation incl. future action recommendation
- Export and Inter-array cables condition data management

Knowledge Support and Cooperation

Based on our long-term experiences in the field of commissioning and maintenance of electrical systems like power cables, power transformers and GIS we can support our customers with:

- Full site acceptance test (SAT) services of newly installed cables
- Condition assessment and condition-based maintenance (CBM) recommendations
- Data evaluation of PD measurements
- Supervision and expertise support
- Training & knowledge support

Power cables PD-monitored damped AC (DAC) site acceptance testing and diagnosis possibilities using optionally High Power and Dual-Side

- Inter-array cables strings up to 33 kV by DAC MV60os
- Inter-array cables strings up to 66 kV by DAC HV110os DP DS
- Export cable circuits up to 275 kV by DAC HV300 HP DS

Export cables testing using DAC HV110 system: Master unit with Dual-Power installed on the on-shore substation (on the bottom). Far-end unit with Dual-Side installed on the off-shore substation (on the top)

Cooperation parties

In the past years we have worked successfully world-wide together with the different parties in the field of OWF installation and operation:

- Cable manufacturers of onshore- and offshore cables
- Engineering, procurement, and construction (EPC) contractors
- Supervising- and research institutes
- Developers and consultants
- Offshore wind farm owners and operators

Construction & design, laying

For more details see on https://onsitehv.com/en/ our flyer:

Technical consultancy for investors, insurers & developers of offshore wind farms with an emphasis on power cable reliability

Offshore Wind Farms Power Cables Reliability

The increasing demand for renewable energy worldwide has contributed to the fast development in the quantity and size of installed offshore wind farms.

For this type of generation, the submarine power cables are of great importance for the power transmission from the wind turbines to the offshore- and to the onshore substations.
The experience from the last 20 years shows that:

- Inter-array and export power cables are the largest contributor to the failures of the power supply from the offshore plants
- Repairs of such a critical infrastructure are extremely challenging and costly
- Several aspects of the design, transportation, installation, quality testing and maintenance of power cables at offshore wind farms require special attention

Failures of offshore power cables

Based on the experiences from the last twenty years of OWF operation, the offshore cable failures are responsible for up to 80% of the total financial losses and insurance claims. Recent studies by international entities have shown, that:

- In the case of inter-array and export cables used in OWFs, four main failure modes can be distinguished: 46% incorrect installation, 31% manufacturing irregularities, 15% ineffective cable design and 8% external damage,
- Due to a failure and the repair, the average downtime for an inter-array cable is more than 1 month and for an export cable more than 2 months.

This situation is much more remarkable and worrisome because, when considering the total costs of a windfarm, the offshore cables account for less than 10% of the total capital costs.

In the last 7 years, about 90 offshore cable failures have been reported with over € 350 million in insurance claims.

The average cost of insurance claims in last 9 years has increased sevenfold. As a general rule of thumb, as turbine capacity increases, so does repair costs, and therefore compensation, for every 1 MW of capacity more is added during the repair of 1 million euros.

Depending on the size of the OWF and the location of the failed turbine the financial impact of a single inter-array cable failure can range between 200 thousand euros up to 3 million euros per case.
The expected worldwide annual growth of installed OWF from 117 GW in 2023 forecasts by the end of 2030 a total global capacity of 234 GW.

Field examples of mechanical damage on the armour of an inter-array cable

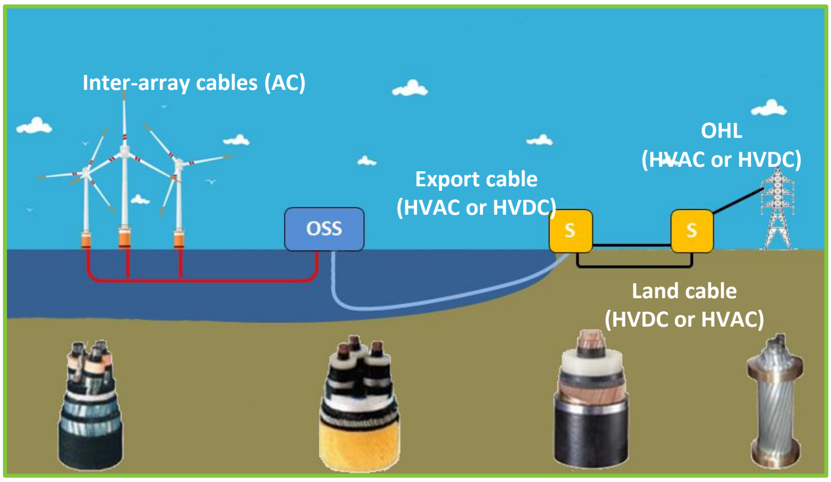
The following major problems are often resulting in OWF power cables failures:

- The pressure to reduce levelized cost of electricity, triggers questionable decisions on manufacturers, developers- and contractors- sides
- The offshore industry is focused on strongly driving down the costs with less room for motivating the development and innovations
- The technical solutions are constantly being under the development to target specific problems that occur during installation and operation
- There is combination of insufficient risk identification, the (project specific) subsea cable design and the shortcomings in how specific quality assurance testing procedures are finally implemented
- Faults in the open sea, caused by dragging fishing nets, anchor strikes and erosion

Quality Control of Offshore Power Cable Systems

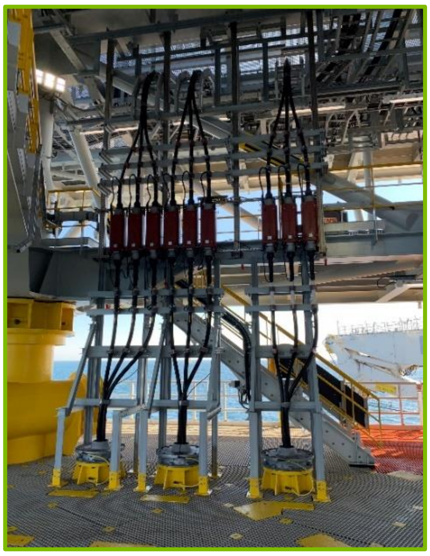
Export cables up to 275 kV might be of very long length connections e.g. up to 120 kilometers and the quality of installation is extremely important for OWF power delivery from the offshore substation to the shore.

Inter-array cables are connected through single turbines to strings with lengths up to 20 km lengths and the quality of installation is extremely important for power delivery from strings with up to a number wind turbine generators installed in one such a string.

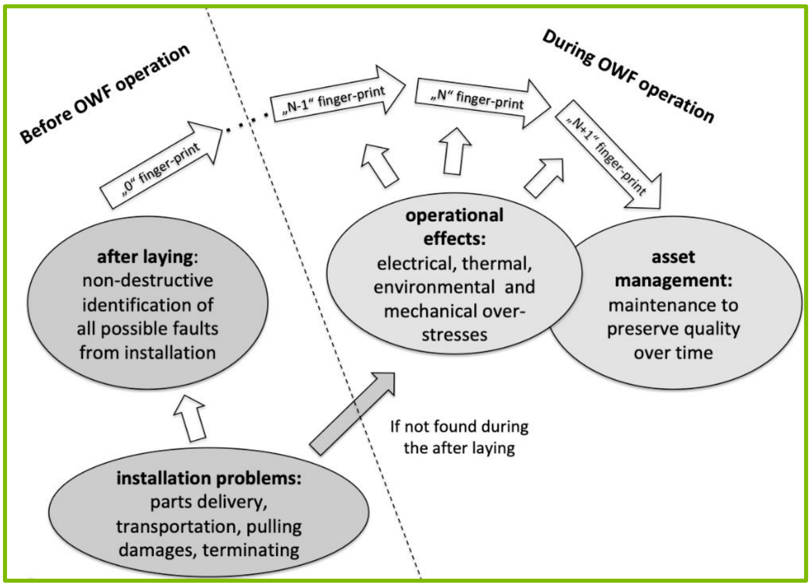


Depending on the OWF size and configuration in case of a cable failure an off-shore repair of any damages of such critical cabling infrastructure is challenging and very costly.
Site acceptance tests (SAT) of offshore wind farm (OWF) power cables both export (EC) and inter-array (IAC) cables are not easy to execute due to

- cable lengths: EC up to 120 km and IAC up to 20 km,
- their position in the sea,
- conditions such as weather, logistics, costs, planning, execution risks, etc.



Despite above, to maintain the required reliability of cable installation for future operation, the terms of acceptance tests must be agreed according to
- what is practically possible to achieve in marine conditions,
- which best practice method constitutes a solid basis for proper assessment of the quality of complete offshore cable installations



Basic asset management aspects determining a safe and reliable grid operation for OWF power cables. The "finger-print" approach means a cable system quality determination over the overall life-time by evaluation of diagnostic parameters e.g. partial discharges monitored voltage testing, dissipation factor (tan δ), etc.

The developments of IEEE standards in last 15 years which are made in cooperation between power companies, manufacturers and service companies, and are referring to selected IEC measurement documents, describe the best state-of-the-art of modern non-destructive methods for both after-installation and maintenance testing and diagnosis, see for more details the relevant international standards & guidelines and publications on page 10.

On-site testing and diagnosis of export- and inter-array cable systems

Considering the risks, the offshore industry needs to setup own reliable specifications for submarine cable testing and condition assessment.

In general, an effective after-laying testing technology has to be dedicated:

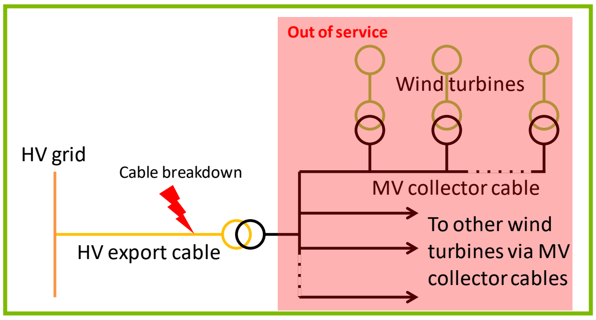
- for off-shore testing
- to provide the adequate information like voltage testing and condition finger printing (e.g.. PD, tan δ) during whole installation and operation process
- to ensure a reliable operation of export and inter-array cables
- to provide contractors the basis for lowering the risks during the warranty period
- to enable service providers during operation sound basis for condition-based maintenance (CBM)

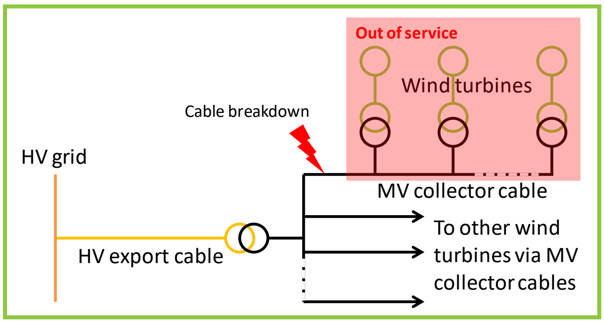
Testing considerations

As present international recommendations for off-shore after-installation are mainly made based on-shore grid application and present off-shore procedures are recommending low cost basic testing with no sensitivity to detect possible weak spots.
This situation shows certain deficiency regarding reliable testing of submarine cables and for sure it is not considering optimal reduction of the risks of possible failures and very high costs of repairs.
Therefore, testing procedures during manufacturing, transportation/storage, installation and operation are needed to exclude or at least to reduce possible risks of a damage during transportation/storage respectively installation and consecutively of a failure during operation.
Higher efficiency rating of OWF installations and optimal quality control will provide protection:

- of the investments of OWF farm owners
- against the warranty risks for contractors and subcontractors
- in the interests of insurers
- against unexpected operational failures and high repair and maintenance costs

The use of damped AC (DAC) technology provides since almost 25 years in on-shore and since more than 5 years in off-shore approved testing after-installation and condition assessment protocol for power cables up to 400 kV.
As a result, dedicated partial discharge- and tan δ- monitored voltage testing is the most modern way for sensitive and non-destructive testing and diagnosis of export- and inter-array cables.





Example of failure consequences: (left) in case of a failure in the HV export cable, (right) in case of a failure of a inter-array cable section that is a part or the complete string of wind turbines

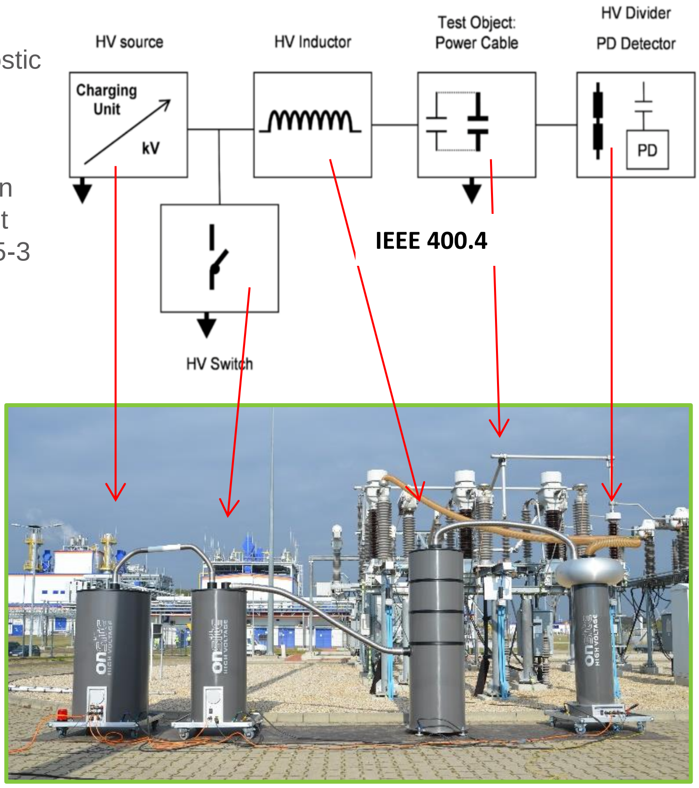
Damped AC (DAC) Testing and PD Diagnosis of Offshore Windfarms Power Cables

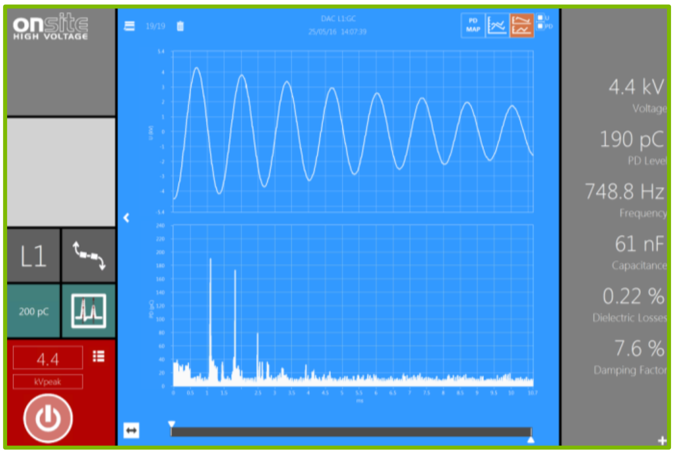
Is for more than 25 years in use and it is in accordance with relevant testing parameters from international standards and recommendations (e.g. IEEE, IEC, CIGRE, CENELEC, ACP) as well as from national recommendations (e.g. UKPN, UNE, SEP, PTPiREE).

Due to its extremely low input power demand and High-Power energizing solution very compact damped AC (DAC) technology makes easy energizing of very long lengths of power cables.

Applicable for on-site after-laying/commissioning, and diagnostic testing of all types of AC and HVDC on- and off-shore power cables up to 400 kV.

Due to Dual-Side solution provides standardized PD detection and dissipation factor estimation during voltage withstand test and partial discharge test according to IEC 60270, IEC 60885-3 and IEEE 400.4.





On-site testing of export and inter-array power cables by damped AC technology

Various damped AC (DAC) system solutions are available for testing of OWF inter-array cable strings up to lengths of more than 20 km and export power cable systems with lengths up to 120 km.

Off-shore side

On-shore side

Export cable up to 275 kV

Damped AC (DAC) 300 kV (Dual-Side and High-Power) for testing export cables up to 275 kV

Damped AC (DAC) 110 kV* off-shore version for cables up to 66 kV

Damped AC (DAC) 60 kV * off-shore version for cables up to 33 kV

* Dual-Side and Dual-Power configuration available

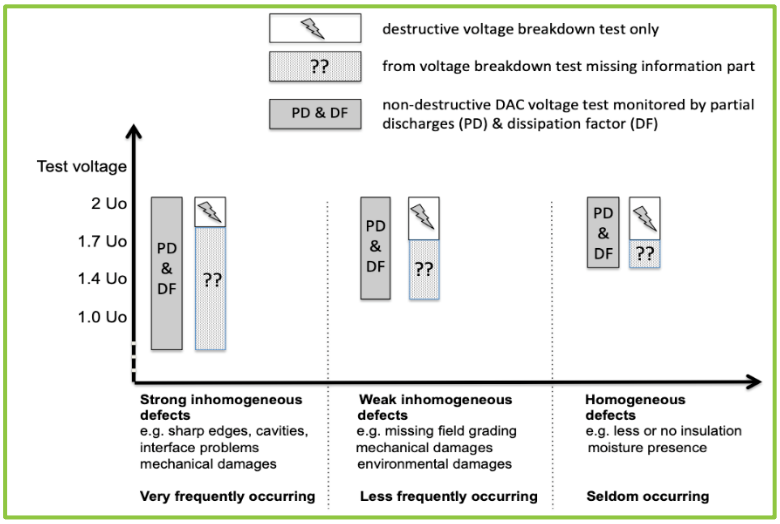
Partial Discharge Monitored Testing and Diagnosis

Considering the complexity of the installation process in an off-shore environment, as well as all risks coming from the manufacturing and transportation, a dedicated testing of the installed cables is crucial for verification of the complete cable system integrity and to exclude defects e.g.:

- voids and cuts in polymeric materials
- delamination and
- contaminations of interfaces
- protrusions or wrong use of shield materials
- missing or wrongly applied components or connections or incorrect dimensions
- misalignment of accessories

All that potentially might lead to an increase of the local stress and can eventually lead to early failure or during operation a higher aging rate.

A safe and reliable OWF cable grid operation starts already at the moment of commissioning a newly installed cable circuit followed by an adequate condition-based maintenance (CBM).



The best effectiveness to detect insulation defects in an offshore power cable system can be obtained using PD and dissipation factor monitored damped AC (DAC) testing

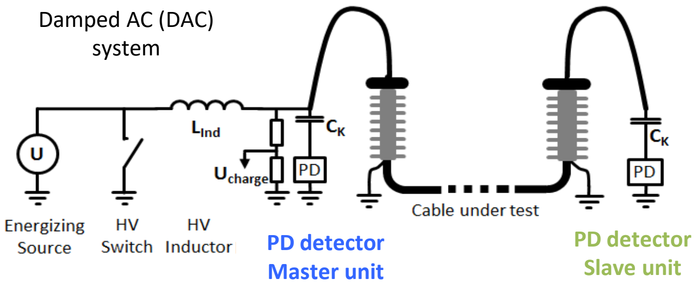
As on- and off-shore HV cable links are getting longer and longer, it has to be taken into account that:

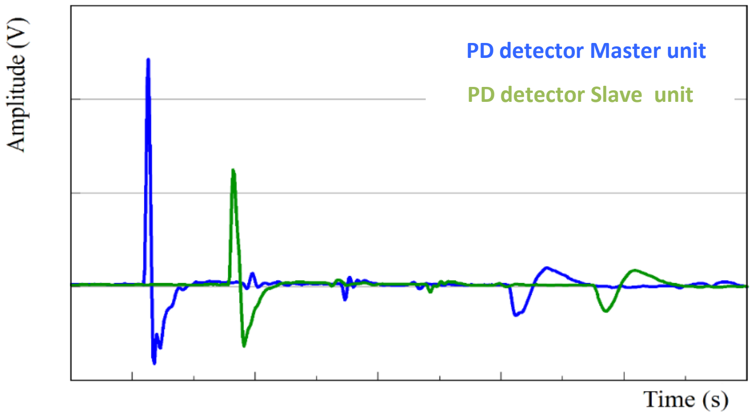
- Destructive over-voltage testing only is not technically optimal and sufficient for the detection of all possible installation defects
- For long length dedicated PD diagnosis is more sensitive to detect all defects

Sensitive PD-monitored withstand test can be more effective in the identification of faults originating from poor installation and to providing the so-called “0”-fingerprint for further condition evaluation of a cable circuit, e.g. to be compared just before the end of the warranty period.

Dual-Side PD measurements

- DAC technology provides the possibility to energize high capacitances, i.e. very long lengths of power cables, with a low input power demand combined with a sensitive PD detection and localization
- Detection and localization of PD in cable systems with long length can be improved by performing PD measurements at both sides of the cable circuit
- PD detectors are installed on both sides of the cable system
- The detectors have to be synchronized to correlate the measurement data of both sides
- In this particular configuration the PD pulses are directly measured and there is no need to take reflections as is the case with the single sided TDR evaluation
- As both units are synchronized, the difference in the arrival times of the pulses at both sides together with the pulse velocity obtained from the calibration provides the location of the discharging defect





Relevant International Standards, Guidelines and international Publications

General

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 Rated 5 kV and Above

IEEE 400.4: Guide for Field-Testing of Shielded Power Cable Systems Rated 5 kV and Above with Damped Alternating Current Voltage (DAC)

IEC 63026: Submarine power cables with extruded insulation and their accessories for rated voltages from 6 kV (Um = 7,2 kV) up to 60 kV (Um = 72,5 kV) - Test methods and requirements

HD 620 S2 (CENELEC): Distribution Cables with Extruded Insulation for Rated Voltages from 6 kV up to 36 kV

IEC 60840: Power Cables with Extruded Insulation and Their Accessories for Rated Voltages Above 30kV up to 150kV – Test Methods and Requirements

IEC 62067: Power Cables with Extruded Insulation and Their Accessories for Rated Voltages Above 150 kV up to 500 kV – Test Methods and Requirements

HD 632 S2 (CENELEC): Power Cables with Extruded Insulation and Their Accessories for Rated Voltages Above 36kV up to 150kV

Cigré TB 496: Recommendations for Testing DC Extruded Cable Systems for Power Transmission at a Rated Voltage up to 500 kV

Cigre TB 841: After laying tests on AC and DC cable systems with new technologies

Energies: Damped AC Testing and Diagnosis of Wind Farms HVAC Long Length Cable Circuits, Energies 2022, 15, 8426. / https://doi.org/10.3390/en15228426.

Energies: Offshore Wind Farms On-Site Submarine Cable Testing and Diagnosis with Damped AC. Energies 2019, 12, 3703 https://www.mdpi.com/1996-1073/12/19/3703

Cigre Science and Engineering: Testing and Diagnosis of Power Cables using Damped AC Voltages, Cigre Science and Engineering, CSE no. 29, 2023, https://cse.cigre.org/cse-n029/testing-and-diagnosis-of-power-cables-using-damped-ac-voltages.html

ACP OCRP-2024: Recommended Practice for Design, Deployment, and Operation of Submarine Cables in the United States (OCRP5), by American Clean Power Association Standards Committee, 2024.

Standardized PD detection

IEEE 400.3: Guide for PD Testing of Shielded Power Cable Systems in a Field Environment

IEC 60270: Partial discharges measurements

IEC 60885-3: Test Methods for Partial Discharges Measurements on Lengths of Extruded Power Cable

Cigré TB 502: High-Voltage On-Site Testing with Partial Discharge Measurement

IEC 62478: High voltage Test Techniques - Measurement of Partial Discharges by Electromagnetic and Acoustic Methods

Cigré TB 444: Guidelines for Unconventional Partial Discharge Measurements

Cigré TB 662: Guidelines for Partial Discharge Detection Using Conventional (IEC 60270) and Unconventional Methods

Dissipation factor diagnosis

IEC 60141: Tests on Oil-Filled and Gas-Pressure Cables and Their Accessories

IEEE 1425: Guide for the Evaluating of the Remaining Life of Impregnated Paper-insulated Transmission Cables Systems

IEC 60141: Tests on Oil-Filled and Gas-Pressure Cables and Their Accessories

Cigré TB 627: Condition Assessment for Fluid-Filled Insulation in AC Cables

Inter-array Cable Strings Testing and Diagnosis

Example of criteria for the risk management for de contractor (e.g. 5 years warranty) system operators, insurers have to be related to the quality control e.g.:

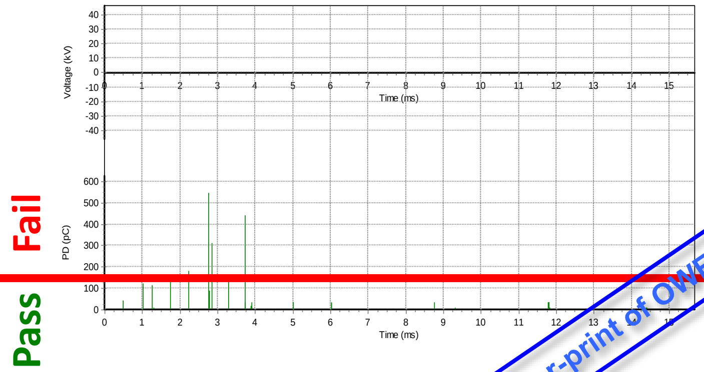
Soak test = due to lack of information about operational reliability = **No warranty** *

AC Voltage test only = due to showing by an over-voltage extreme defects only = **Limited warranty**

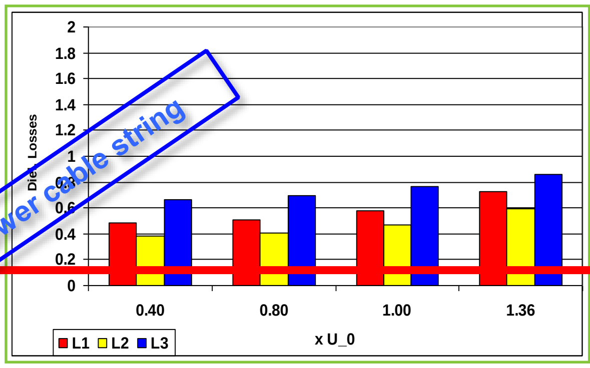
Damped AC voltage test = due to sensitive (PD- and Tan δ) finger printing = **Full warranty** *

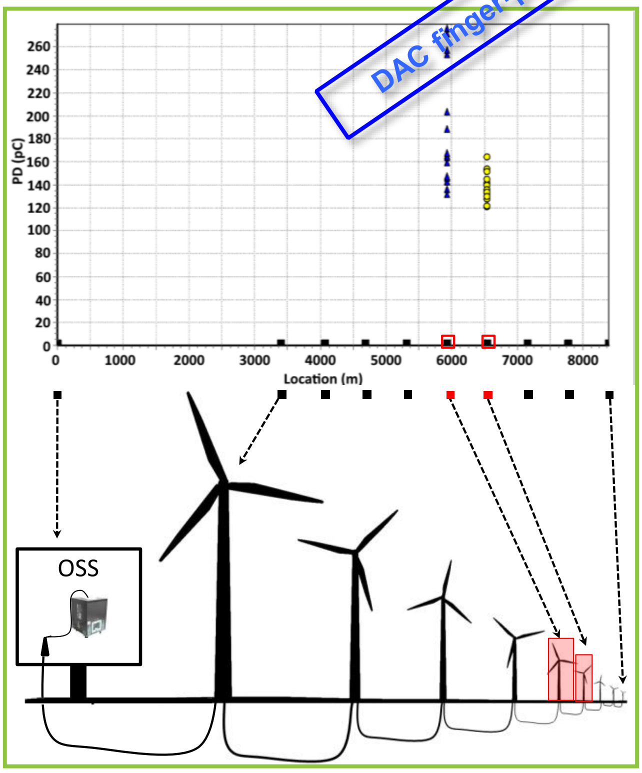
* In case of very long OWF export cables more and more employers are combining PD-monitored damped AC voltage test followed by a Soak test.

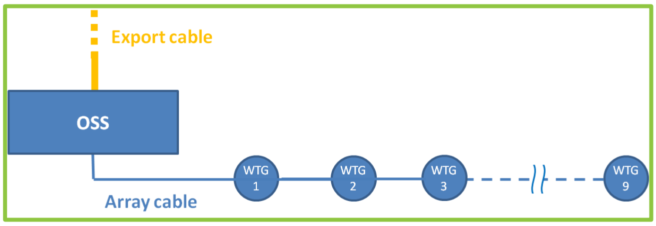
Partial Discharge pattern



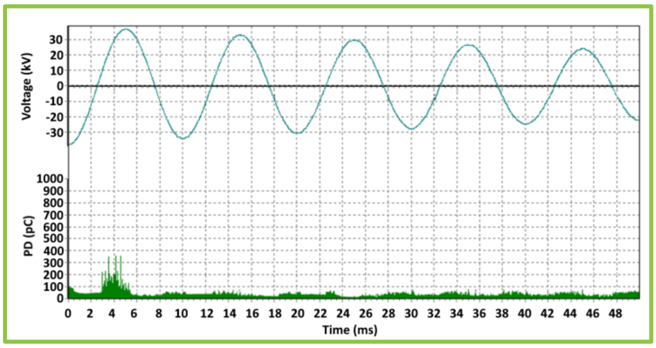
Dissipation factor (tan δ)







Layout of a string. Test has been performed from the OSS and the complete string with 9 WTGs is tested at once indicating all risk related site in the complete string



DAC PD measurement and PD mapping of a complete string performed from the OSS, indicating the location of the PD defect in the string (cable terminations) at WTG 5 (phase L3 and WTG 6 (phase L2)

Export Cable Testing and Diagnosis

The Offshore wind farms export cable circuits are characterized by:

- High capacitance which requires extremely high power demand for conventional AC test systems
- Due to very long factory lengths large number of (factory) joints are installed
- There is a need to test the complete cable drum in the factory before shipping and on-site after installation
- Accessibility and space constraints regarding off-shore access to the cable
- No possibility for distributed partial discharge measurements on individual joints of a subsea cable
- In the case of HVAC or HVDC cables, any possible defects due to installation and transportation can only be detected and located with damped AC voltage testing including partial discharge detection

Export cables testing using DAC 300 kV system: Master unit with High-Power installed on the on-shore substation (on the left) Slave unit with Dual-Side installed on the off-shore substation (on the right)

DAC testing of long lengths export power circuits

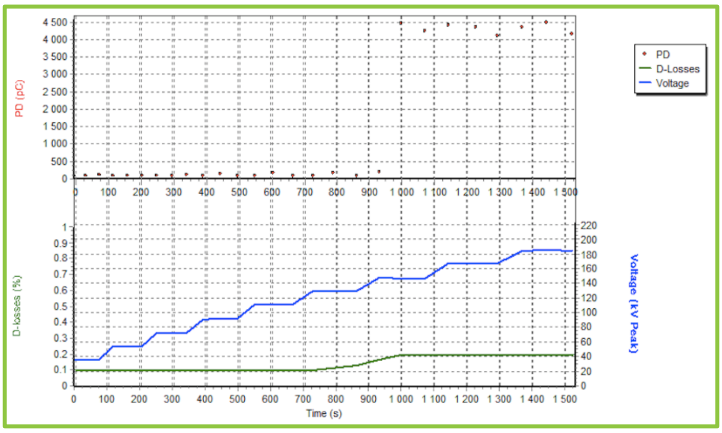
- Due to its low external input power demand and high-power solutions damped AC technology makes it possible to energize very long lengths (up to 120 kilometers) of HVAC and HVDC power cable with a high capacitance
- Applicable for all types HVAC and HVDC HV and EHV power cables
- Applicable for on-site after-laying / commissioning, maintenance and diagnostic tests
- Approved testing methodology, meeting relevant test parameters from relevant international standards and recommendations (IEEE, IEC, CIGRE, ACP)
- Possibility of dual-sided partial discharge detection on very long lengths (up to 120 kilometers) of power cables

Transition point of 220 kV cable from land- to submarine.

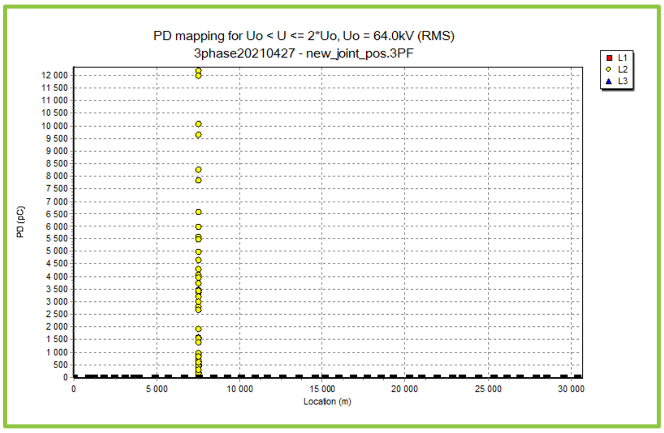
During the after-laying test by PD monitored DAC testing within the recommended power frequency testing range (20 Hz-300 Hz) PD activity has been detected and localized in one phase at a joint position (land part)

Dual-Side PD measurement on long lengths export and inter-array power cable systems

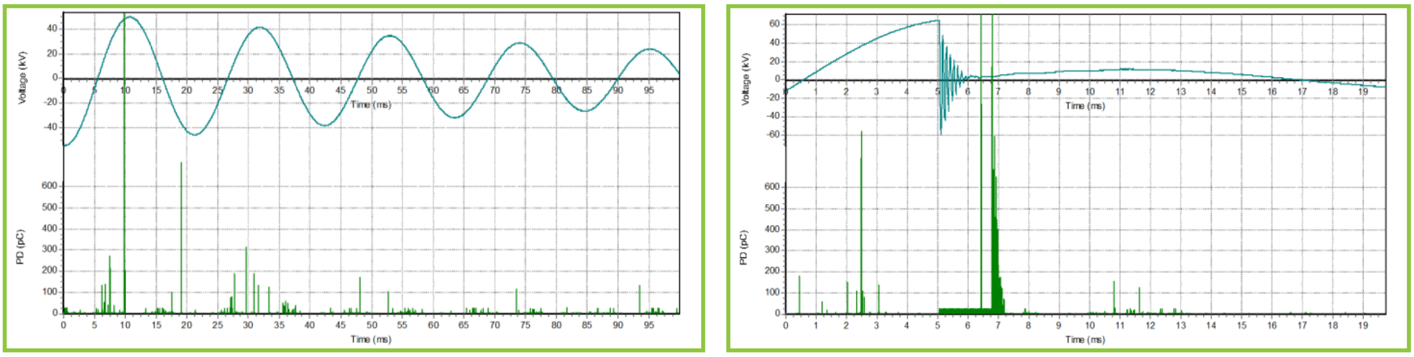
- Dual-Side PD testing and diagnosis is dedicated for long transmission cable circuits
- Localization along the complete cable circuit of all types of insulation defects
- Improvement of over-all PD measurement performance up to 200 %
- Highly sensitive PD measurement with automatic real-time PD localization
- Fully integrated advanced PD diagnosis for a complete cable condition picture
- Simple setup with intelligent inter-communication and synchronization



Ramp-up during voltage withstand test showing PD inception at 1.6Uo



PD-mapping of Dual-Side localized PD pulses indicates a joint with PD in a 30 km long 110 kV cable



DAC PD patterns before / at the moment insulation breakdown during after-lying test of a 13.3 km long land- to submarine 220 kV cable

Voltage class	Cable insulation	Cable lengths
132 kV	XLPE	25 km, 50 km, 60 km
230 kV	Oil-filled	27 km and 28 km
110 kV	XLPE	19 km, 28 km, 38 km, 50 km
110 kV	XLPE	31 km, 30.9 km, 27 km, 21 km
50 kV	XLPE	22.2 km and 17.5 km
35 kV	XLPE	27 km and 18 km
30 kV	XLPE	25 km and 26 km
33 kV	XLPE	different up to 15 km
220 kV	XLPE	14 km
150 kV	XLPE	18 km
66 kV	XLPE	different up to 33 km

Examples of recent site acceptance testing projects of on- and offshore long cable lengths with damped AC technology

HVDC Cable Testing and Diagnosis

Typical challenges of submarine HVDC power cable circuits

- Installing a submarine HVDC cable is a costly and challenging activity. The lifetime of a submarine cable might be tens of years and the technical interventions for its repairing in case of faults are also costly and difficult
- Cigré TB 496 states for the routine test testing with AC voltage could be considered, but that long manufacturing lengths and high voltage levels may render AC testing impractical, fortunately this can be overcome by testing with DAC
- Cigré TB 496 recommends for the after-installations test a DC voltage of 1.45 Uo (for 1 hour), where a negative polarity shall be used regardless of the polarity of the pole
- It is obvious that the Cigré TB 496 is not providing the desired optimal selection criteria to obtain an overall cable condition assessment
- Additionally, an HV DAC test combined with a partial discharge test could be performed on the complete installed lengths
- DC over-voltage test is not sufficient to demonstrate the presence of insulation defects in cable insulation and in the accessories and only AC stresses can demonstrate these defects
- Due to high capacitance of HVDC cables which requires extremely high power demand for conventional AC test systems the application of damped AC is most obvious to check the quality of a large number of (factory) joints installed and the complete cable insulation

Suitability of damped AC (DAC) for after-laying testing of HVDC power cables

- On-site after-laying test has the goal to verify the quality of the complete cable system
- It is a field test performed after the complete cable system installation, including terminations and joints, before the cable system is put into normal service operation
- The after-laying test has to be performed with a PD monitored damped AC (DAC) withstand test
- This test consists of a high voltage test with a predetermined magnitude (IEC conform) and the monitoring of partial discharges improves the evaluation and determination of the overall cable condition
- The combination of a voltage withstand test with PD detection and dissipation factor (tan δ) provides information of an insulation weak spot and insulation degradation prior to breakdown
- Regarding the complete installed HVDC cable length any possible defects as introduced in the factory or after the installation and transportation, can only be detected and located by means of AC electric stresses e.g. by damped AC (DAC) voltage testing including single- or dual-side partial discharge detection at the cable terminations

Damped AC test with PD measurements of a 320 kV HVDC cable

Condition Based Maintenance (CBM) of Offshore Inter-array Cable Strings

Using a dedicated method like DAC technology better quality control of newly installed offshore power cable circuits and approaches to preserve power cable quality (CAPEX) over the OWF operation time will be possible, resulting in a higher reliability and consequently lower costs of outages (OPEX).

Based on non-destructive advanced DAC diagnosis of service aged inter-array cable strings actual insulation condition can be determined and used for condition-based maintenance (CBM).

By using cable condition knowledge rules, the asset management decisions of OWF cable networks can be supported.

Cable circuit	Actual condition	Recommendations
String 5: OSS to WTG 5_8	Internal PD found at: 1. Location WTG 5_6, phase L1 2. Location WTG 5_1, phases L1, L3 and L3 3. Location WTG 5_6, phase L3	Investigate/repair the indicated location. The next maintenance tests should be done within a period of 1 years if no repair action will be performed to verify the PD development.

Cable circuit	Actual condition	Recommendations
String 3: OSS to WTG 3_8	Internal PD found at: 1. Location WTG 3_5, phases L1 and L3 2. Location WTG 3_3, phase L1	Investigate/repair the indicated location. The next maintenance tests should be done within a period of approximately 3 years if no repair action will be performed to verify the PD development.
String 4: OSS to WTG 4_8	Internal PD found at: 1. Location WTG 4_3, phase L2 2. Location WTG 4_4, phase L1	

Cable circuit	Actual condition	Recommendations
String 1: OSS to WTG 1_8	No internal PD sources found	Next maintenance test within 5 years
String 2: OSS to WTG 2_8	No internal PD sources found	Next maintenance test within 5 years

* recommendations are based on the results of the DAC condition assessment done in two years inspection interval.

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