PD MONITORING
for HV Cables

Doble's Calisto Cable Condition Monitoring

Partial Discharge Detection on High Voltage Cables

Doble's Calisto Cable Condition Monitoring solution continuously monitors Partial Discharge (PD) activity in HV and MV cable using state of the art technology and proprietary TF Map™ software. Built on the same core technology used for manufacturing and commissioning acceptance testing, our solution helps customers prevent major faults in transmission and distribution cables, helping the electric power industry operate cable systems of any voltage in a more reliable, safe and secure manner. Doble's Calisto Cable Condition Monitoring architecture is flexible and scalable to meet the specific demands of a diversity of applications providing near real-time asset health and condition data to cable owners and operators.

Preventing Failure on Cables with Calisto Cable Condition Monitoring

Continuously measuring and trending Partial Discharge activity provides the data necessary for our customers to avoid major faults in monitored cables. Main defects in cables include:

- Internal PD in the cable and its accessories
- Surface PD on cable terminations
- Corroded shield
- Broken Jacket

Typical reasons for harmful PD

Different aging processes can be present at the same time on any individual cable:

ELECTROTHERMAL AGEING

- Breakdown of polymeric chains
- Insulating material oxidation

THERMAL CYCLING

- Thermal cycles (expansion and contractions) due to different load conditions

MECHANICAL AGEING

- Vibration and mechanical forces due to both external causes and electromagnetic forces caused by flowing current

EXTERNAL ENVIRONMENT AGEING

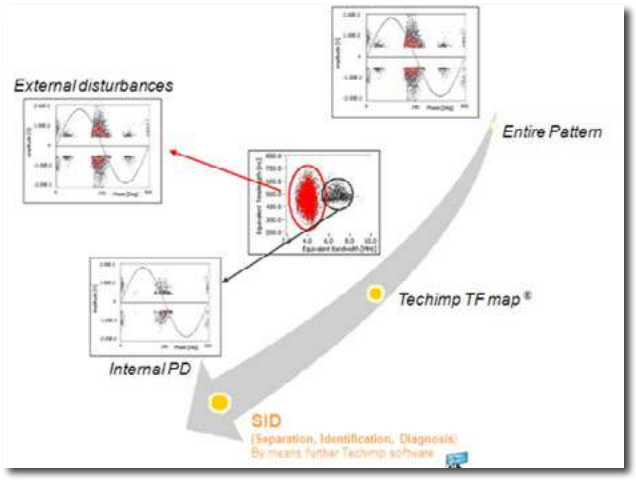
- Possible ingress of moisture and/or external contaminants

Advanced Partial Discharge Detection

- Proprietary TF Map technology
- Enhanced noise rejection through real-time pulse analysis
- Separation and classification of individual PD phenomena
- Time trends of PD parameters for each individual PD phenomenon, such as Qmax and repetition rate
- Distance to PD phenomenon

Benefits of TF Map Technology

- Phenomena separation (Noise, Disturbances, Multiple PD activities, etc.)
- Noise rejection
- Individual phenomenon identification and tracking
- PD Localization



Doble's Calisto Cable Condition Monitoring Solution

The Cable Monitoring solution is a permanently installed system that provides near real-time data on PD activity of the cables, accessories, and terminations. It is a modular system that includes:

- **PD Hub™** containing the PD acquisition unit
- Different kinds of **sensors** according to the type of application (HFCT, Clamp HFCT, Flexible Magnetic Coupler, TEV sensor)
- A central monitoring software **TiSCADA** that shows real time data, trends and current profiles and allows data analysis.

All of these elements are part of a flexible architecture that allows Doble to design the Cable Condition Monitoring system according to our customer requirements and integrate alarms into SCADA or other asset management systems.

Components

PD Hub™

The PD Hub is the core of the PD monitoring system and is available as a 3, 6, 9 and 12-channel device. Its UWB acquisition unit operates from 16kHz to 30MHz with a fast sampling rate of 100MS/s that captures the entire waveform of a large number of pulses. The TF Map allows the system to differentiate between different pulses with different shapes improving the signal to noise ratio and collect mainly pulses related to PD activity. The unit is powered and protected by a LV switchboard. The PD Hub is available in IP65 as well as IP68, where required. The PD Hub is typically installed close to the cable terminations and cable joints.

PD Hub

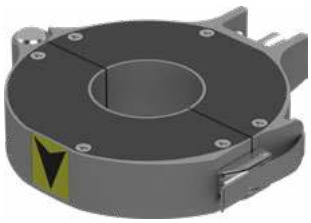
Calisto Cable Condition Monitoring Sensors

Several sensors are used to detect PD signals coming from inside the cable. The most often used type of sensor for cable PD monitoring is the HFCT. Doble's family of HFCT combine an excellent frequency response with robustness a long-lasting installation. At cable terminations, sensors are usually installed inside grounding boxes or directly on the ground connection cables at GIS or transformer termination. At cable joints, HFCT are integrated in the link-box either around the ground connection cables or around cross-bonding bars inside.

Doble offers a wide range of sensors:

- HFCT sensor Ø 30-50 mm
- HFCT clamp sensors Ø 39-140 mm
- FMC Flexible Magnetic Coupler
- TEV Sensor

HFCT sensor Ø 30-50-87 mm

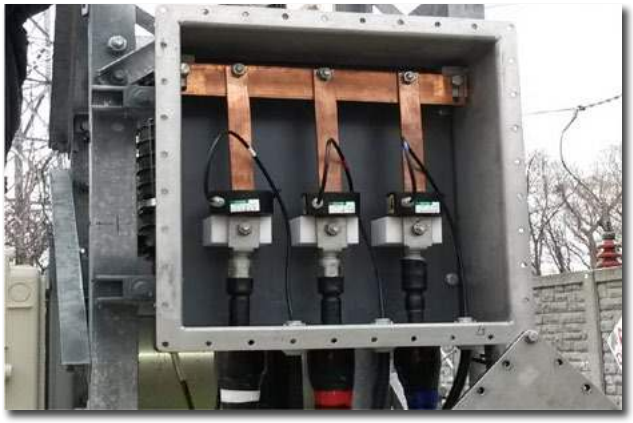


HFCT clamp sensor
Ø 39-140 mm

FMC Flexible
Magnetic Coupler

TEV sensor

HFCT Installations



HFCT installation on OUTDOOR TERMINATIONS, inside grounding box.

HFCT installation on SECTIONALIZED CABLE JOINTS, around ground connection cables inside link-box.

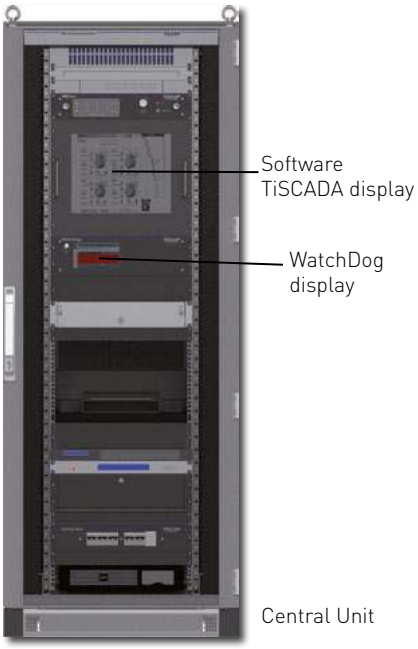
HFCT installation on SECTIONALIZED CABLE JOINTS, around ground connection cables outside link-box.

PPS Permanent Power Supply for PD HUB

PPS concept has been developed to allow permanent PD monitoring on HV cable joints when there is no LV power available at the manholes. PPS gets the required energy from the High Voltage power line being monitored by means of one or more toroidal units clamped on the HV power cable(s). PPS is able to continuously supply up to 60W @ 24Vdc when the HV cable is energized and allows to have a synchronization signal for the whole monitoring system. PPS is made up of two main devices: the clamp toroidal transformer (180mm diameter max) and the electronic controlled supply unit. Depending on the power level required from the PD system, the PPS is able to provide up to 60W using up to three clamp transformers.

Central Unit with Monitoring Software TiSCADA

The central unit is a 19" rack cabinet containing the server and the processing software. The server is an industrial PC with redundant hard drives and power supplies, to ensure maximum reliability. The software is supplied as virtualized system (Virtual Machine), so it can be easily restored and moved to other machines. The central unit can be provided with an UPS and a WatchDog unit as well.

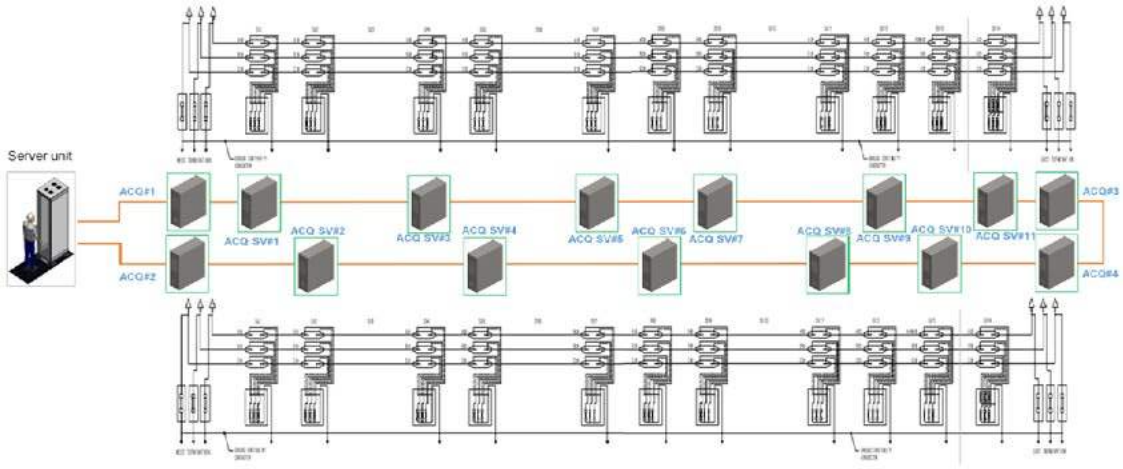


Fiber Optic Communication and LV Power Supply

The PD Acquisition Unit installed inside each PD Hub requires a 5 Vdc, 2 A max LV power supply. The PD Hub are typically powered by a low voltage power feeder through the protection switchboard installed inside the splice vault or at the termination. All PD Hub™ and the central unit are connected together by means of a fiber optic network.

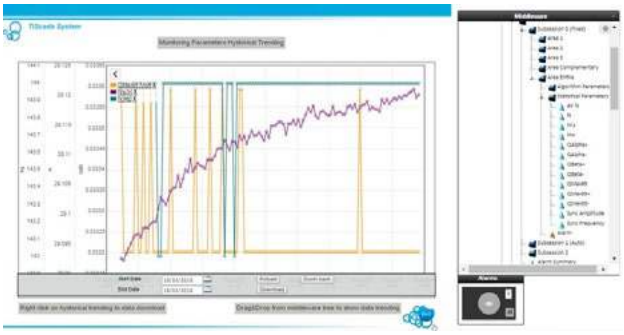
This network is made as a loop, in order to prevent a failure in the communication in case of interruption of one segment of fiber. The fiber can be either single-mode or multi-mode, terminated with ST connectors.

HV Cable Monitoring System Architecture



TiSCADA

The graphical interface of the Doble PD Monitoring System (TiSCADA) reports the status of the monitored electrical assets in a single screen. This screen allows operators to view any part of the insulation system affected by partial discharges. In addition, it is possible to analyze acquired data, to plot data trending, and to perform advanced queries to the Database (e.g. comparing data among equipment of the same plant, among the phases of the same EUT, the PD data can be correlated with the trend of other monitored quantities such as temperature, load, etc...). Thanks to the Web Server the graphical interface of the system can be accessed locally or by any other user connected (by means of LAN or modem) to the Central Control unit, with proper login credentials. Allowing maintenance personnel and asset management to access the PDM data with no need of dedicated software.



System Specification

PD SCOPE	
PD Channels	3 based UWB Channels (expandable to 6 or 12)
Bandwidth	16kH-30MHz, built in UWB filter (extendable to 1GHz with external Frequency Shifter, installed in the PDHub)
Resolution	10 bit
Input Impedance	50 Ohm
Recording time length	1 µs (min) 20 µs (max)
Connectors type	BNC
Sampling rate	100 MS/s

PD HUB	
Material	Steel, painted RAL 7035 (other colours and materials available)
Communication	Ethernet RJ45 and/or fiber optic ST
Protection degree	IP 65 - IP 68
Dimensions	600x600x221mm (PDHub-3&6CH) ; 800x800x250mm (PDHub-12CH)
Weight	Approx. 35kg (PDHub-3&6CH) ; Approx 50kg (PDHub-12CH)
Power requirement	50W MAX for standard configuration ; 220VAC 50/60Hz (other on request)
Working temperature range	Standard +5°C ÷ +50°C Extended with heating option: -20° ÷ +50°C Extended with cooling option: +5°C ÷ +65°C Extended with heating and cooling option: -20°÷ +65°C

HFCT PD sensor (Ø 30mm)	
Bandwidth (-6dB)	1MHz ÷ 60 MHz
Max sensitivity (Vout / Iin at 42 MHz, 50 Ω load)	17 mV / mA
Load impedance	50 Ω
Hole dimension	Ø 30.5 mm
Operating temperature	-20°C ÷ +70°C

HFCT PD sensor (Ø 50mm)	
Bandwidth (-6dB)	1MHz ÷ 80 MHz
Max sensitivity (Vout / Iin at 42 MHz, 50 Ω load)	15 mV / mA
Load impedance	50 Ω
Hole dimension	Ø 50 mm
Operating temperature	-20°C ÷ +70°C

HFCT PD sensor (Ø 87mm)	
Bandwidth (-6dB)	0.3MHz ÷ 15 MHz1
Max sensitivity (Vout / Iin at 1 MHz, 50 Ω load)	10 mV / mA
Load impedance	50 Ω
Hole dimension	Ø 87 mm
Operating temperature	-20°C ÷ +70°C

CLAMP HFCT PD sensor (Ø 39mm)	
Bandwidth (-6dB)	1MHz ÷ 80 MHz
Max sensitivity (Vout / Iin at 42 MHz, 50 Ω load)	15 mV / mA
Load impedance	50 Ω
Hole dimension	Ø 39 mm
Operating temperature	-20°C ÷ +70°C

CLAMP HFCT PD sensor (Ø 140mm)	
Bandwidth (-6dB)	2MHz ÷ 100 MHz
Max sensitivity (Vout / Iin at 42 MHz, 50 Ω load)	10 mV / mA
Load impedance	50 Ω
Hole dimension	Ø 140 mm
Operating temperature	-20°C ÷ +70°C

FLEXIBLE MAGNETIC COUPLER sensor	
Bandwidth	500 kHz – 50 MHz
Working principle	Inductive coupling
Overall Dimensions (High Voltage version)	500 x 120 x 10 mm
Connector	BNC
Power Supply	Needed only for optional devices
Installation	Tied to the cable near cable joint or cable terminal
Operating temperature	-20°C ÷ +65°C

Permanent Power Supply (PPS)	
Max output power	60 W (using up to 3 toroids)
Output voltage	24 Vdc ±5%
Output current	Up to 2.5 A
"Power Good" signal	Open collector, <24Vdc, <20mA
Synchronization signal (V)	15 Vp/p, square wave
Sync phase shift respect primary current	6°±5°
Supply current	0 ÷ 2kA (per phase)

About Doble Engineering

The team at Doble ensures reliable, safe and secure power for all. We do this by providing comprehensive diagnostics and engineering expertise for the energy industry.

Founded in 1920, Doble is committed to the continuing education of our customers, and the support and training of the next generation of power industry workers – uniting the utility sector for an innovative future.

Doble is part of the Utility Solutions Group of ESCO Technologies Inc. (NYSE: ESE). For more information, visit: www.doble.com, follow us on Twitter @doble and connect on LinkedIn.

Doble Engineering
Worldwide Headquarters
123 Felton Street, Marlborough, MA 01752 USA
tel +1 617 926 4900 | fax +1 617 926 0528
www.doble.com

PUBLISHED: SEPTEMBER, 2022