Partial Discharge Monitoring

How to increase both electricity supply integrity and customer satisfaction, by improving maintenance quality but reducing maintenance cost.

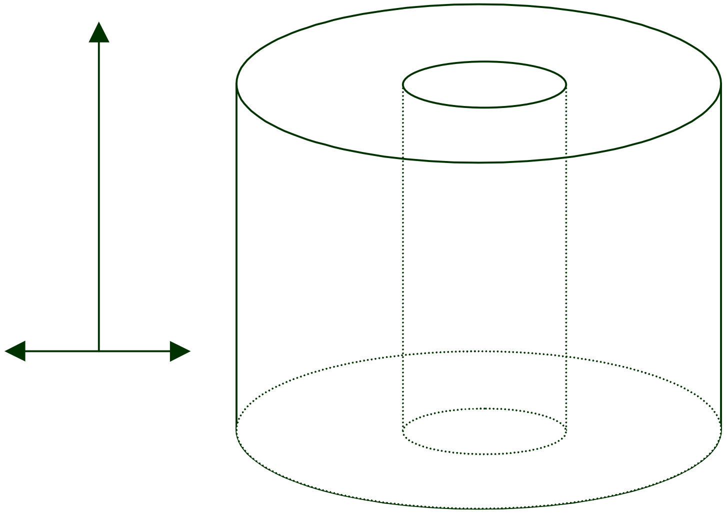
Partial Discharge (PD) - Background

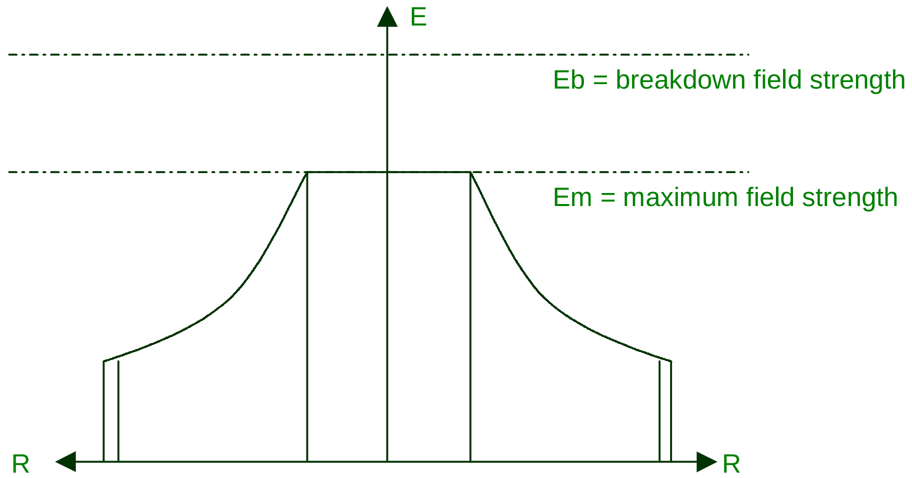
What is Partial Discharge? Why does it happen? So what happens?

What is Partial Discharge (PD)?

PD is an electric discharge which only partially bridges the insulation between conductors.

For example consider a perfect cable:



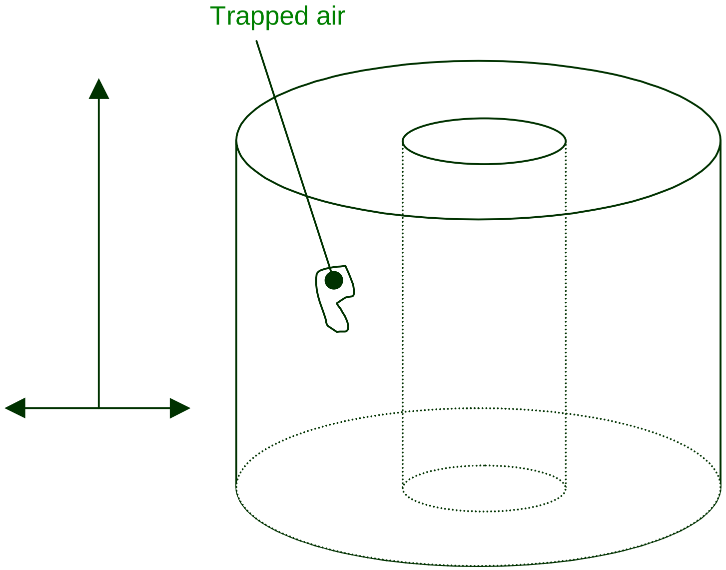


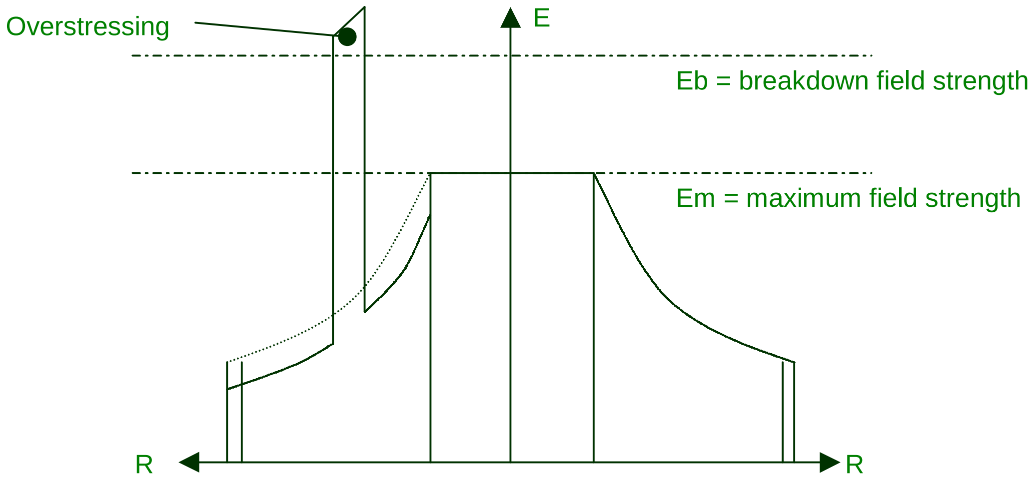
Cables are designed to withstand their expected maximum field strength (Em) which includes operational stresses such as transient loading.

Eb is the breakdown strength which, if exceeded, produces catastrophic failures.

Why does it happen?

In the real world our cable may have minor imperfections. Consider a small void occurring in the solid dielectric:





The presence of the void will cause an asymmetry in the field (hence the lower field strength), and when partial discharge occurs across the void a high energy spike occurs forcing the field beyond the cable's design strength.

It is for this reason that all HV cables are tested for PD during manufacture using a variety of laboratory and production test methods. (Ref. 'Partial Discharge Measurements' IEC Publication 270). However, these tests are not suited to an operational environment, and international standards avoid defining any relevant quantitative methodology.

Partial Discharge occurring in service comes as a result of ageing, operational stresses and minor imperfections in manufacture becoming more significant with time.

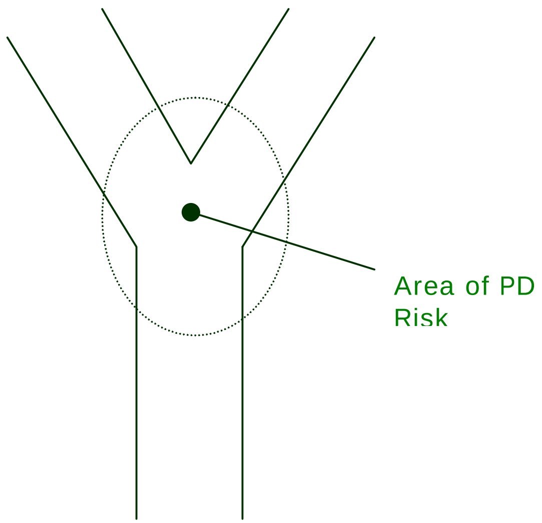
So what happens?

Most distribution companies recognise PD as the main cause of long term degradation in HV insulation and contacts.

The range of equipment PD occurs in is very diverse. However, two manifestations are without doubt the most common:

'Y' crutch cable Joint

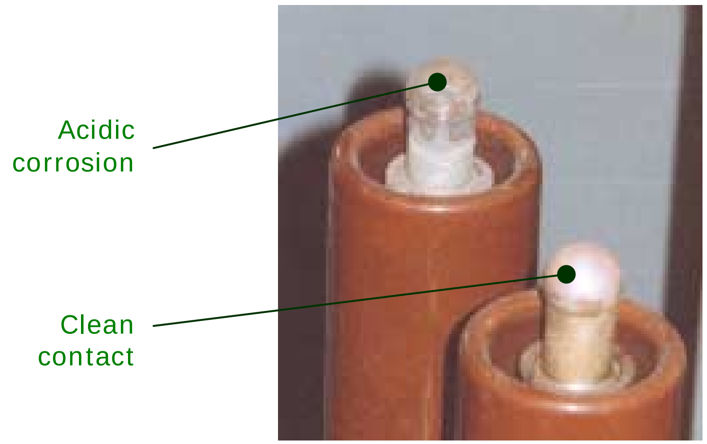
An HV cable entering the back of a switchboard is split by splicing and adding more insulation. This process is prone to manufacturing error and is a source of classic 'gas filled void' failure.



Result: Mechanical stress resulting in cable bursts (insulation explosion) if not detected.

HV Contactors

PD between the contacts causes the breakdown of air into nitrogen and oxygen, recombining to form nitric acid.



Result: Failure due to chemical corrosion and deposition of metallic oxides, causing busbar dropouts and loss of supply.

Impacts on an electricity supplier

The operational implications of PD on commercial generators and distributors

What operational problems are caused by Partial Discharge or its lack of monitoring?

- Supply outages are an immediate customer quality judgement
- Supply outages may carry financial penalties from major customers
- Routine time-interval maintenance is required as a preventative method
- Emergency maintenance call-out is required
- Quality of maintenance is indeterminate
- Lockouts or downtime is required for unnecessary maintenance
- Potential catastrophies are rarely detected
- Accidents happen (fires, physical damage, personnel risk)

Possible solutions

There are several technologies to monitor PD, but which way gives optimum information and minimum operational intrusion in a maintenance environment?

What methods are available and what are their relative merits?

	Parameter	Method	Deployment	Benefits	Disadvantages	Noise susceptibility
1.a	Voltage drop	Decoupled via electric field using coupling capacitor (IEC-270)	Direct connection to HV	Calibrated to a recognised standard. Can be induced during maintenance outage	Direct connection to HV. Needs a coupling capacitor. Maintenance outage for installation.	Very High
1.b	Voltage drop	Decoupled via electric field using 'free' capacitor	Indirect but 'hot-stick'	In-service test without direct connection. Easy inspection	Poor sensitivity. Poor directionality. Won't work outside shields. Instant fault only	Very high
3	Current impulse	Decoupled via magnetic field using coupling inductor	Indirect but physical contact to ground wire	In-service test without direct connection. Easy inspection. Sensitive	Poor directionality. Won't work outside shields. Needs direct access to ground cable.	High to wideband.
4	UHF	High attenuation properties of insulation to locate source of UHF	Non-contact but 'hot-stick' very close to conductor.	In-service but safe working practice required. Good locational accuracy.	Requires access to insulator surface. Very localised signal. Won't work outside most shields. Instant fault only. No calibration.	Very Low
5	Ultrasonic	Airborne ultrasonic emissions to detect relative levels of PD	Non-contact and remote.	In service testing. Can be very remote (10's of m). Easy inspection. Works through air-gaps in shields. Also detects corona discharge.	No *absolute* calibration possible. Locational accuracy is iterative. Needs acoustic line-of-sight (i.e. an air channel).	Low
6	Light flash	Detects UV radiation	line-of-sight positioning	In-service testing without direct connection.	Needs visible line-of-sight to source of PD.	Very Low
7	Chemical dissipation	"Gas in Oil analysis"	Laboratory analysis	'Forensic' analysis available	Primarily a research tool	N/A

ULTRASONICS is the maintenance solution

Whilst there are accurate measurements available for PD analysis, their application to the maintenance environment is severely limited and their accuracy is unnecessary. Solutions for production testing during cable manufacture do not immediately translate to the maintenance environment.

E2L have developed equipment specifically for the management of PD driven maintenance. Close working with UK based power distributors (MANWEB and Scottish Power) have proven ultrasonics to be a successful solution over other methodologies.

- In-service deployment without any supply outage
- Very rapid installation (12 contactor system should take <10 minutes)
- Catches PD events over a time period (hand-held equipment often misses this)
- Remote, safe monitoring
- Very low susceptibility to external noise
- Strategies developed to filter discrete noise events
- GO/NO-GO test
- Simple to use – minimum training required for maintenance operators
- Fine tuning available based on environmental experience
- Low cost compared with other technologies

ULTRASCAN – PD monitor for HV maintenance

A brief overview of the ULTRASCAN solution (the portable version is described here)

Deployment

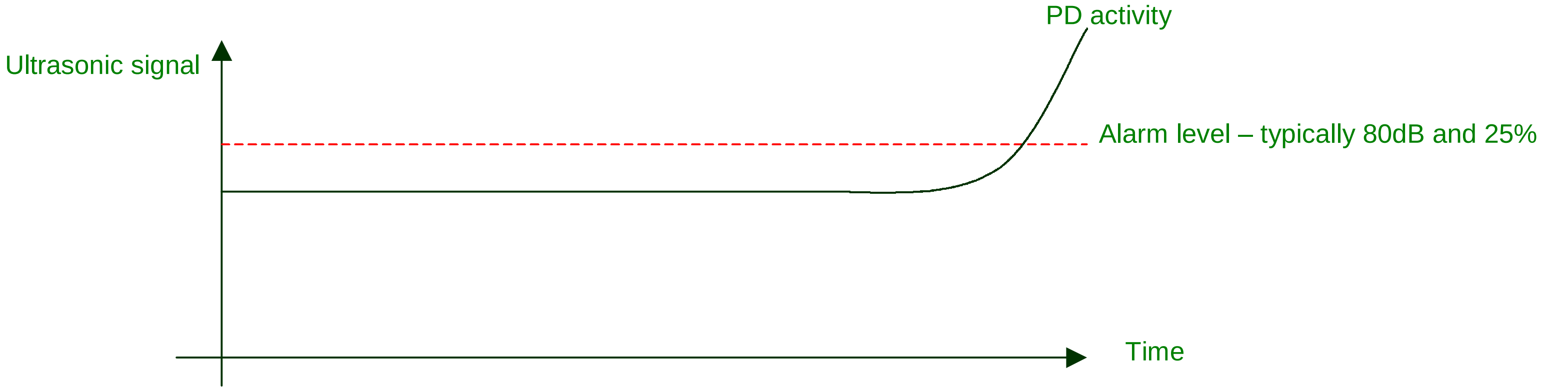
- Probes are directed at airgaps in the switchgear housing and clamped using magnetic mounts.
- All the probes are networked using an intelligent bus system.
- The system can be assembled in any order.
- The final bus connection terminates at the ULTRASCAN control unit.

Operation

- Once connected the system performs a self search to determine its configuration (TEST mode).
- When all the probes are found the unit scans them at one second intervals.
- Alarms are induced using an ultrasonic transmitter
- When all probes are proven then the controller is put into RUN mode
- A count-down starts which allows the room to be evacuated
- When RUN starts each probe is accessed in turn and sampled for a dwell time
- If any unit is alarmed then it is displayed on the screen and a general alarm light is lit.
- After the predefined time period the test stops (1 to 48 hours)
- If the unit is interrupted then the results are kept, less the same evacuation time as at the start.

Noise and threshold parameters

- From twelve years of industrial tests on prototype equipment the gain and threshold figures have been nominally defined. These are a gain of 80dB and a threshold of 25%. Depending on the operator's standard switchboard environment these may need to be changed, but our experience suggests these are a good working value.



- The nature of PD activity in service is that it gives bursts of several minutes duration. Any spurious or Impulse noise can be eliminated by increasing the dwell time of each probe (i.e. the integration time). From working practice 2 seconds seems an optimum time, but could be extended to 60 seconds.
- If impulse noise is sufficient to trigger an alarm condition then there is a secondary filter based on the number of consecutive times this occurs before the alarm is registered. The default for portable units is 3 but could be extended to 8 consecutive samples.
- All alarms are recorded in non-volatile RAM and can be downloadable at the end of a test along with the system parameters.