Partial Discharge Testing on 4kV Rotating Machines

Is it worth it?

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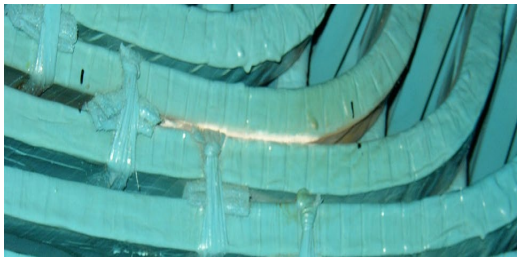
Partial Discharge

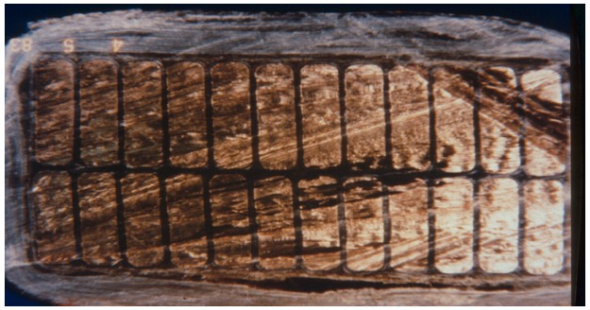
Security System for 4kV Stators?

- **Effectiveness**
  - Problems for 4kV assets
  - Why is PD a symptom?
  - How to detect PD effectively?
    - What works
    - Potholes to avoid
  - What does the PD tell you?
- **Economics**
  - Redundant or Spare

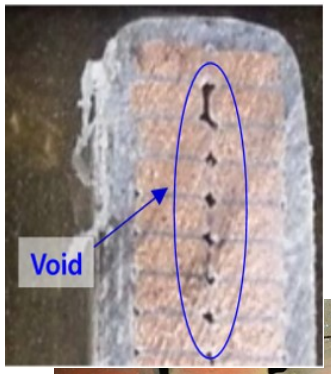
Common 4kV Stator Problems



Phase to Phase



Thermal Stress



Interturn & Slot exit – VFD!

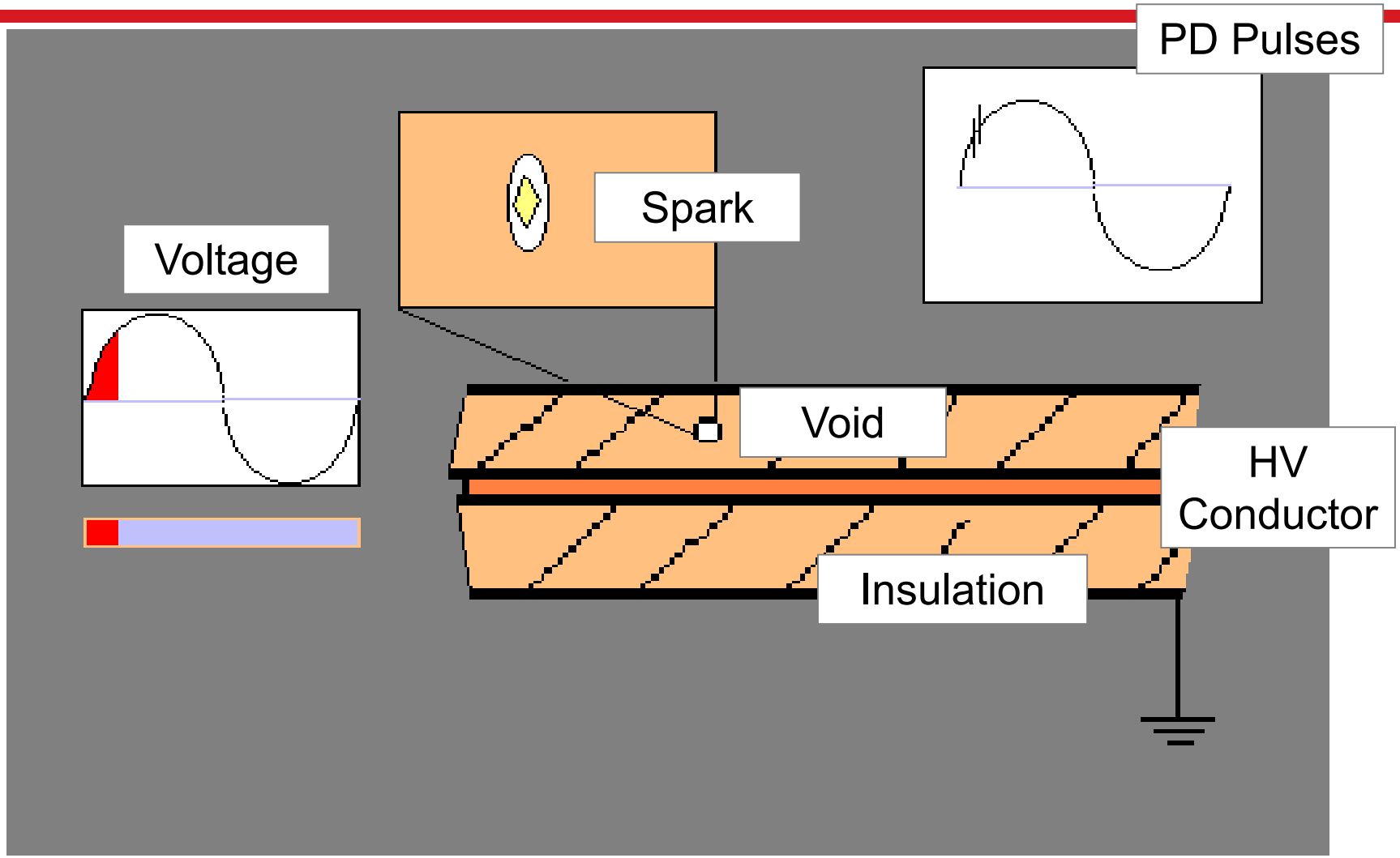
Tracking

Leads

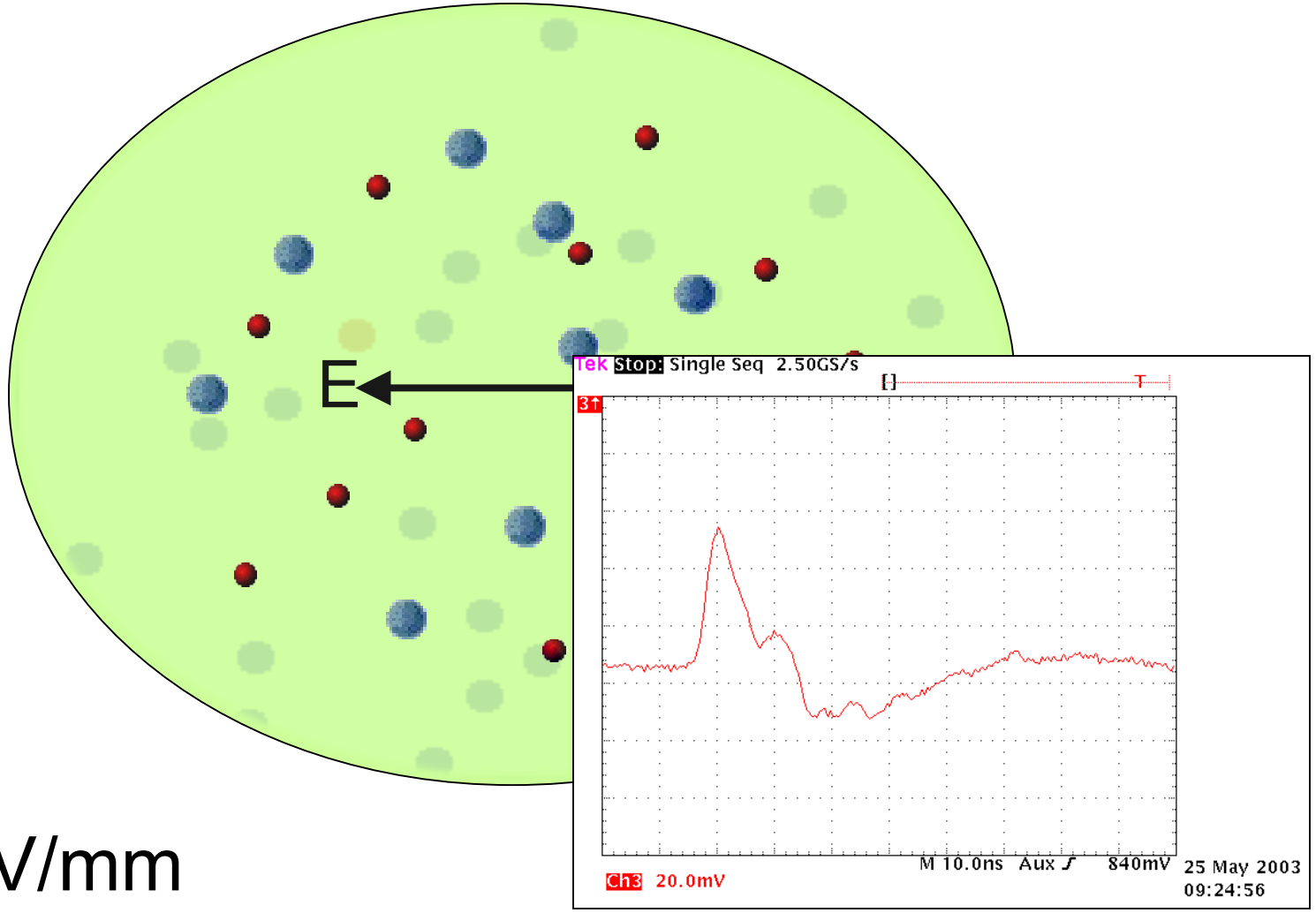
Good news: Mica-based Insulation

PD Resistant
Thermal withstand

Why is PD a Symptom?

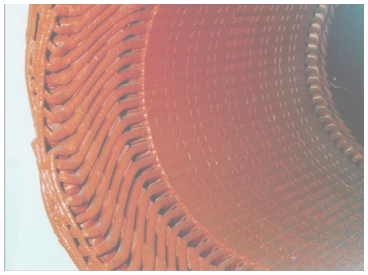


Why is PD a Symptom?



> 3kV/mm

PD Detection: 4kV Motors



Mid 1980's

- Was PD detectable on 4kV motors - Yes
- Was it suitable for a CBM program?
  - Time to failure: detected low PD on a motor and it failed a few weeks later
  - If the motor had a ready spare, was it economically advantageous?

2000's to Today

- PD monitoring successfully used for CBM
- PD used to evaluate VPI penetration
- PD used to monitor failure processes

PD Detection - Online

- Normal Stresses
  - Voltage
  - Load
  - Temperature
  - Ambient conditions
- Early detection
  - Thermal deterioration
  - Coil/bar movement
  - Interphasal
  - Leads
  - Contamination
  - Manufacturing issues
  - ….

IEEE 1434 – practical guide
IEC 60034-27-2 – on-line testing

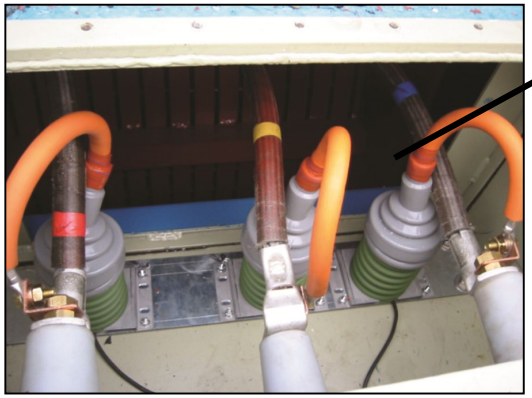
PD Detection - Continuous

Termination Box

DCS

Alerts
Data

80pF sensors



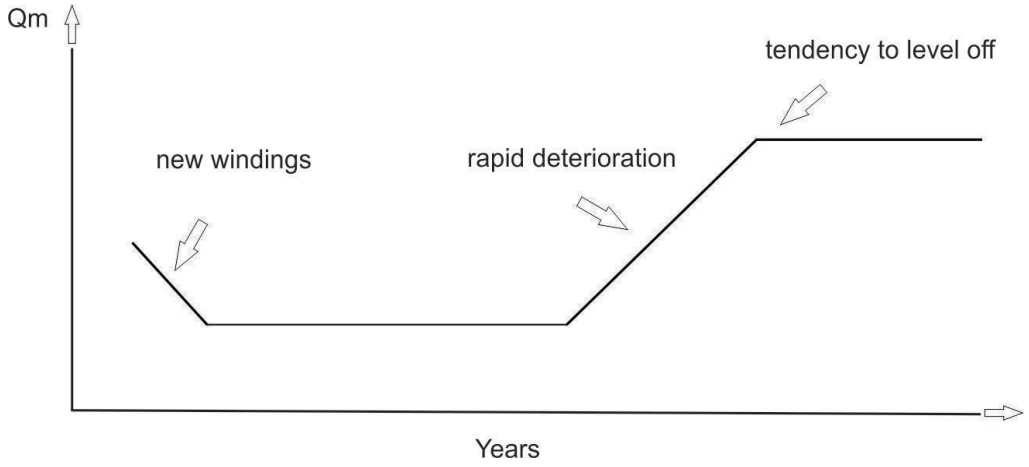
Trends
Alerts
USB Data Access

PD Instrument

PD Trends – 4kV

Long-term Trends

- Purpose
  - Discernible upward movement
- Characteristics
  - Erratic first 12-18 months
  - May stabilize once high



- Repairs may reduce PD
- Can't predict failure

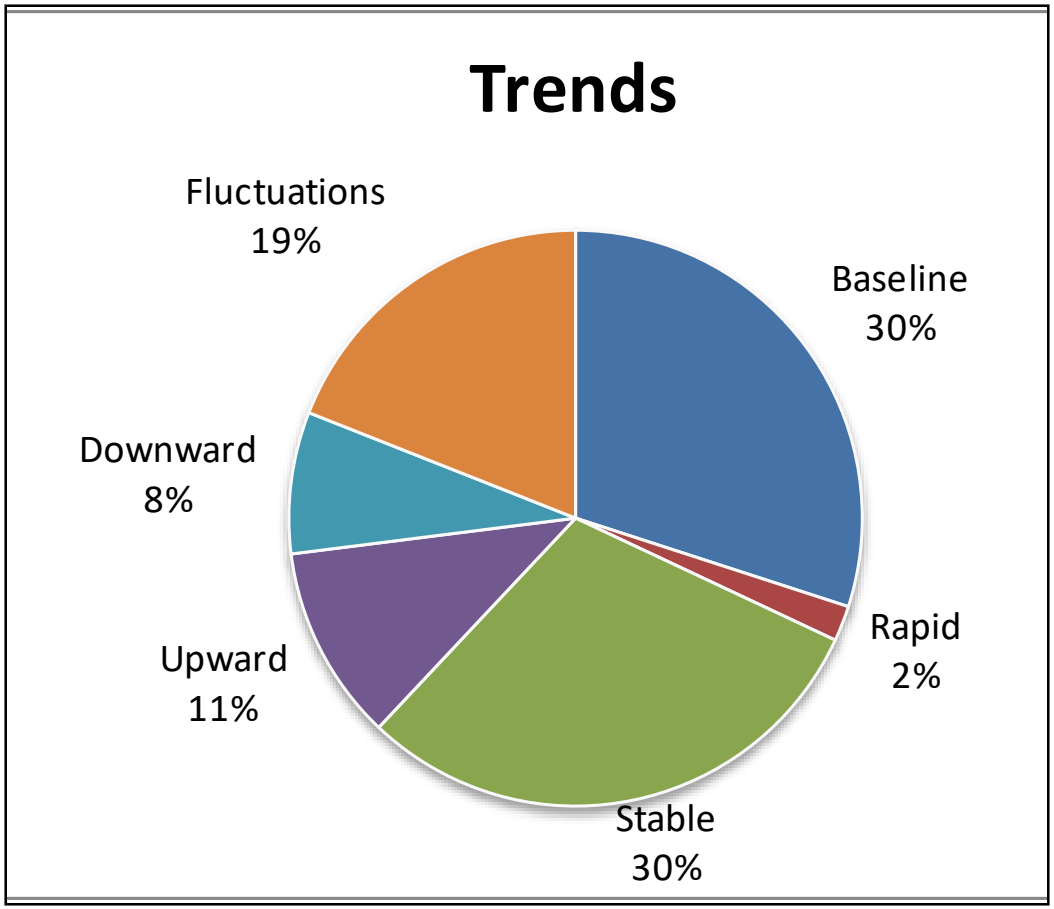
PD Trends – 4kV

Long-term Trends – 200 evaluated

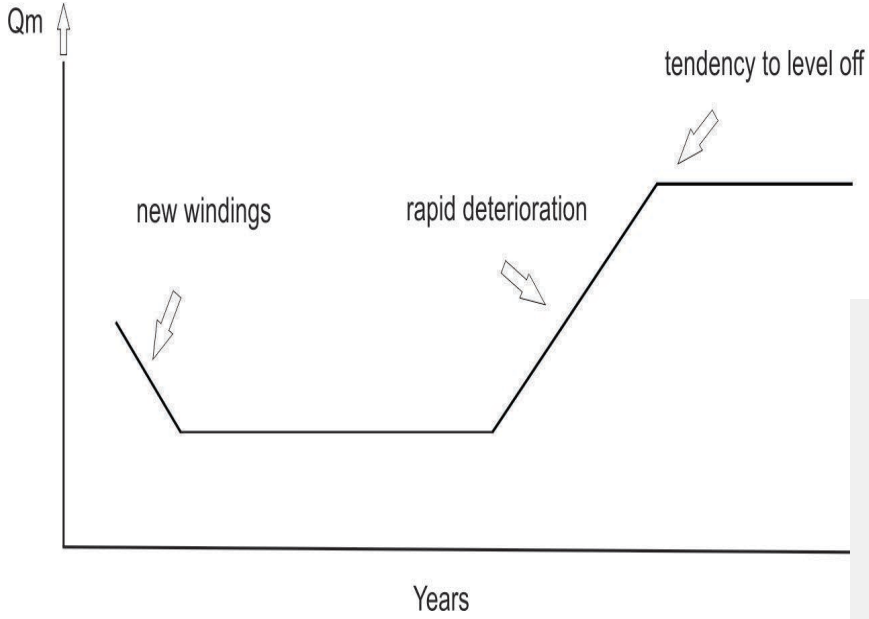
Fluctuations 19%

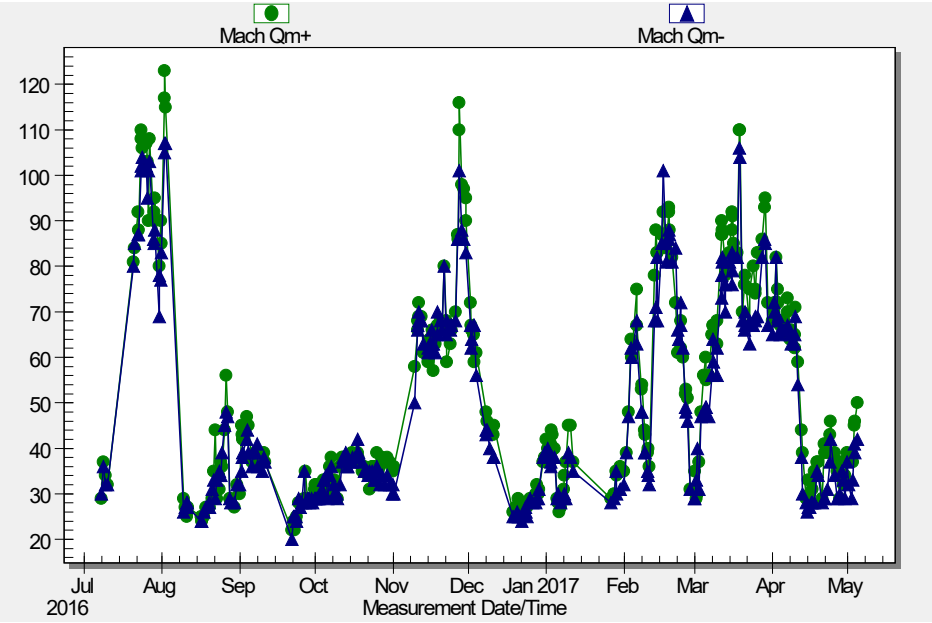
Upward 11%

Rapid 2%



Why Spot-trends aren’t enough?



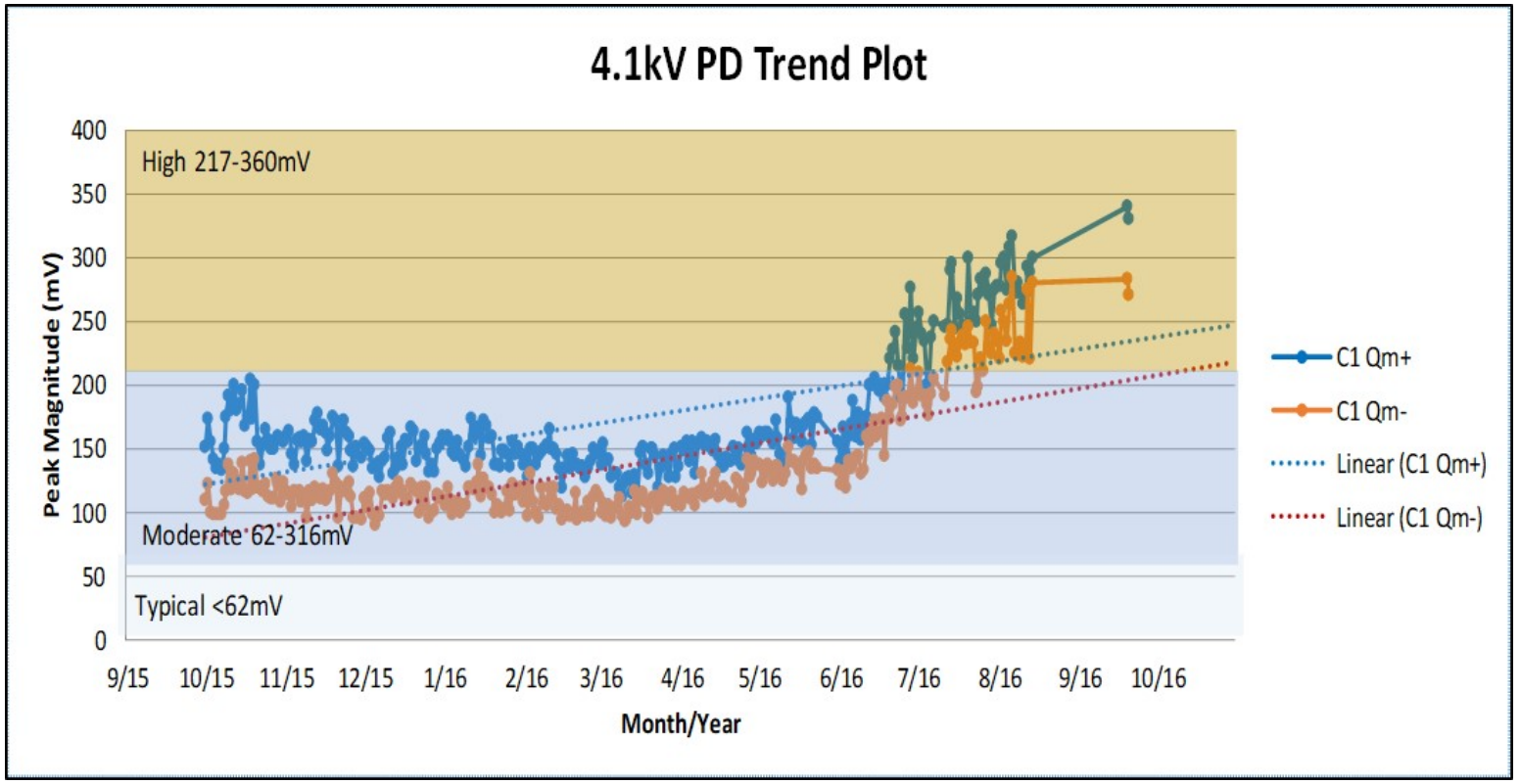


Erratic
Need continuous

80pF sensors at the Terminals

	Rated kV	3-5
Negligible	**25%**	8
Low	**50%**	22
Typical	**75%**	62
Moderate	**90%**	216
High	**95%**	360

Trend & Magnitude



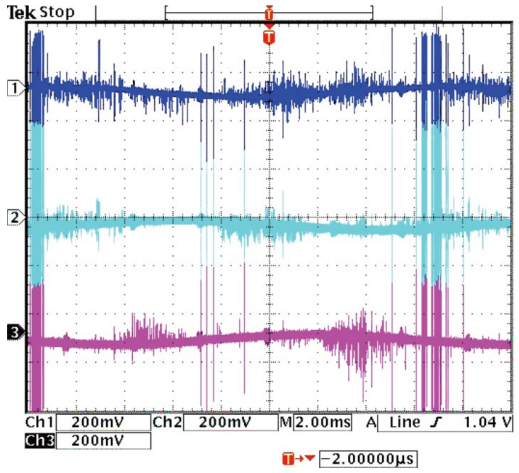
Potholes to avoid

1. Wrong measuring bandwidth
2. Surge protection
3. Infrequent investigation

Measuring Bandwidth

- Low frequency, LF -below 3 MHz (offline)
- High frequency, HF – 3 to 30 MHz (cables)
- Very high frequency, VHF – 30 to 300 MHz
- Ultra high frequency, UHF – 300 to 3000 MHz

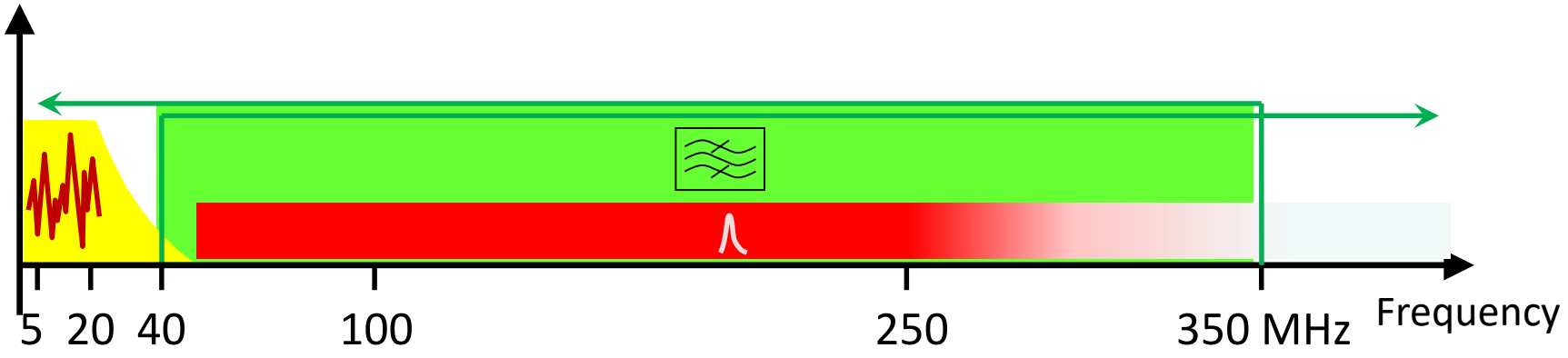
Noise & Disturbances
On-line



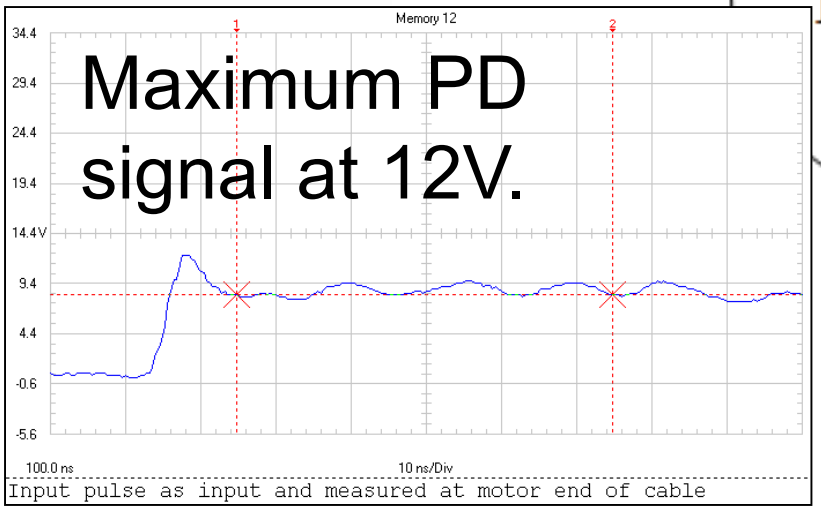
Which Bandwidth is best online?

- Sensor at HV coils/bars where PD occurs – most in 50-350 MHz bandwidth
- Signal-to-Noise Ratio (SNR) increases with the bandwidth up to ~400MHz (upper limit of PD)

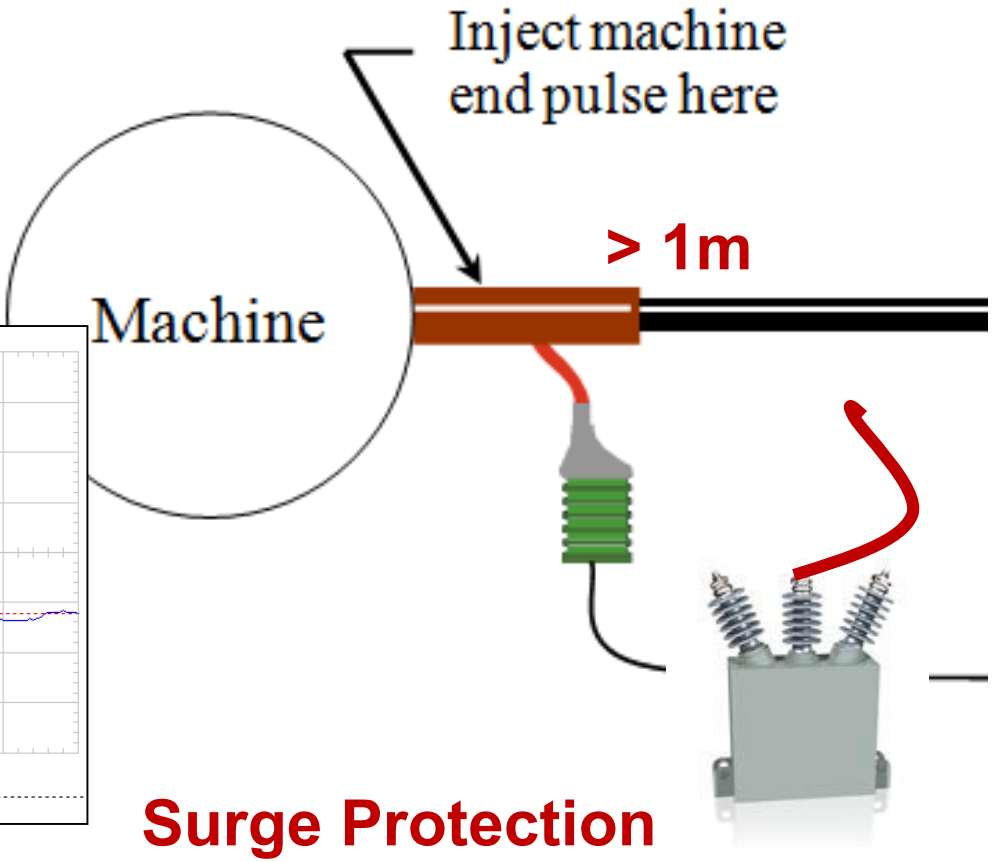
Very high frequency, VHF – 30 to 300 MHz
Ultra high frequency, UHF – 300 to 3000 MHz



Surge Protection

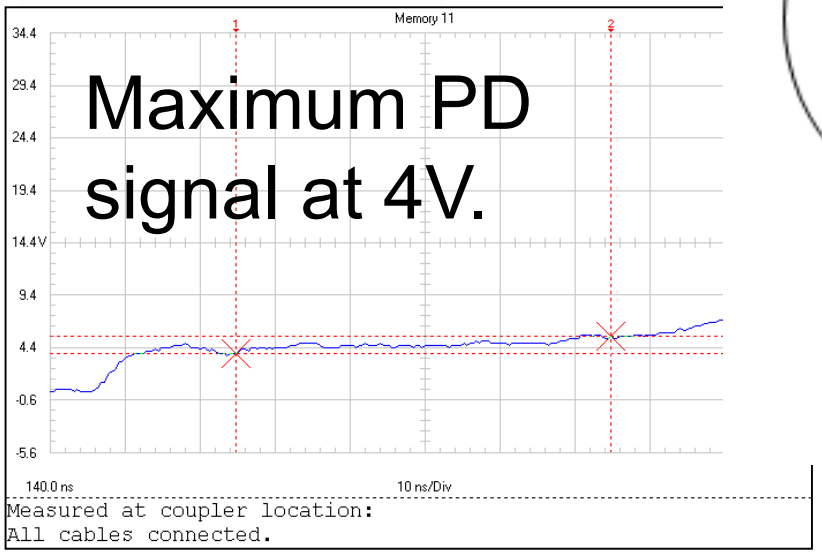


Maximum PD signal at 12V.

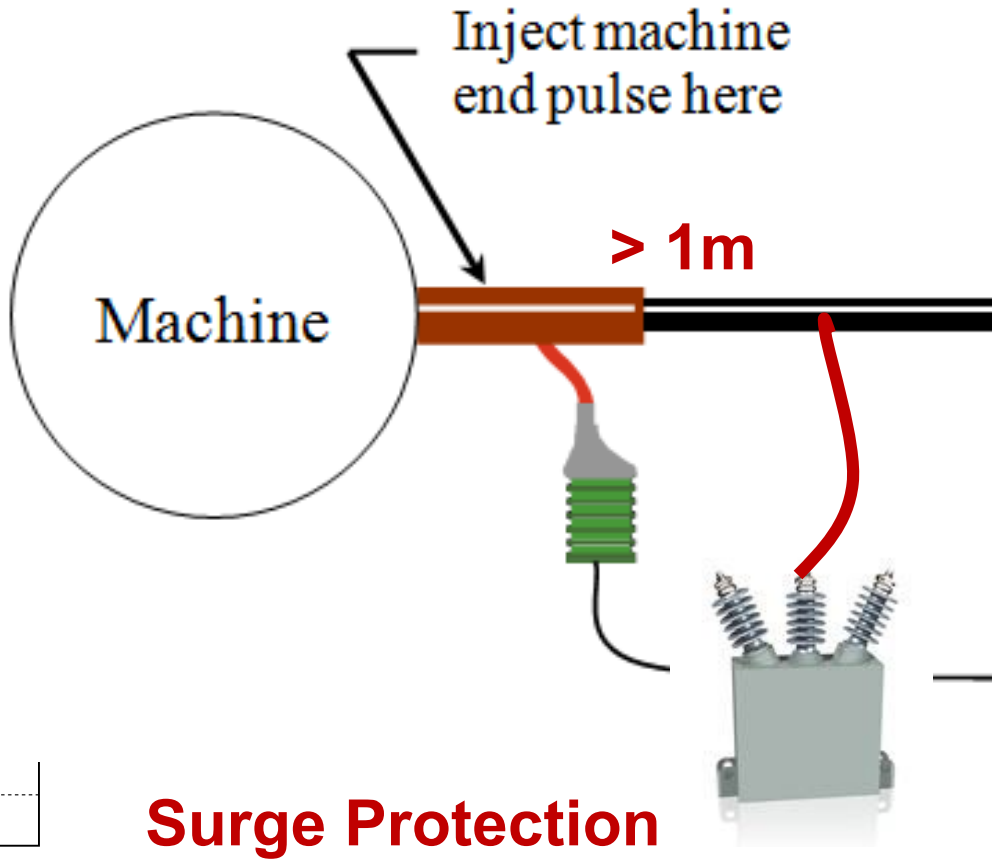


Surge Protection

Surge Protection



Maximum PD signal at 4V.

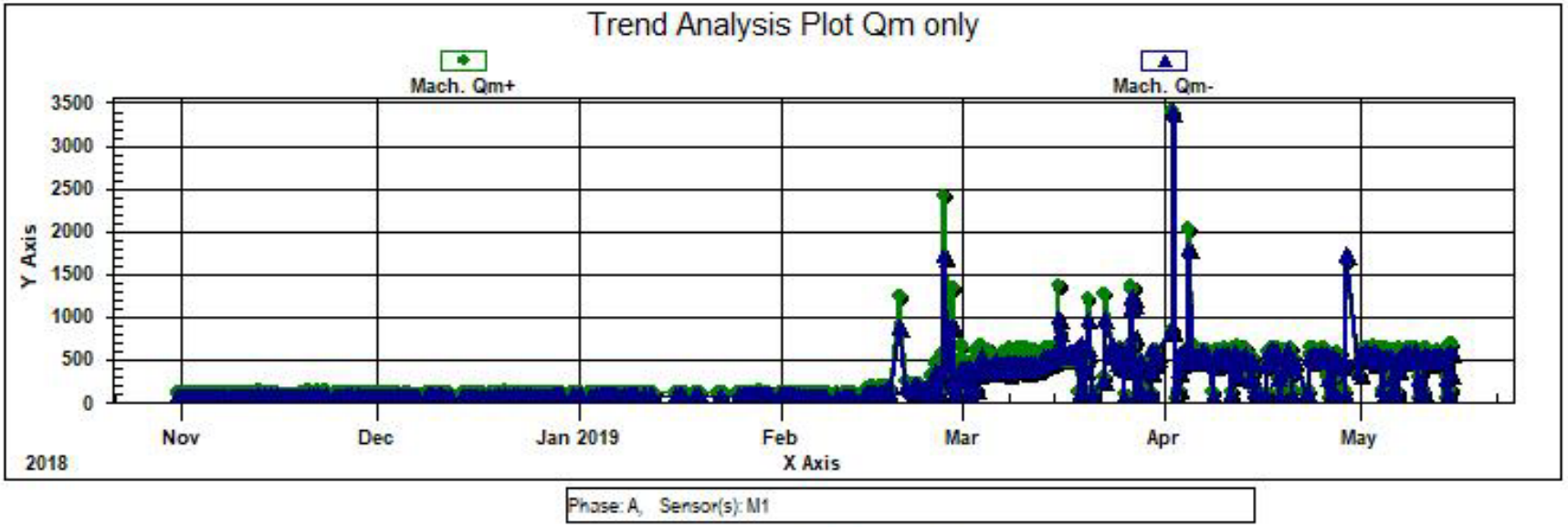


Surge Protection

Infrequent Investigation

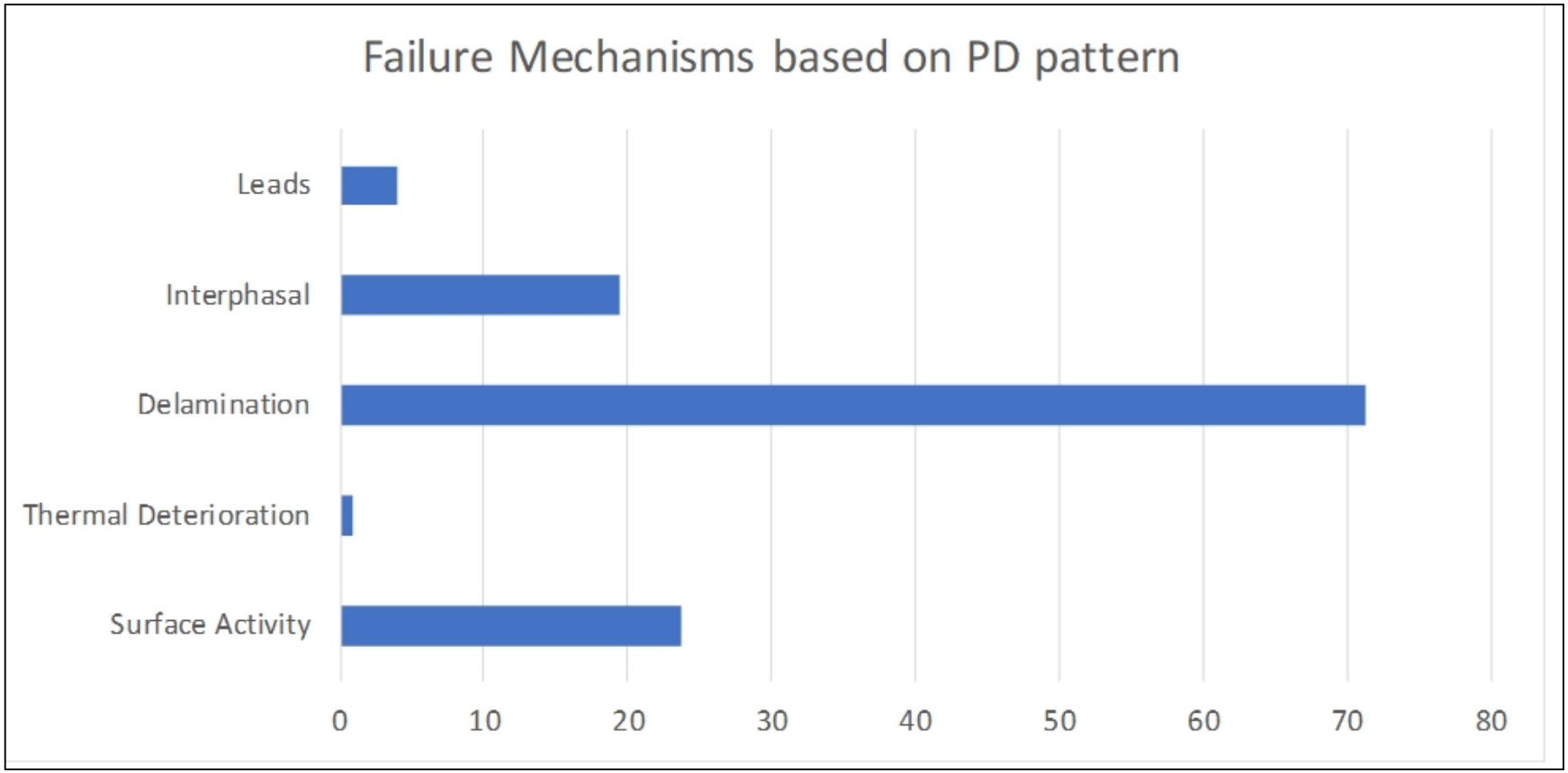
PD appearance to failure

Only 3 months



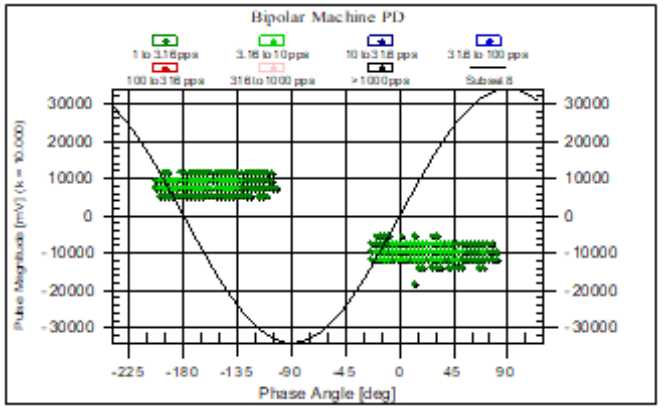
What the PD tells you?

PD Patterns – 200 evaluated



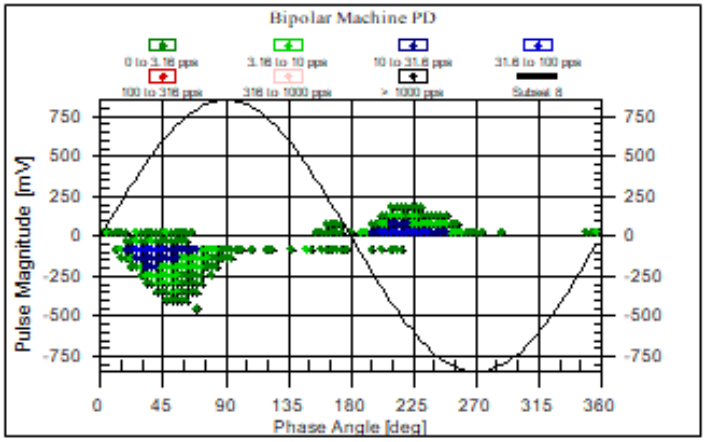
Leads

- Common cause of failure
  - Leads
- Phase-to-phase
- Volatile with humidity
- Cloud??



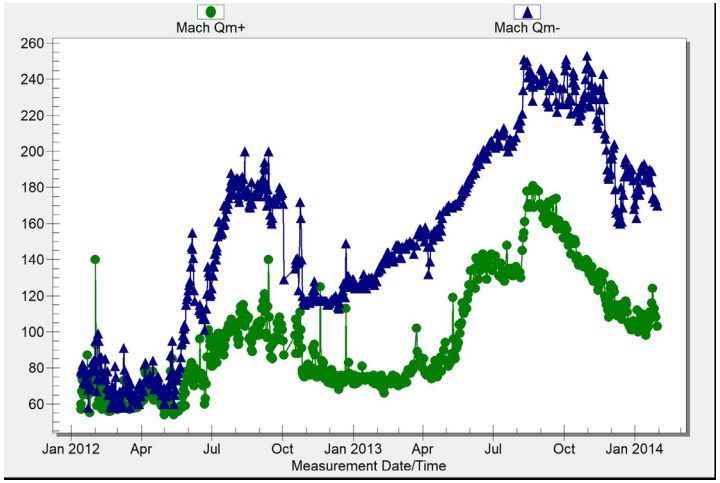
Thermal Delamination

- Common cause of failure
  - Surge of damaged interturn
- PD if part of groundwall "circuit"
- Negative PD



Surface Activity

- Common cause of failure
  - Electrical Tracking
- Volatile with humidity
- Upward/Downward
- Polarity predominance – Negative or Positive



Effectiveness for 4kV

- Several hundred machines currently being monitored
- Consider coupler installation – surge protection
- Continuous instrument with active alerts
- Single measurement evaluation
  - >90% investigate
  - For 4kV, we recommend >75%
- PD Trends
  - Look for changes up or down
  - Ambient condition influence

> 75% or change (mag or pattern) ⇒ investigate

Economics

- One question:
  - **Does it make a difference if a 4kV stator fails without warning?**
    - Spare available?
    - Redundant?
    - Some problems can be “fixed”

- Investment:
  - **Sensors – typically less than 10k per machine**
  - **Instrument – typically less than 20k per machine**
  - **Installation – 2 days**

Your call – is it worth it to you?

Thank you

And good luck keeping your machines running