
Partial Discharge Testing: A Progress Report

Anthology of Previous Papers

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What Are Partial Discharges?

- Small electrical sparks in air-filled cavities in or adjacent to HV electrical insulation
- Occur because breakdown strength of
 - air (**3 kV/mm**) < solid insulation (**~300 kV/mm**)
- PD creates small voltage pulses
 - PD monitoring measures these small pulses



Standardization

- **Sensors**
- 80pF capacitive couplers
- stator slot couplers
- RFCT

- **Test Set-up**
- High SNR
- Noise elimination

PDA-IV™

TGA™

Portable instruments only

- 27,000 coupler installations

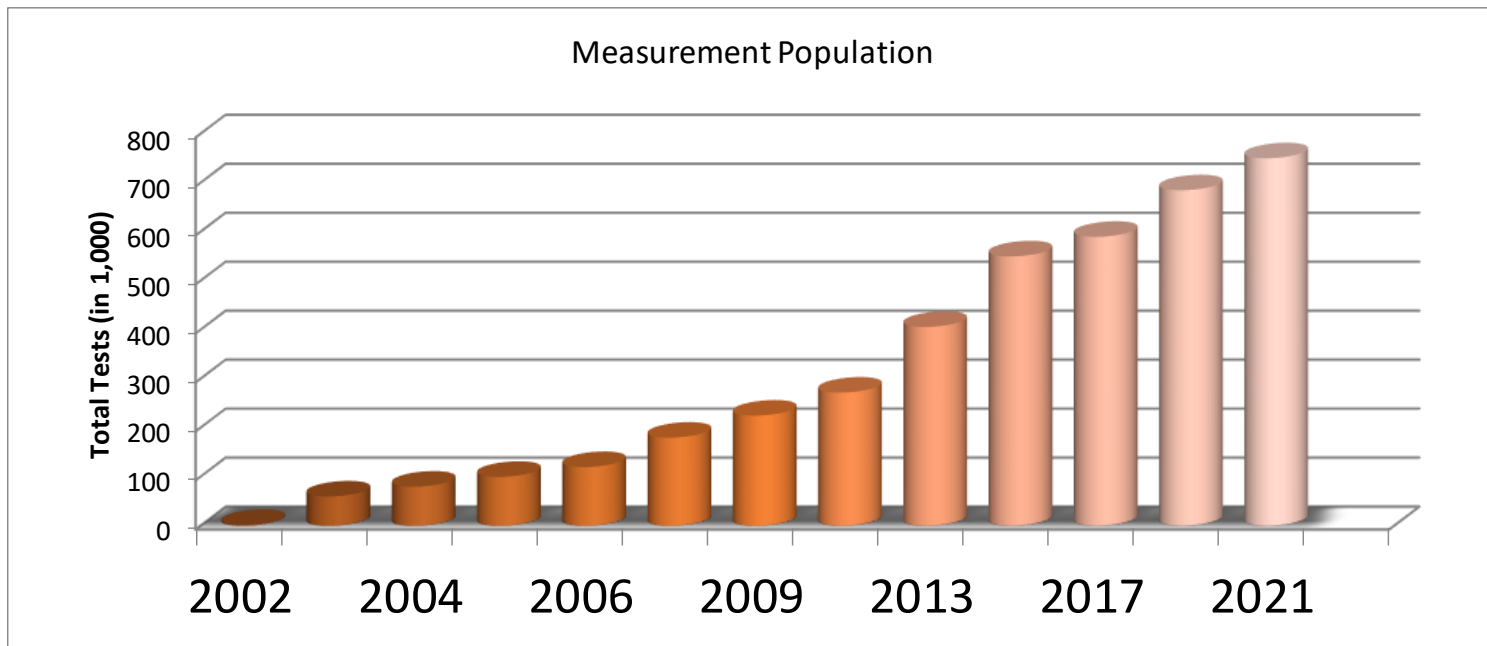
- **8,500 machines in database**

Data Analysis (> 750,000)

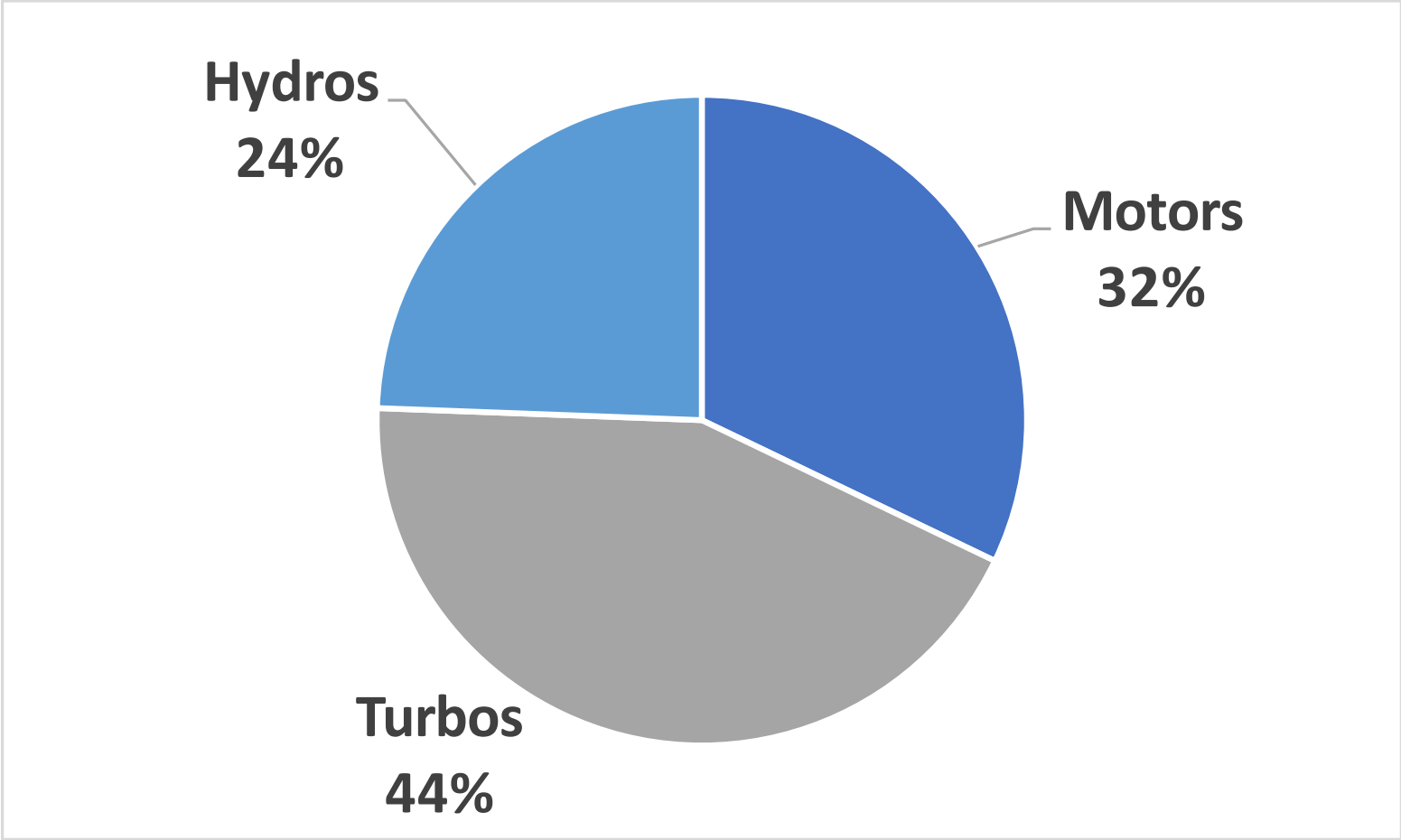
- **Full load hot tests online**
 - VHF and disturbance separation
- **Data separated by**
 - Coupler installation type
 - insulation
 - voltage class
 - gas coolant pressures
 - manufacturer

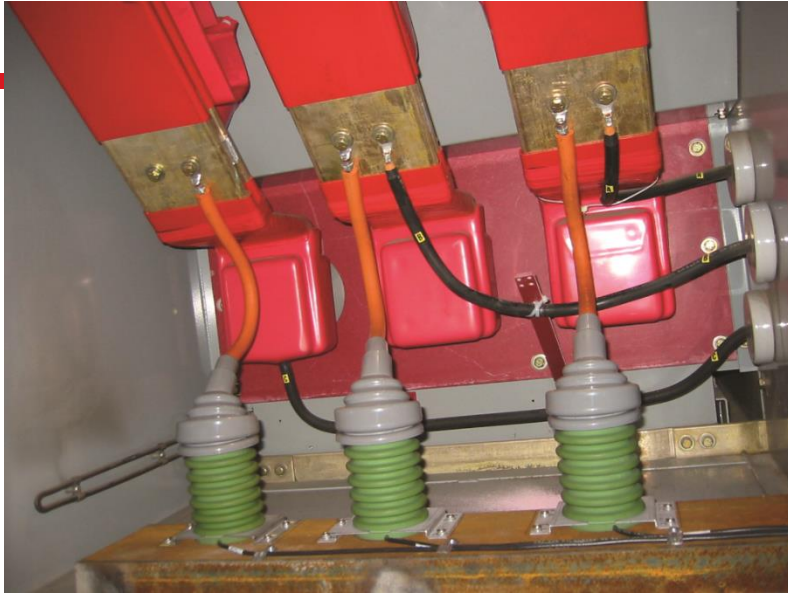
Statistical Database

- Population
 - 750,302 measurements for 2021 database
 - High temperature and high load measurements



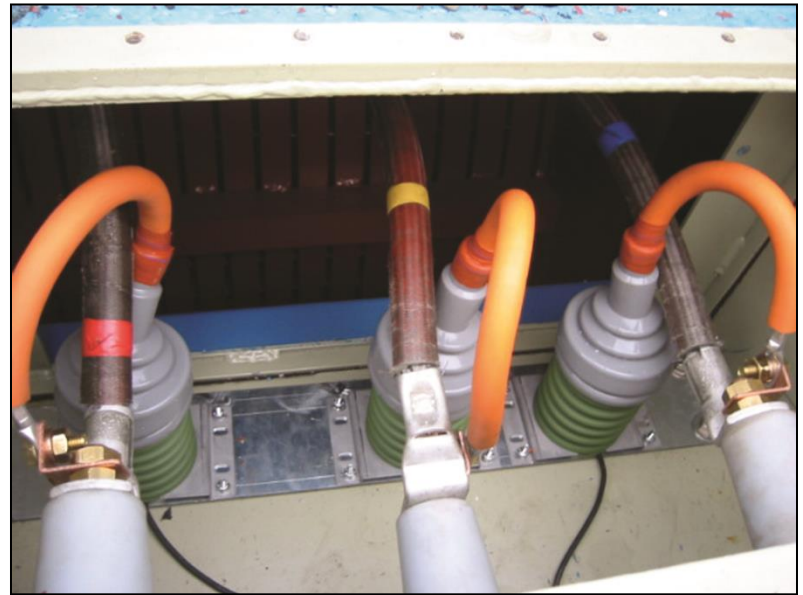
Data collected through 2021





Turbos

80pF sensors



Motors

80pF sensors at the Terminals

Average over the 25 years

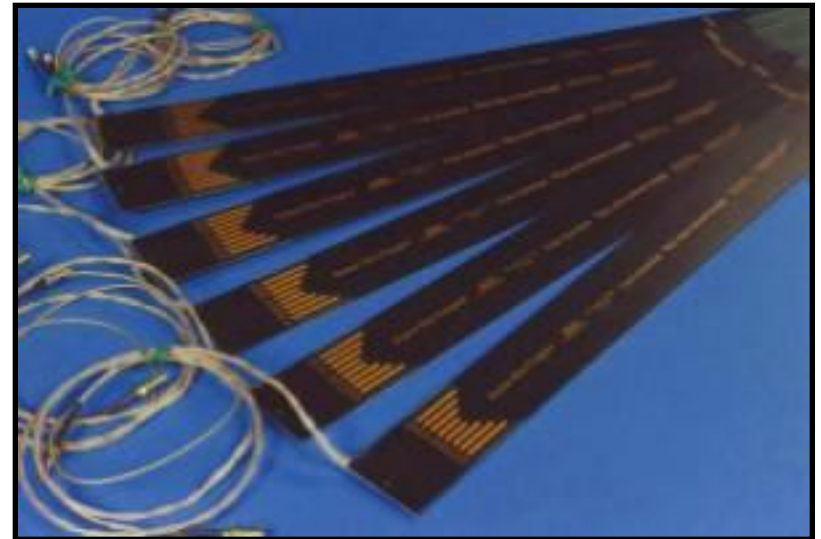
kV	$\geq 6 < 10$	$\geq 10 < 13$	$\geq 13 < 16$	$\geq 16 < 19$
25%	21	32	45	42
50%	55	78	111	85
75%	141	175	239	186
90%	308	368	488	346

PD > 90% indicates problems

Tables for other sensors

In Appendix

- Hydrogenerators
- Hydrogen-cooled Bus
- Air-cooled SSC
- Hydrogen-cooled SSC



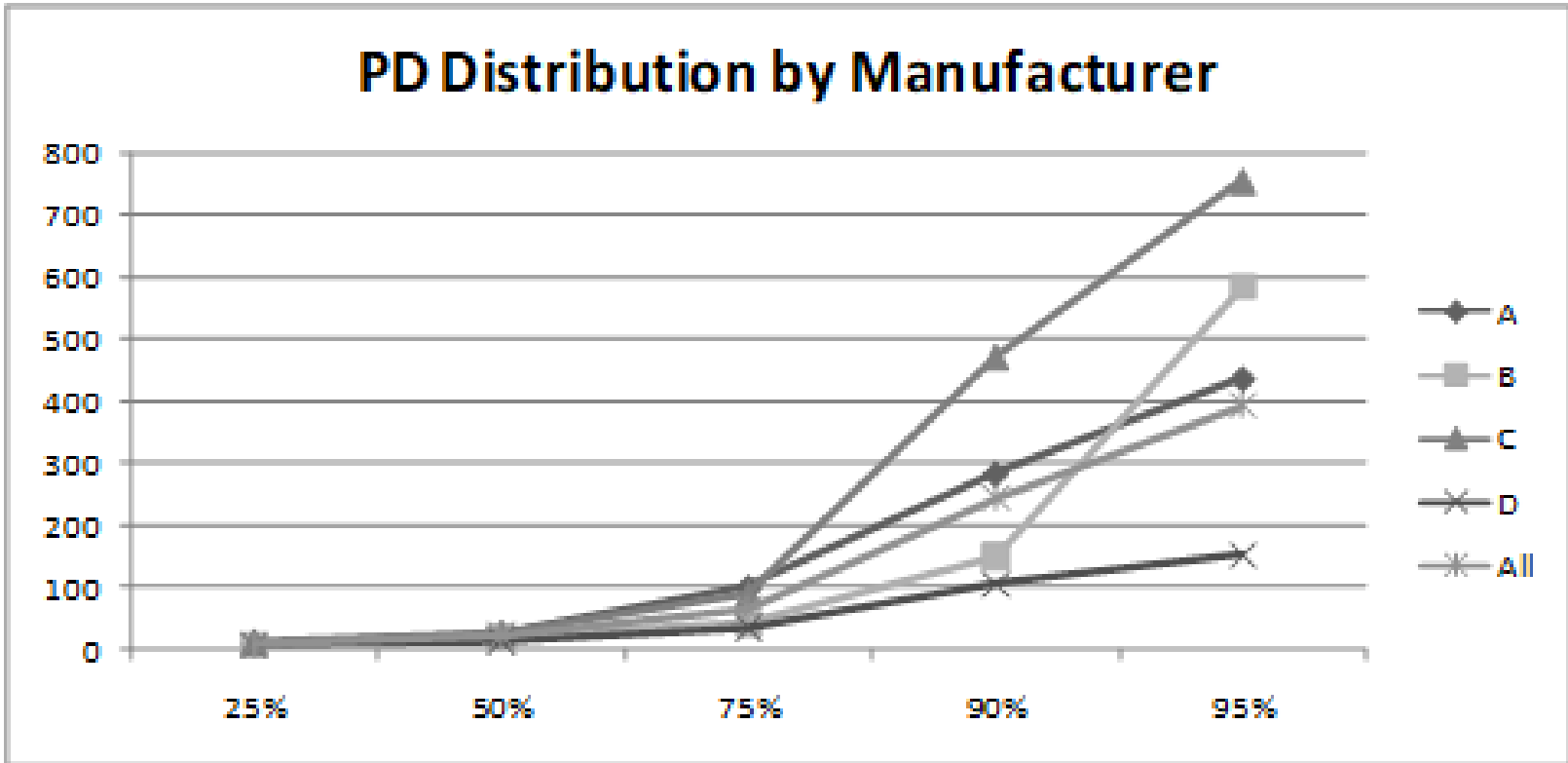


Papers of Interest

- 1. PD on 3-5kV Motor**
- 2. PD in Hydrogen-cooled machines**
- 3. PD in Hydrogen-cooled machines**
- 4. PD by Manufacturer and Age**



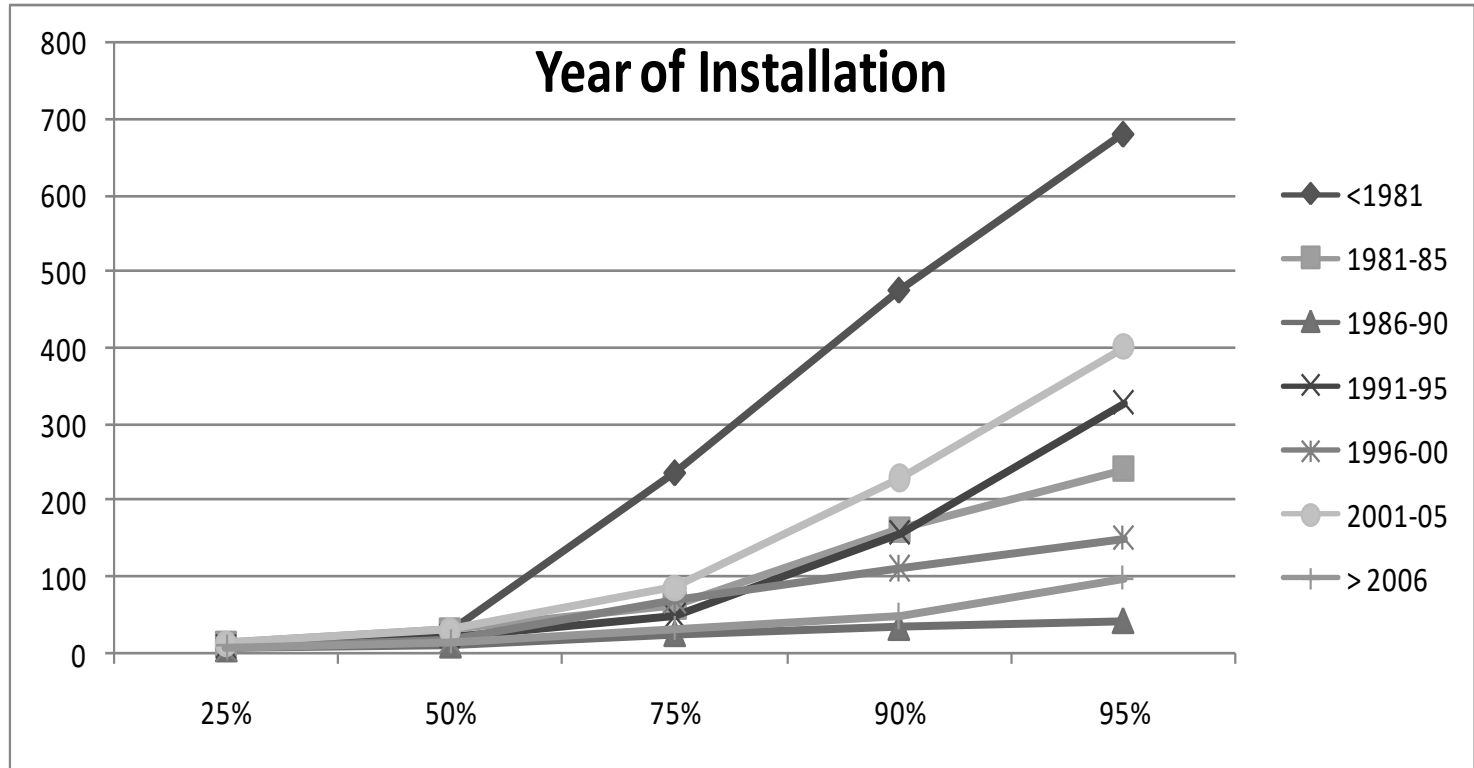
PD on 3-5kV Motors (2014)



Manu C >75%, B >90% higher



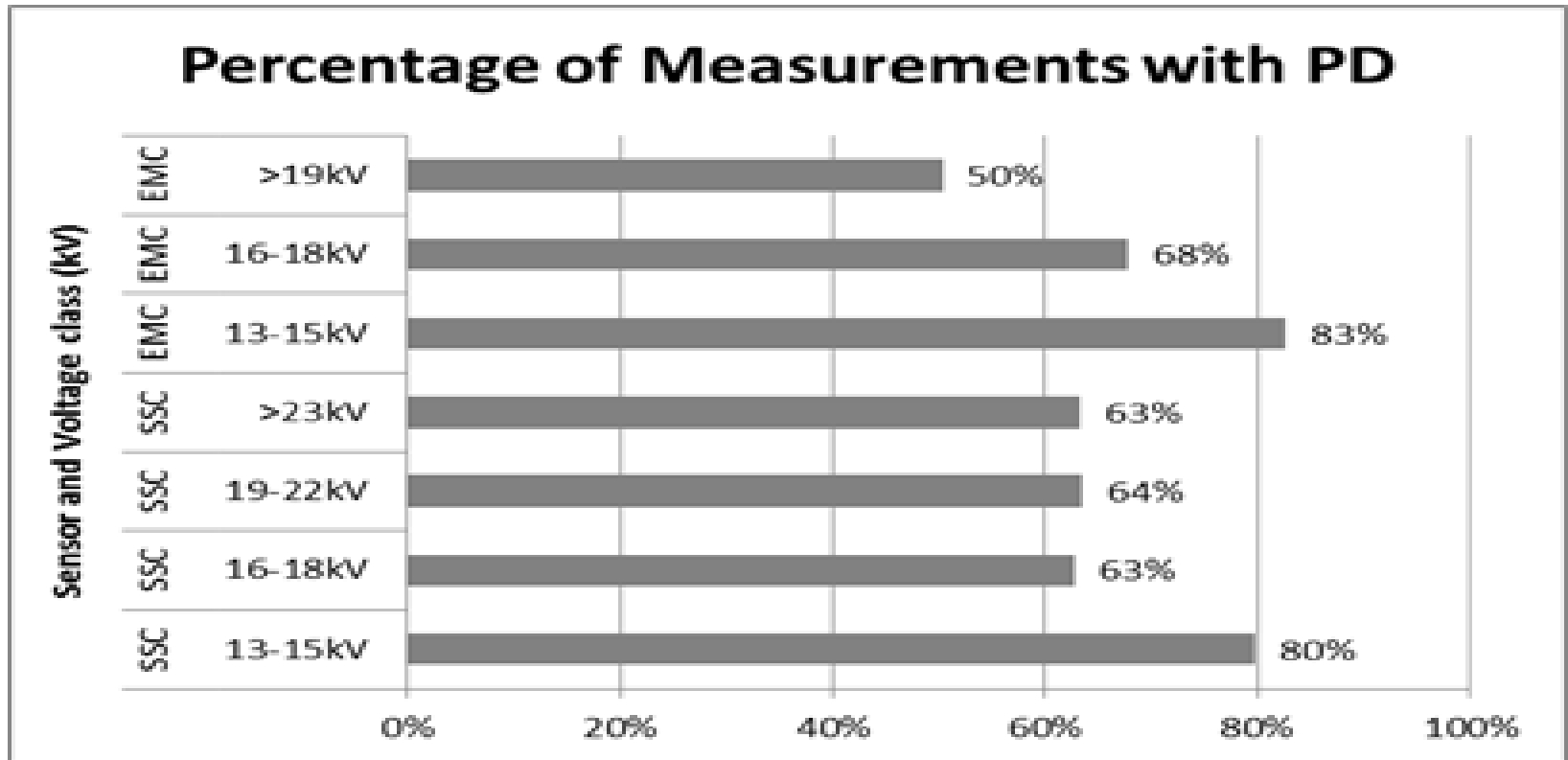
PD on 3-5kV Motors (2014)



<1981 is highest, and 2001-2005 higher



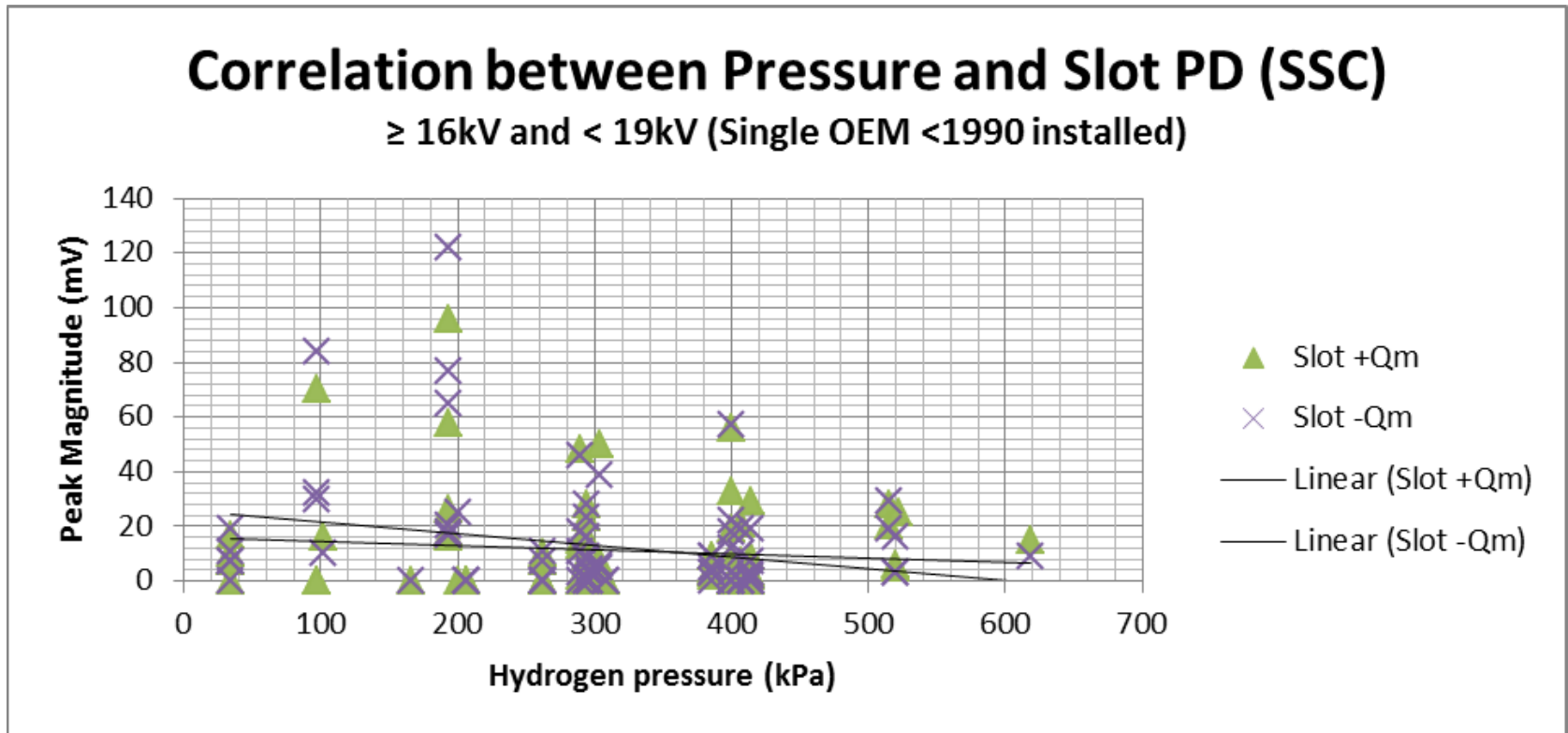
PD in Hydrogen (2016)



>50% in all categories have discernible PD (>1000 assets)



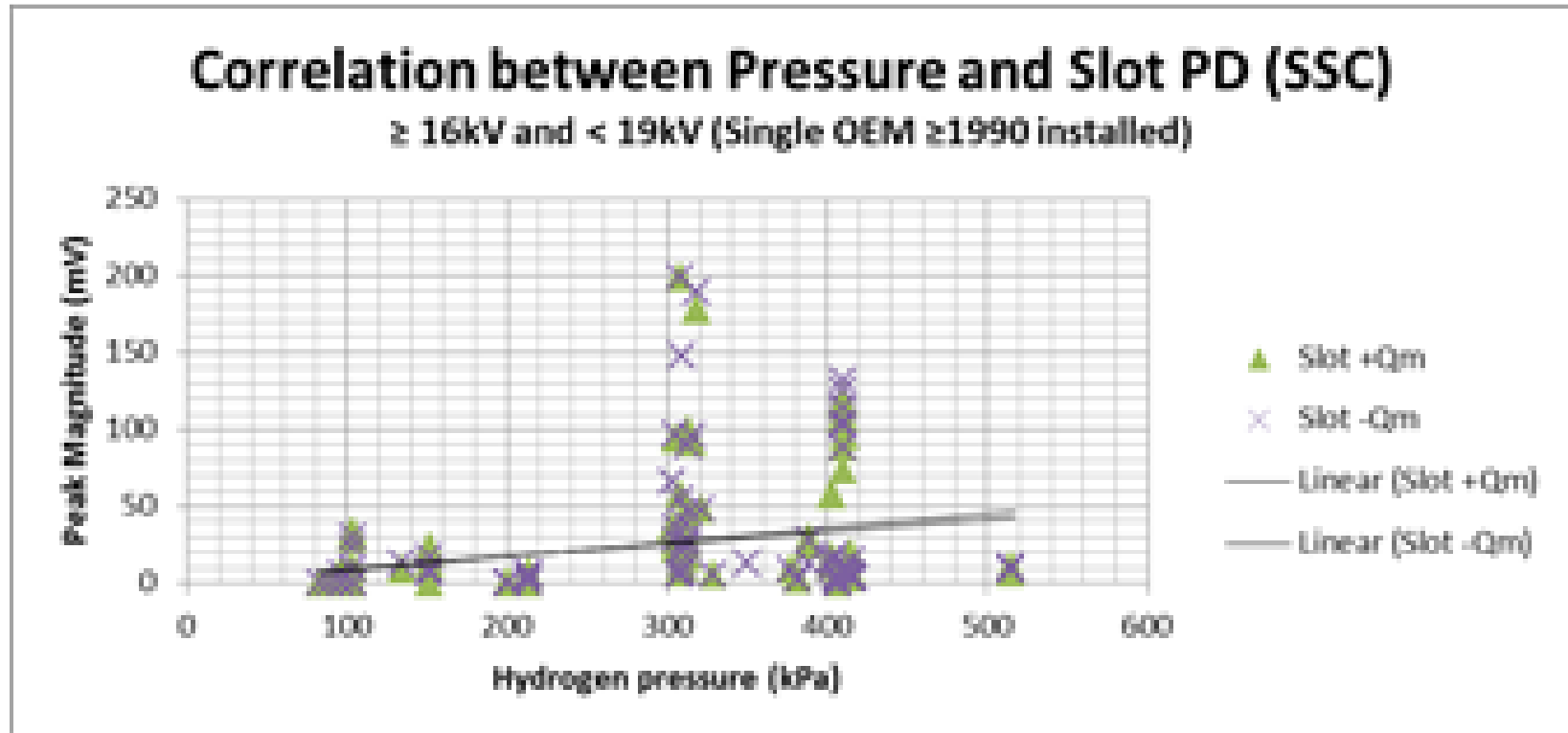
PD in Hydrogen (2016)



Old windings <1990, no evidence of correlation



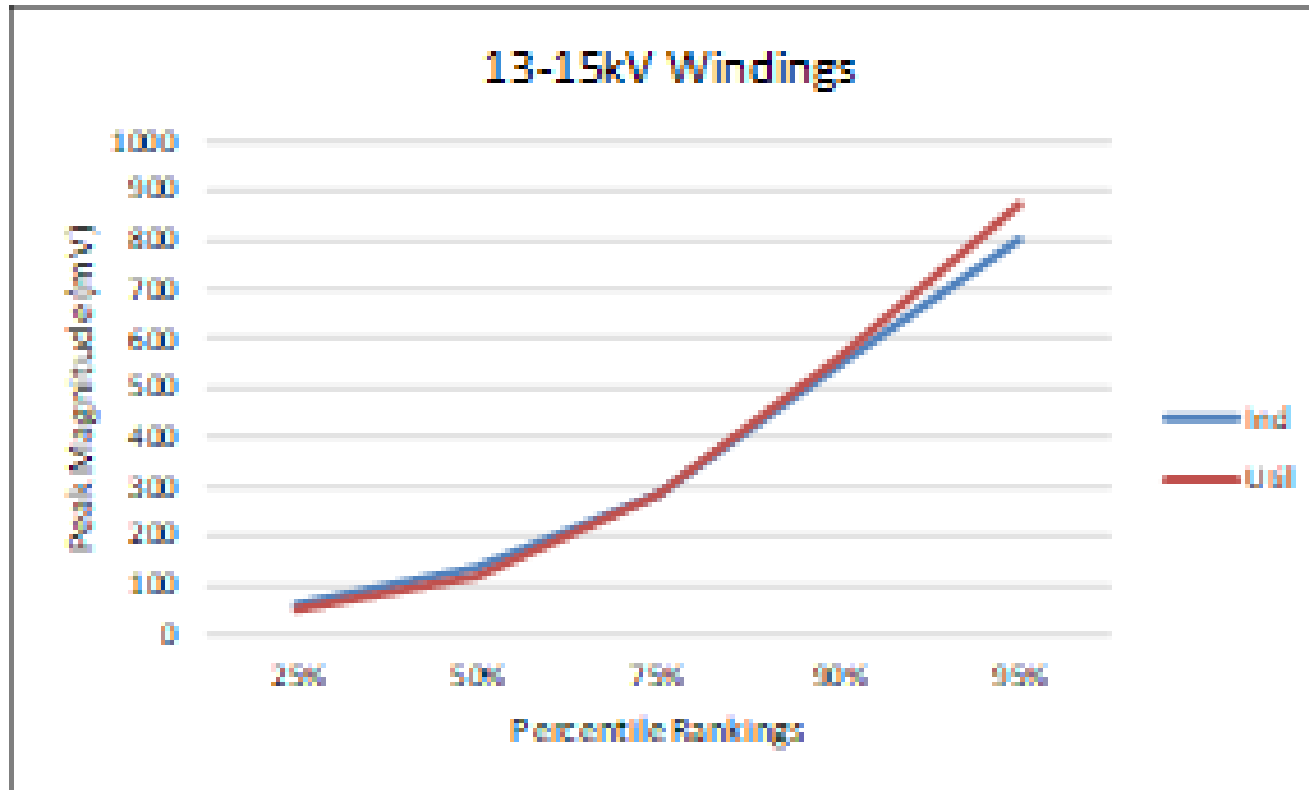
PD in Hydrogen (2016)



Newer windings >1990, slight correlation



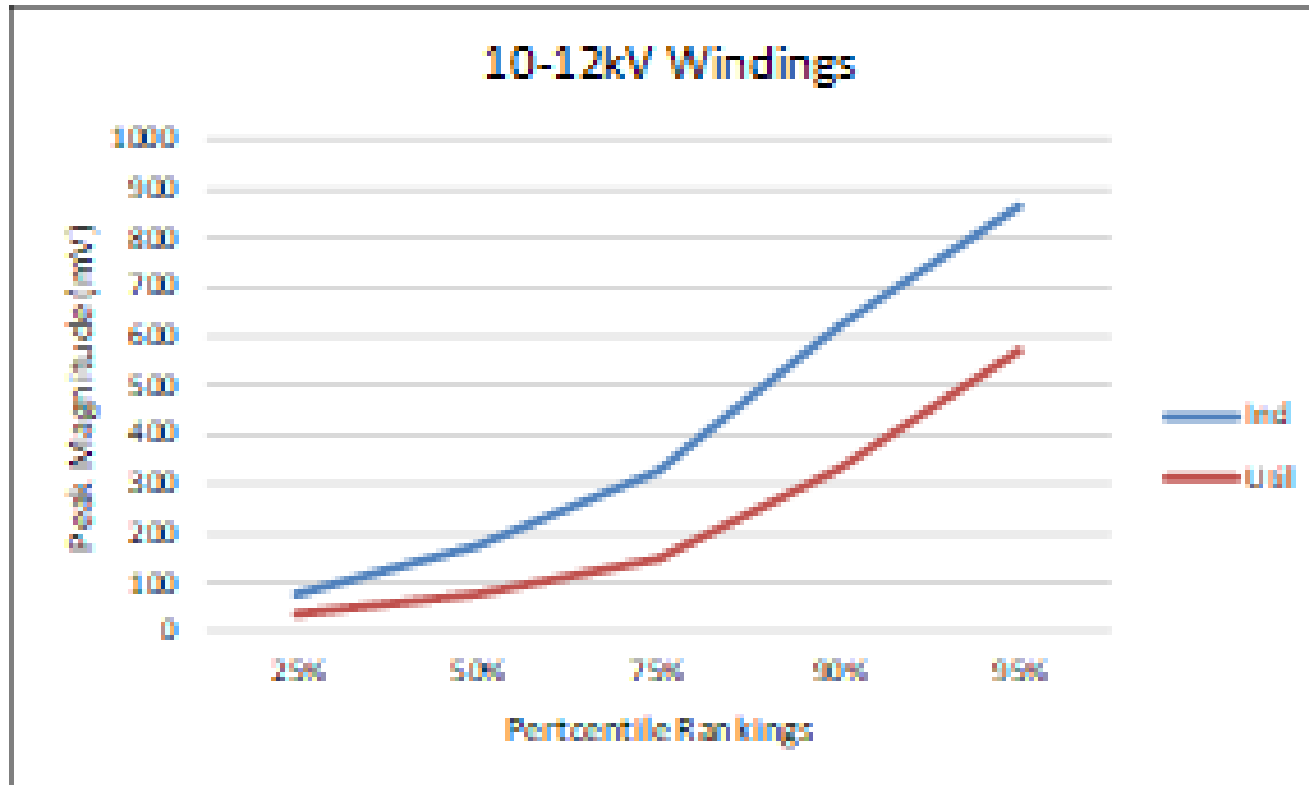
Utility vs Industry (2019)



13-15kV Windings, minimal difference



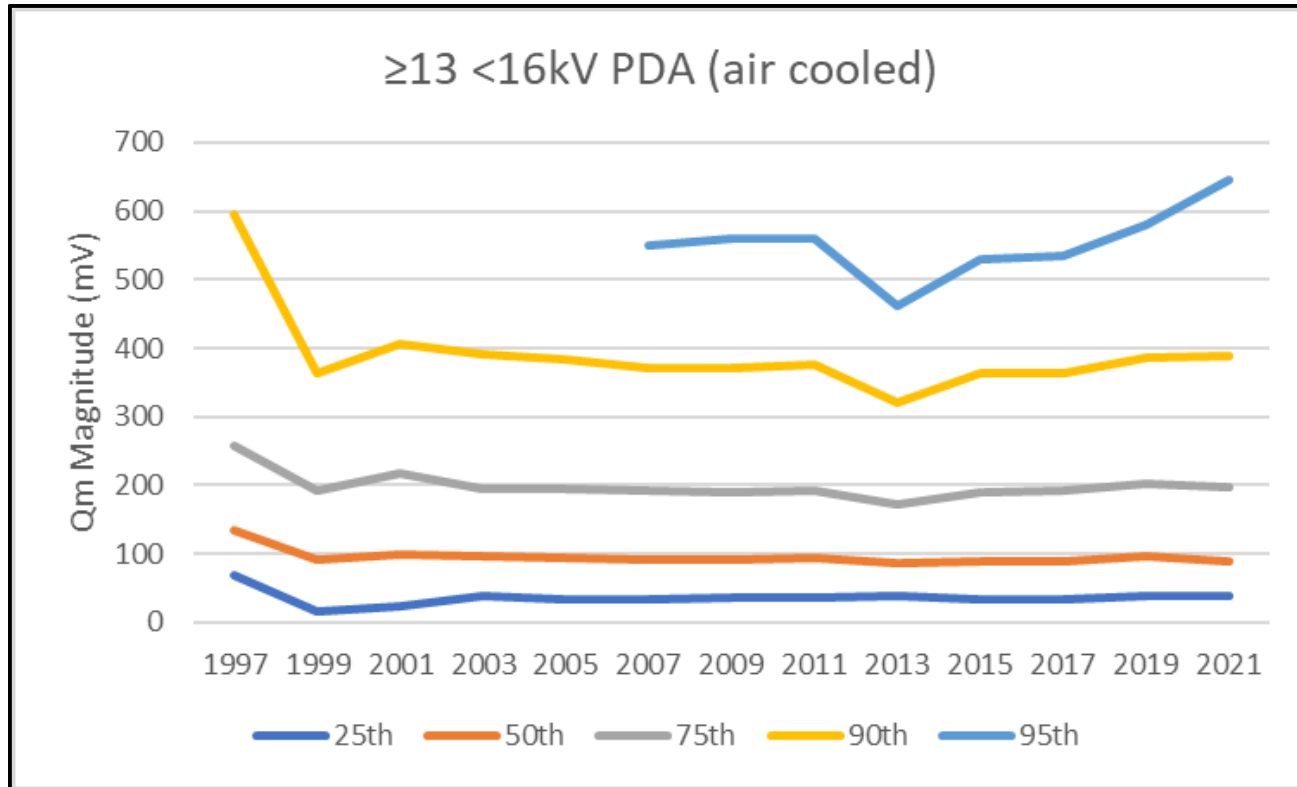
Utility vs Industry (2019)



10-12kV Windings, industry notably higher



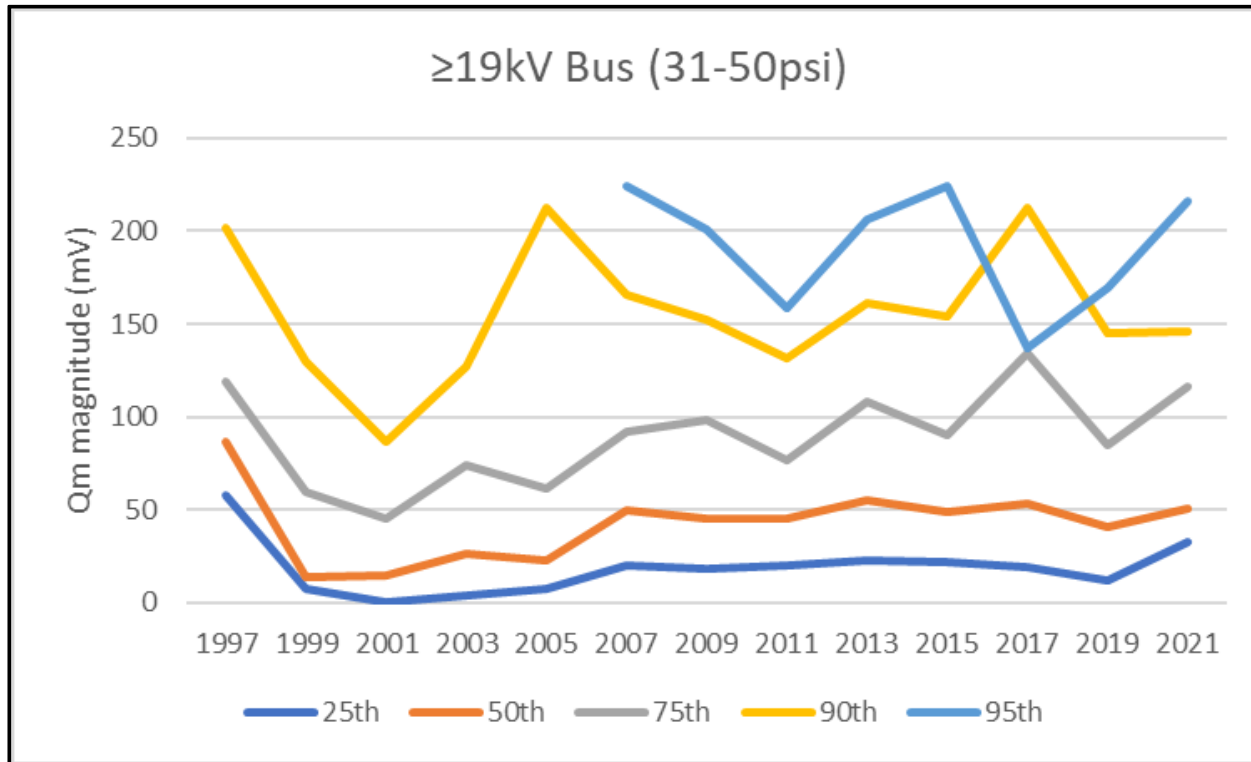
Stability of Results (2022)



13-15kV windings, PD stats stable over 25 years
226 (96%) of categories voltage/sensors were stable



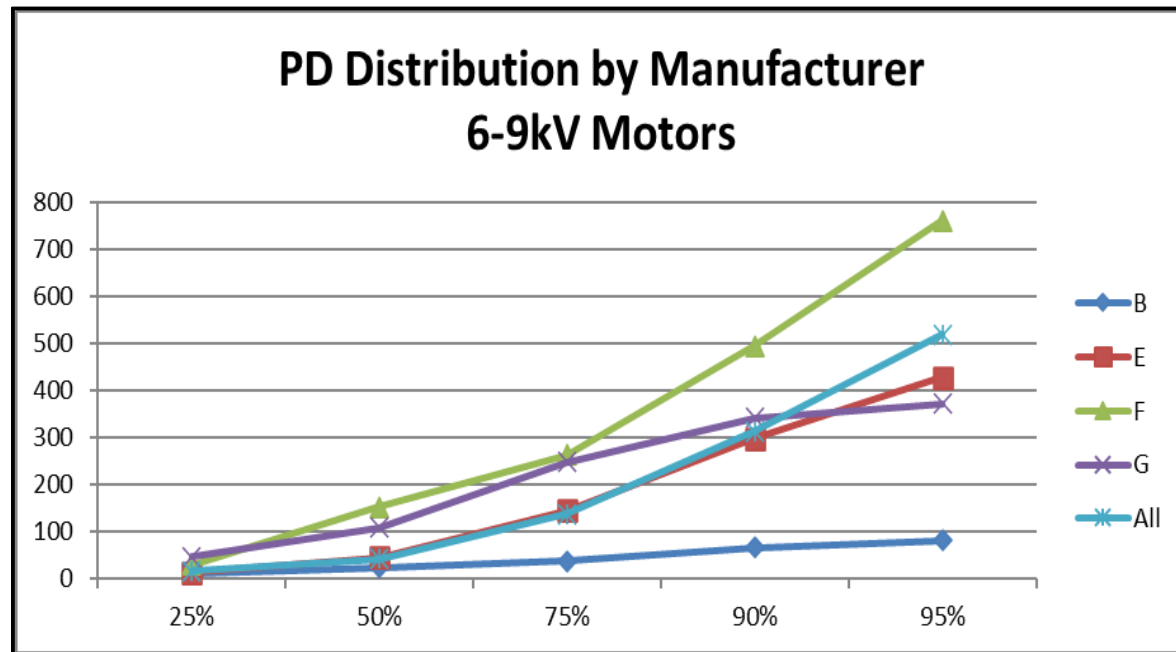
Stability of Results (2022)



≥19kV windings, PD stats stable over 25 years
7 (4%) of categories voltage/sensors were unstable



PD by Manufacturer, by Age (2004, 2010, 2023)

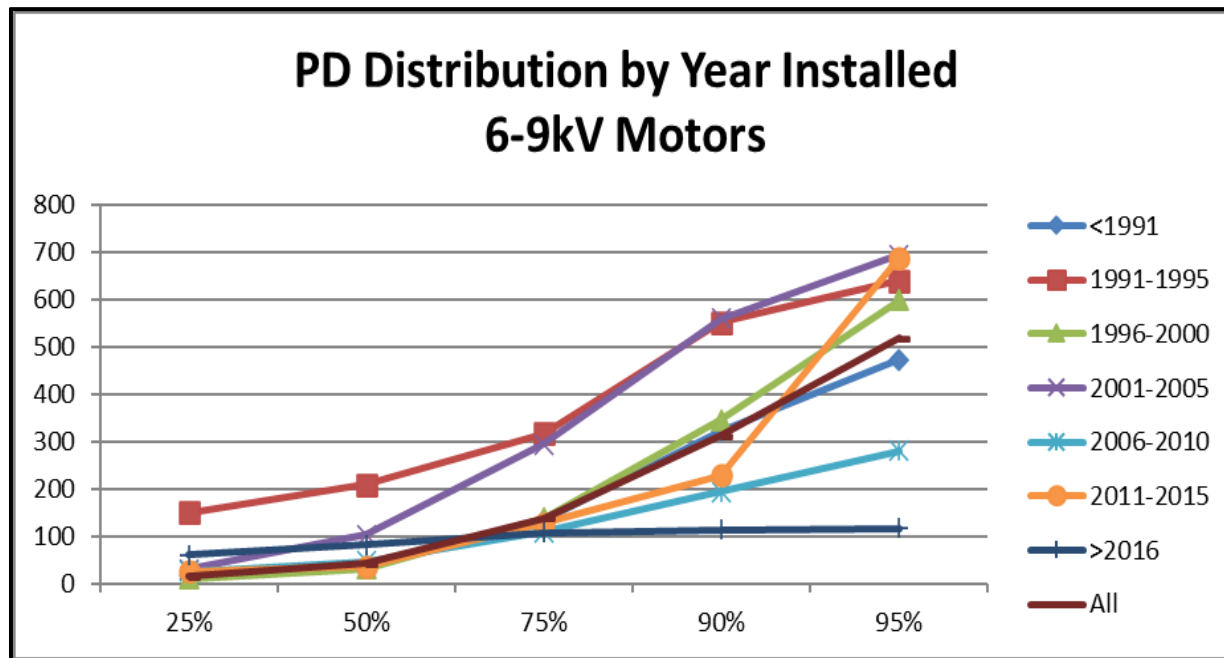


6-9kV windings, Manufacturer F higher



PD by Manufacturer, by Age

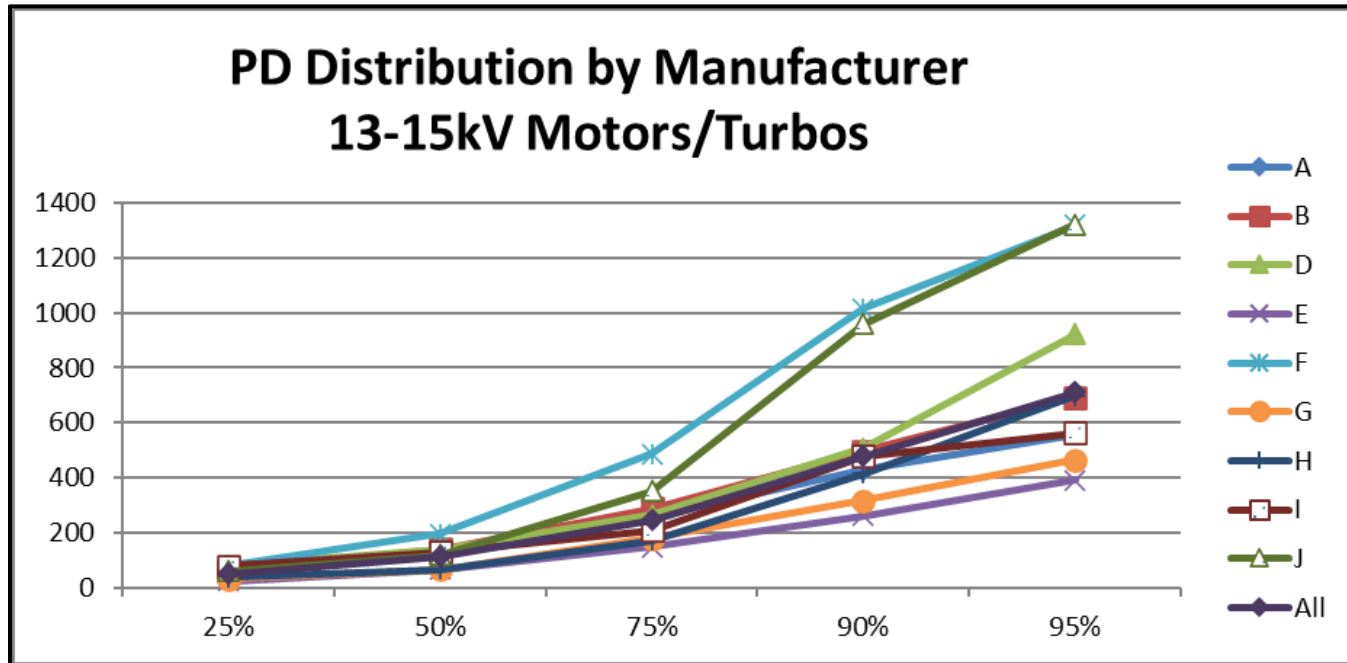
(2004, 2010, 2023)



6-9kV windings, 2001-05 higher, 2011-15 higher



PD by Manufacturer, by Age (2004, 2010, 2023)

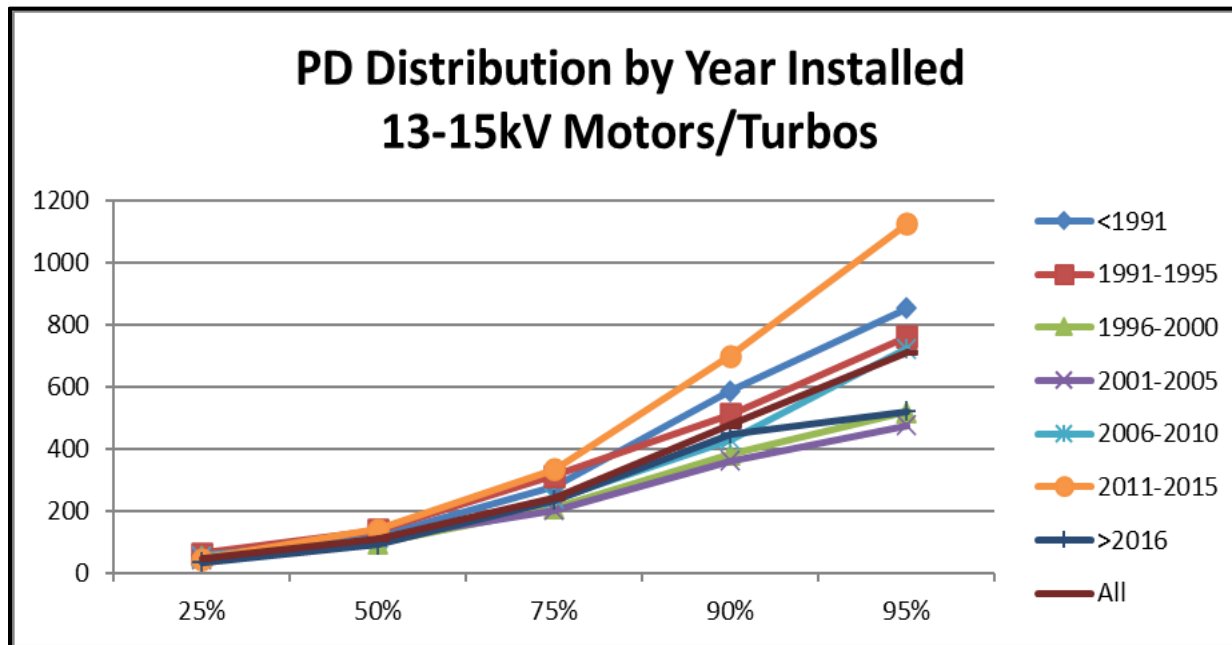


13-15kV windings BUS, Manufacturer F&G higher



PD by Manufacturer, by Age

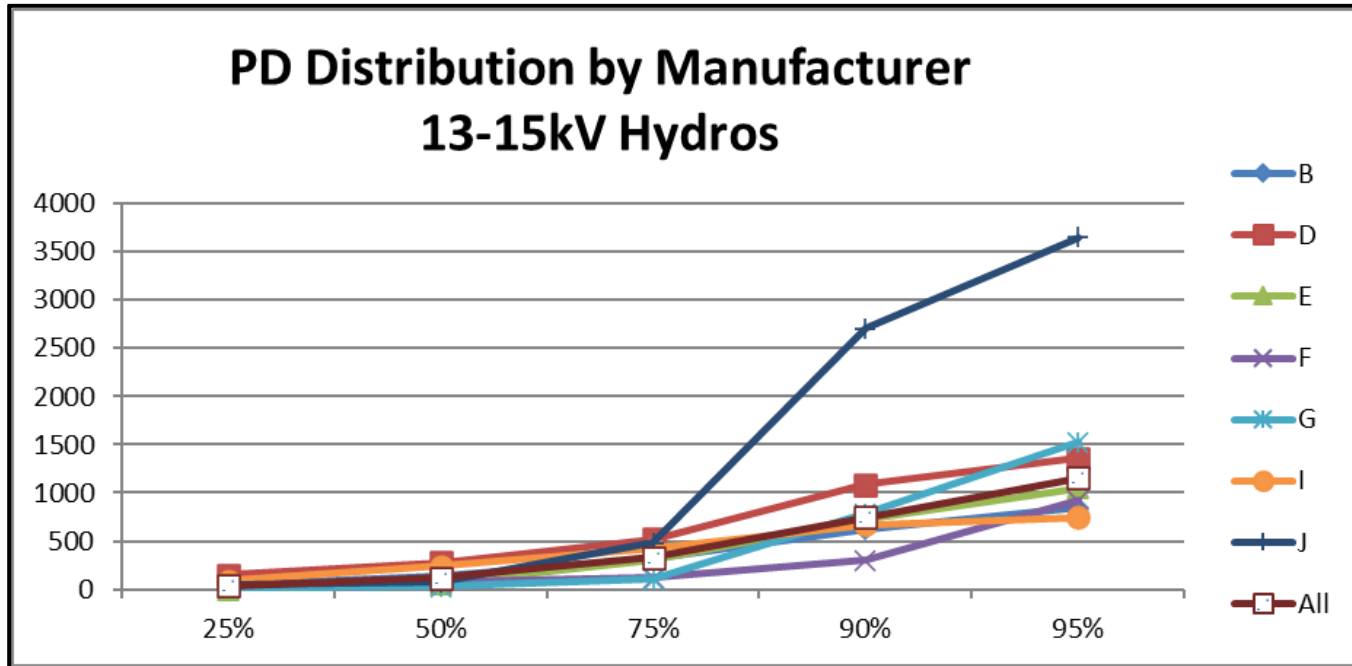
(2004, 2010, 2023)



13-15kV windings BUS, 2011-15 slightly higher



PD by Manufacturer, by Age (2004, 2010, 2023)

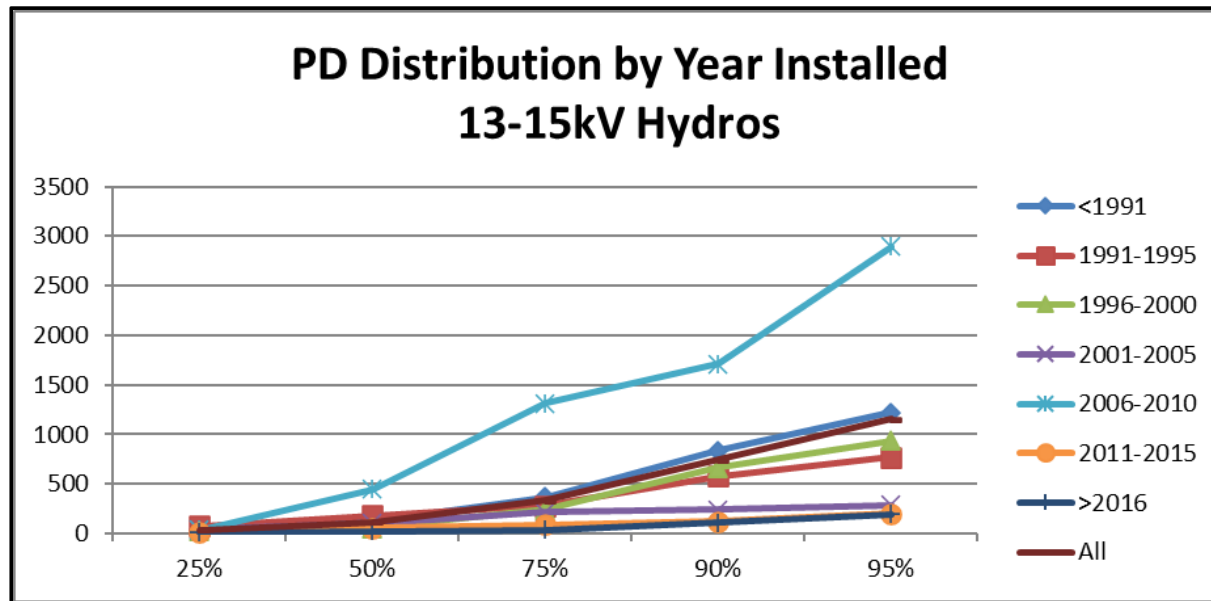


13-15kV windings Hydros, Manufacturer J higher



PD by Manufacturer, by Age

(2004, 2010, 2023)



13-15kV windings Hydros, 2006-10 higher



Summary

- **Proper use of the tables in the Appendix is beneficial**
- **In all cases, the trend of a single asset is the most critical**
- **Some of the interesting PD observations evaluated:**
 - **PD in 3-5kV machines**
 - **PD in hydrogen-cooled machine**
 - **PD in utility vs industrial motors**
 - **Stability of the PD statistics**
 - **PD based on manufacturer and age**

Yellow flag raising



- Doubling
- High PD
- Investigate

PD is a symptom of failure mechanisms

Thank you

And good luck keeping your machines
running