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# Partial Discharge Testing: A Progress Report

Impact of Load (MW/HP)

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# What Are Partial Discharges?

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- 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

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

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

**PDA-IV™**

**TGA™**

Portable instruments only

- 24,000 installations
- **7,500 machines in database**

# Data Analysis (> 685,000)

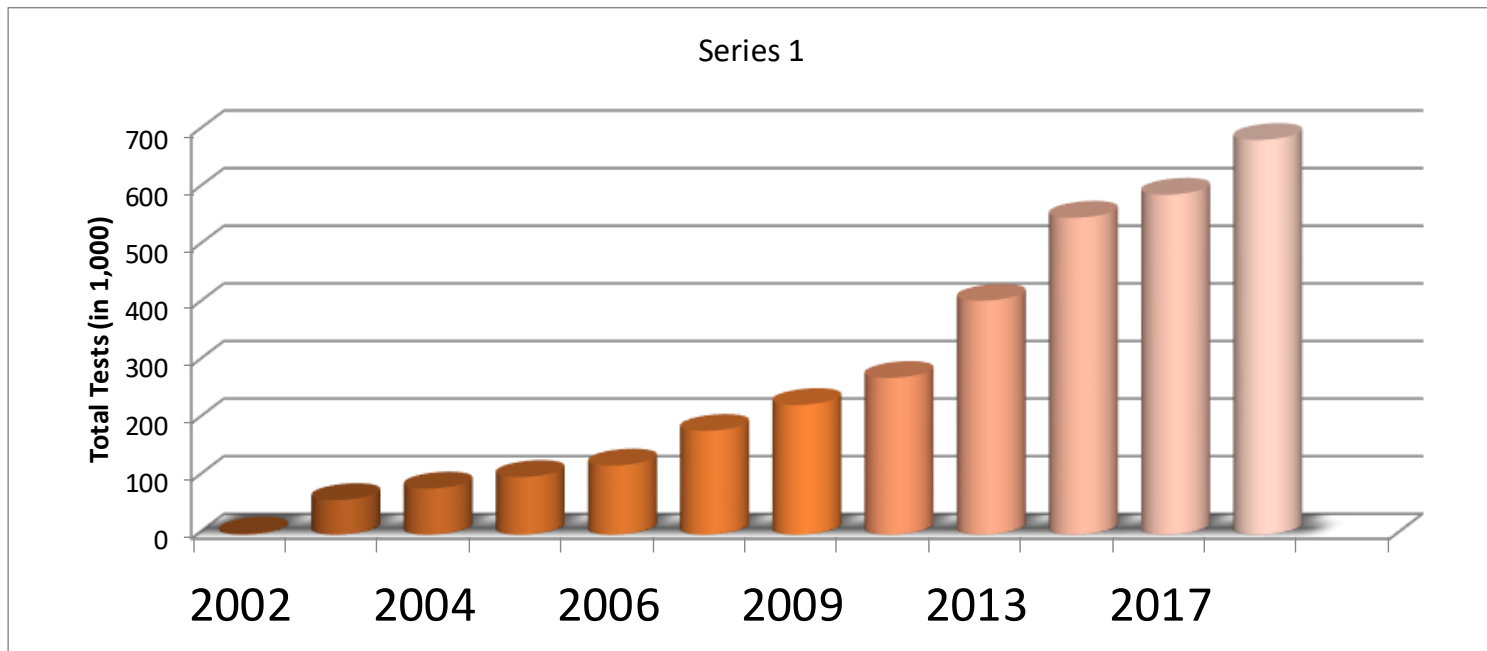
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- Full load hot tests online
  - VHF and disturbance separation
- Data separated by
  - installation
  - insulation
  - voltage class
  - gas coolant pressures
  - manufacturer

# Statistical Database

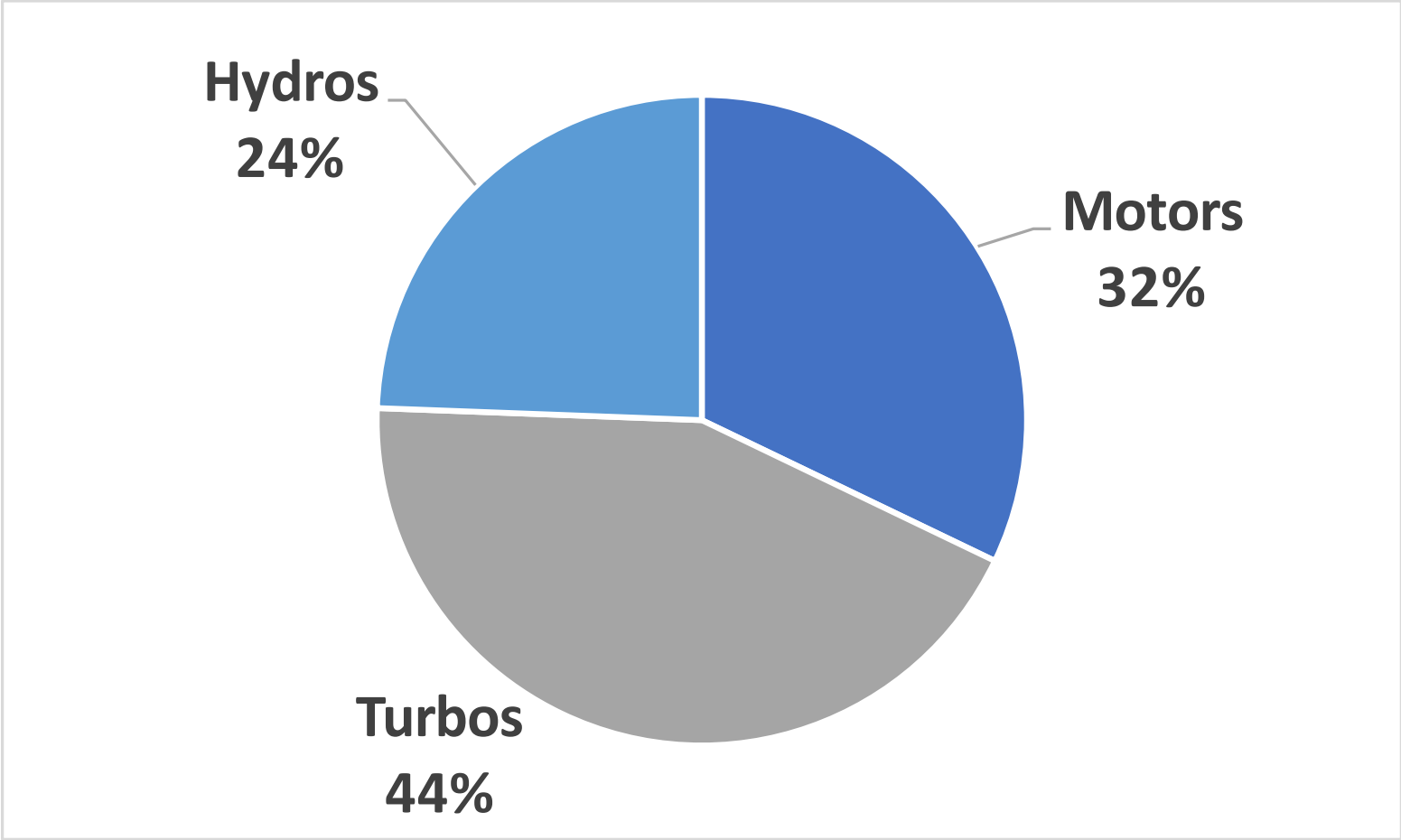
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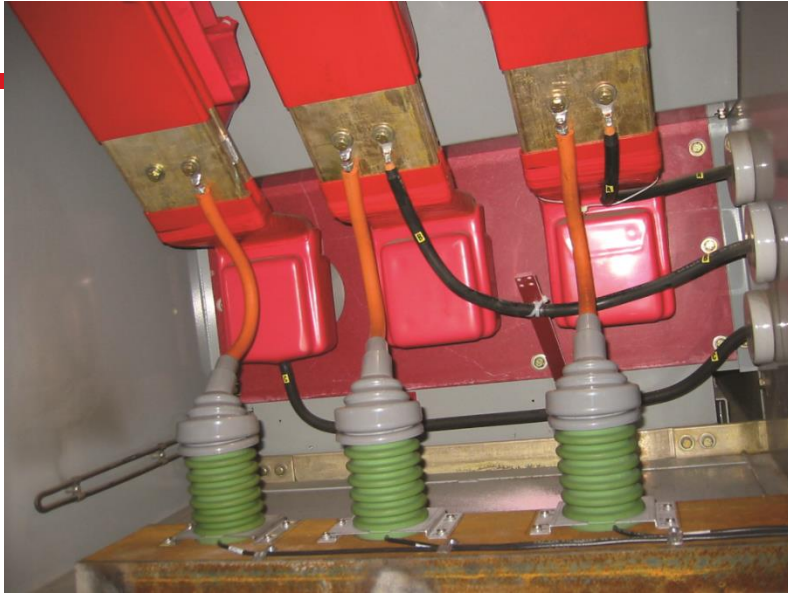
- Population
  - 685,000 measurements for 2019 database
  - High temperature and high load measurements



# Data collected through 2019

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Turbos

# 80pF sensors



Motors

# 80pF sensors at the Terminals

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<b>kV</b>	<b>≥6 &lt;10</b>	<b>≥ 10-&lt;13</b>	<b>≥ 13-&lt;16</b>	<b>≥ 16-&lt;19</b>
<b>25%</b>	25	35	51	39
<b>50%</b>	67	85	115	80
<b>75%</b>	145	196	235	207
<b>90%</b>	331	415	430	313

PD > 90% indicates problems

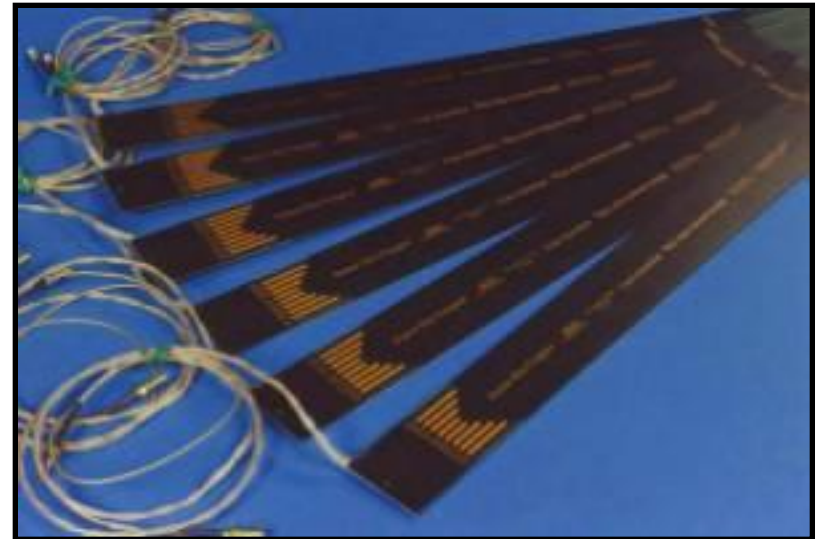


# Tables for other sensors

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## *In Appendix*

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





# Questions

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- 1. Are PD results statistically dependent on voltage? In other words, should voltage be considered an independent variable?**
- 2. Are PD results statistically dependent on rated or operating load (MW/HP) ? In other words, should load be considered an independent variable?**

# Data Limitations

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- Sensor type and location, as well as, air-cooled versus gas-cooled are known to impact results. So only air-cooled machines with either 80pF sensors at terminals (BUS) or attached to circuit rings (PDA) were evaluated.
- And only results with valid Load database entries were included.



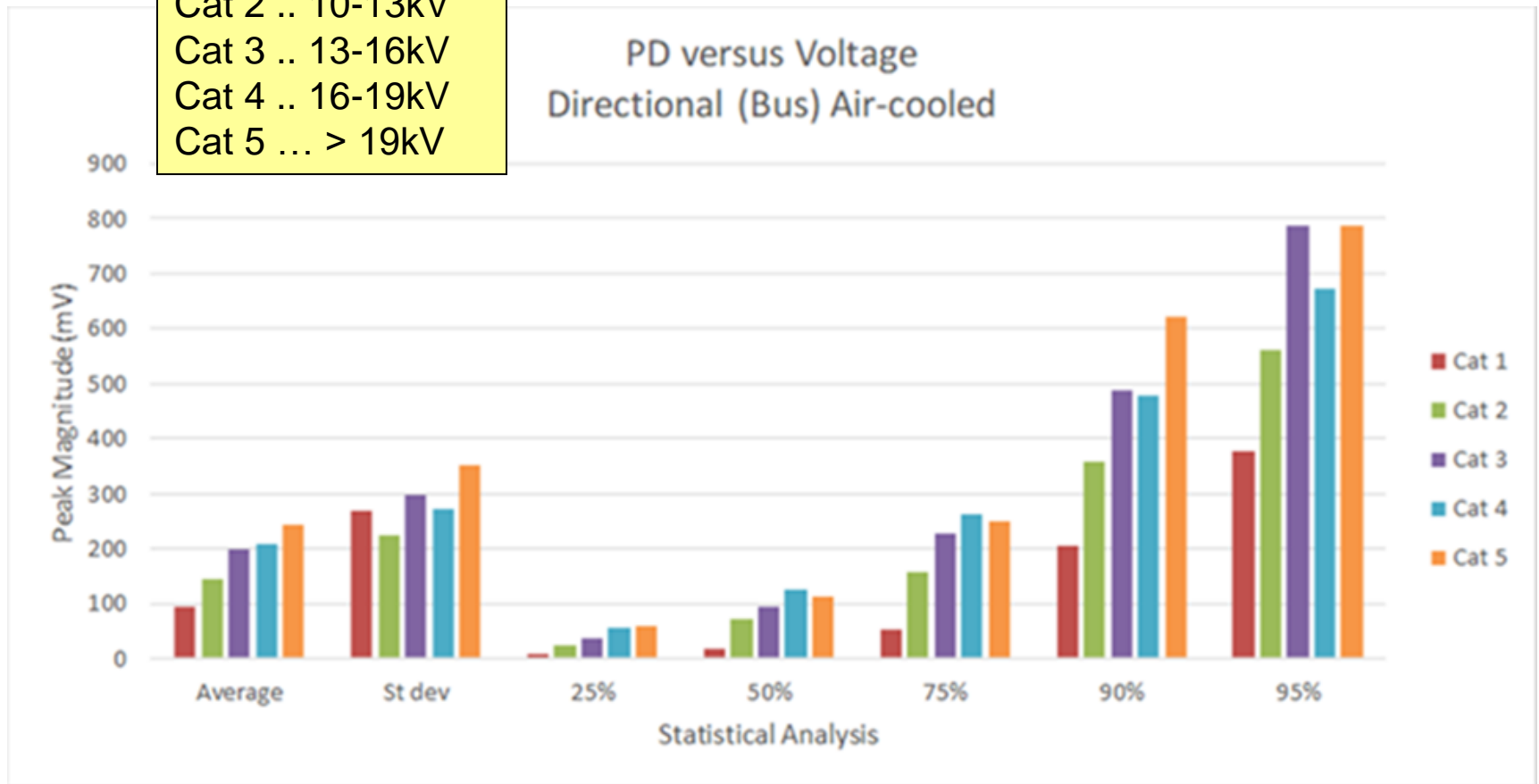
# Questions

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- 1. Are PD results statistically dependent on voltage? In other words, should voltage be considered an independent variable?**
2. Are PD results statistically dependent on rated or operating load (MW/HP) ? In other words, should load be considered an independent variable?

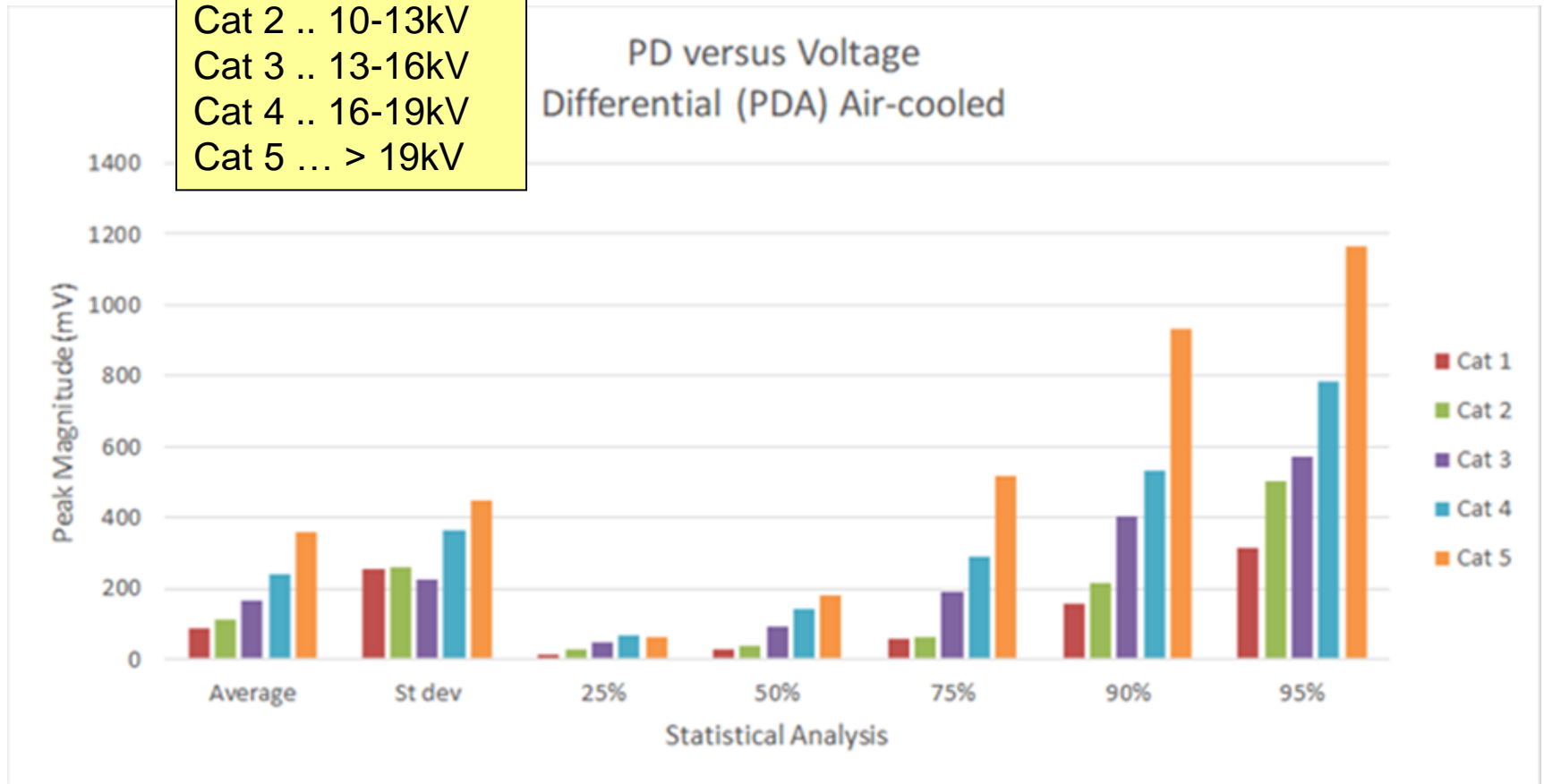
# PD versus Voltage (BUS)

Cat 1 .. 6-10kV  
Cat 2 .. 10-13kV  
Cat 3 .. 13-16kV  
Cat 4 .. 16-19kV  
Cat 5 ... > 19kV



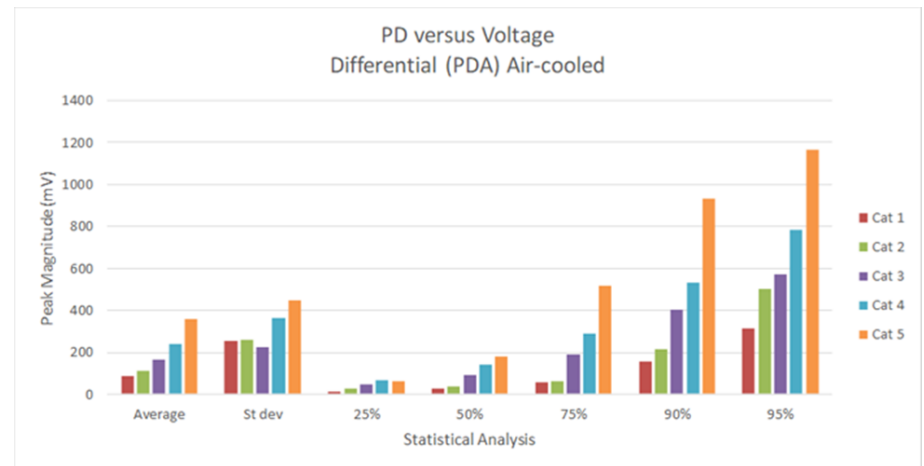
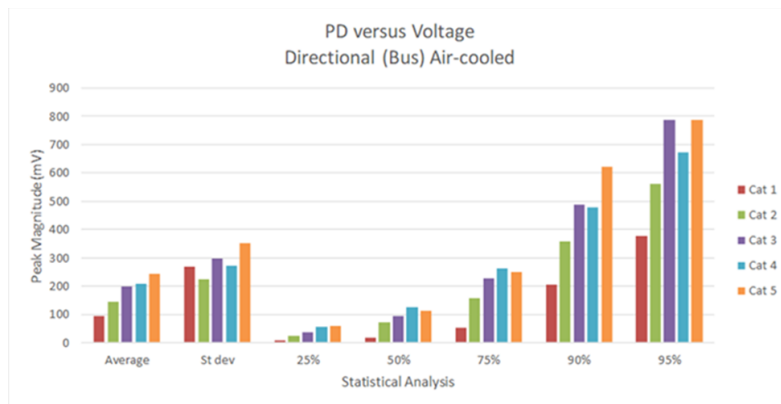
# PD versus Voltage (PDA)

Cat 1 .. <10kV  
Cat 2 .. 10-13kV  
Cat 3 .. 13-16kV  
Cat 4 .. 16-19kV  
Cat 5 ... > 19kV



# Observations (speculations)

- In general, as voltage increases so does the PD at each of the statistical levels.





# Questions

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1. Are PD results statistically dependent on voltage? In other words, should voltage be considered an independent variable? **YES, relatively strong correlation**
2. Are PD results statistically dependent on rated or operating load (MW/HP) ? In other words, should load be considered an independent variable?



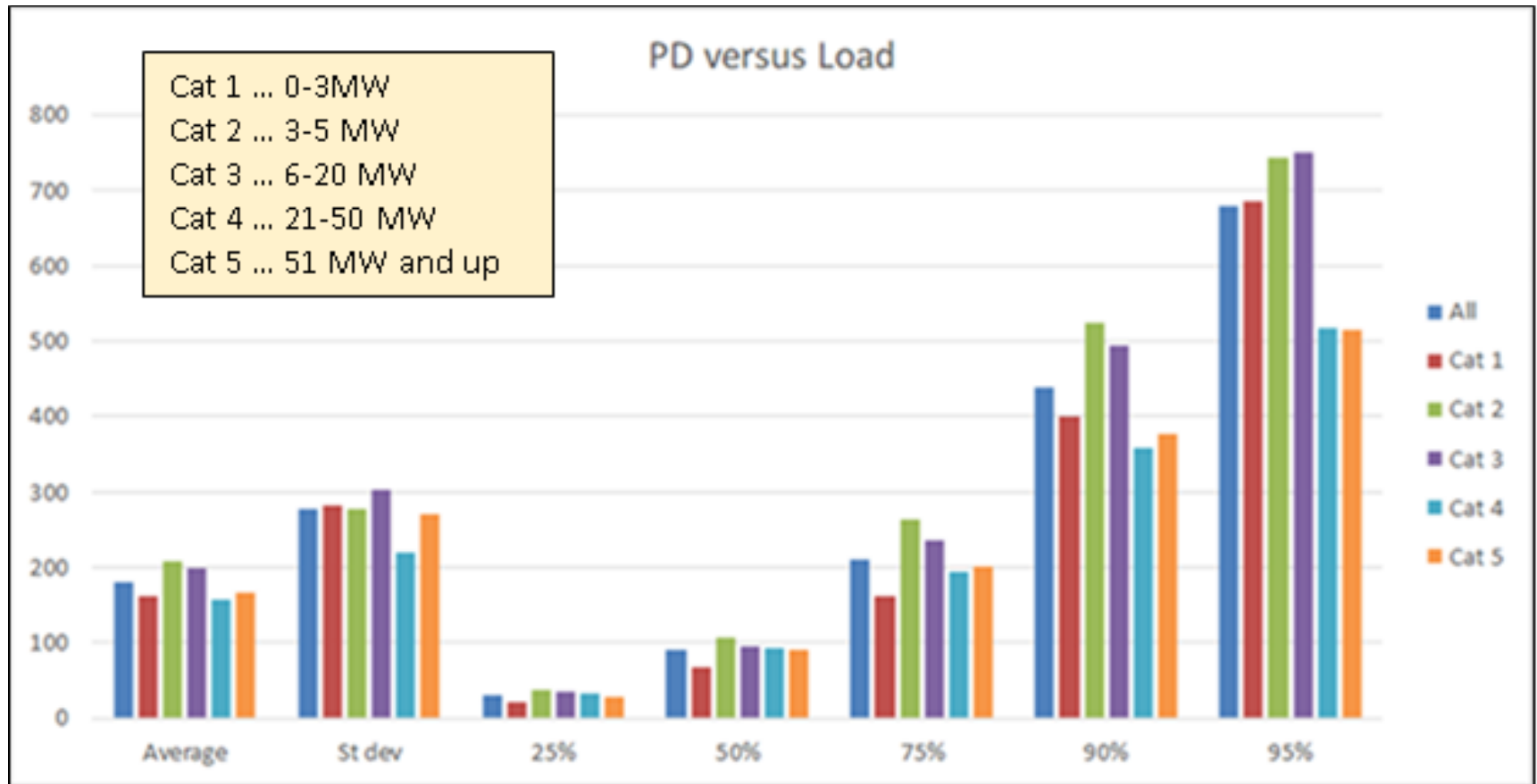


# Questions

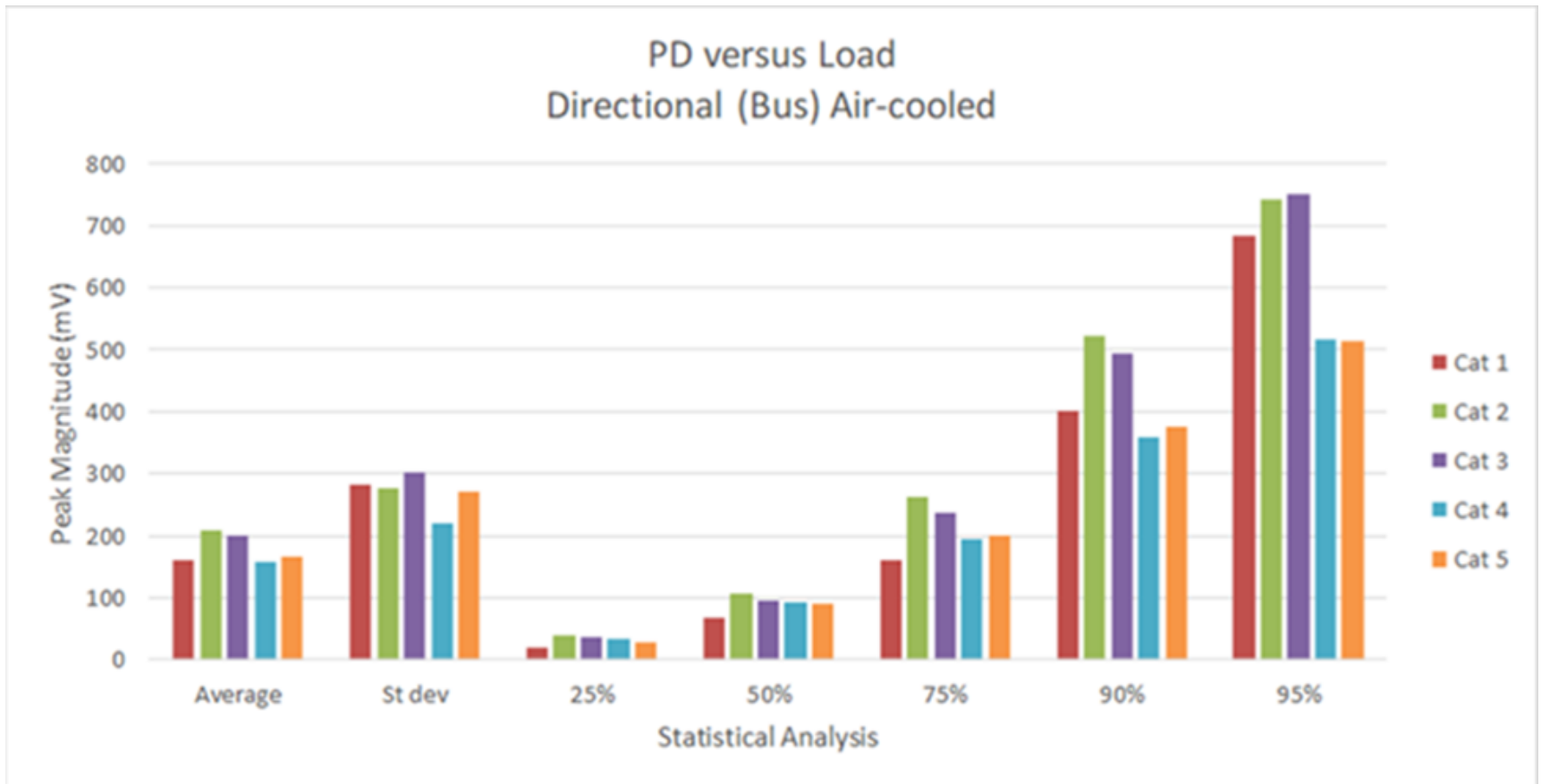
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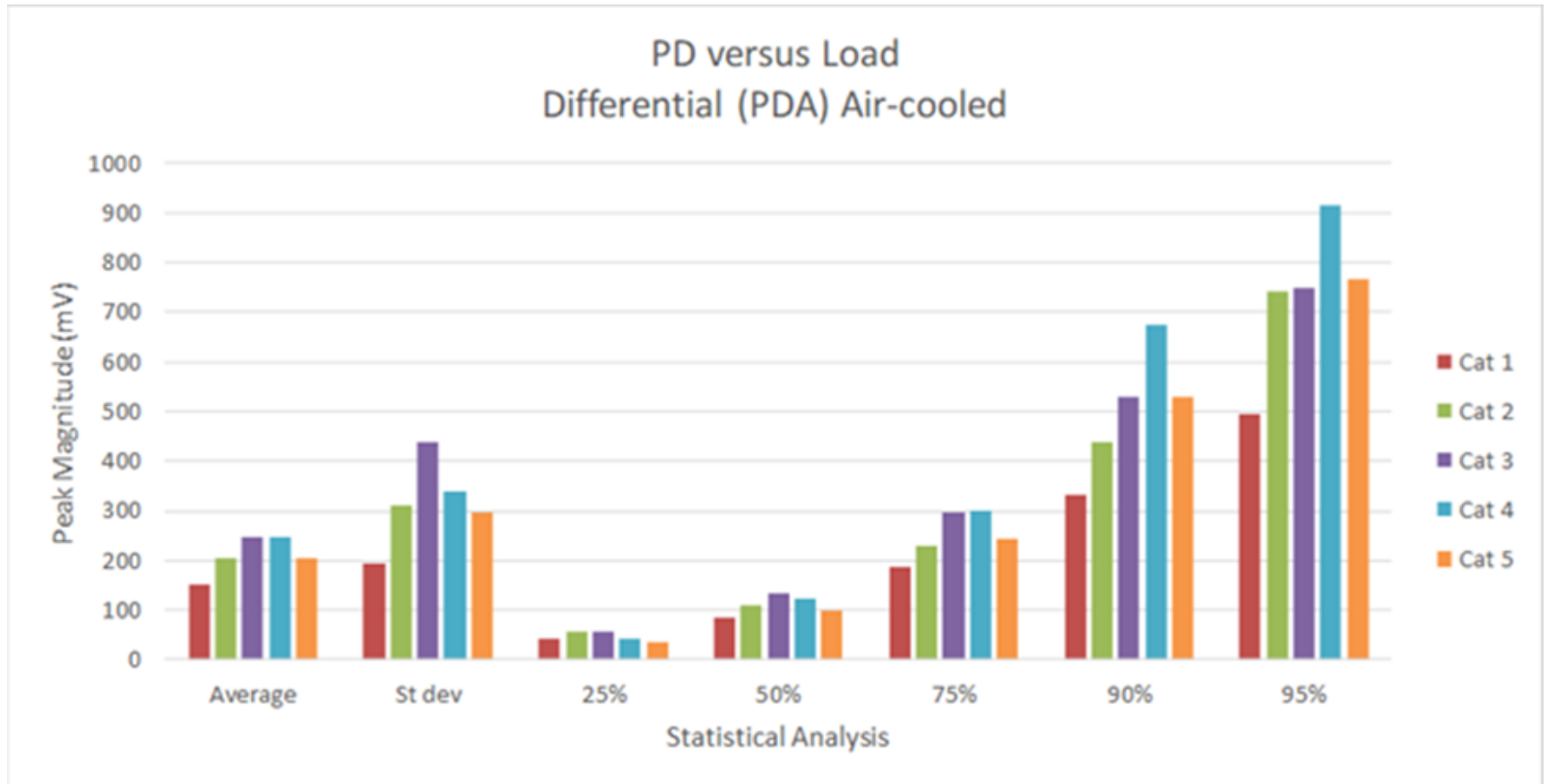
# PD versus Load (air-cooled)



# PD versus Load (BUS)



# PD versus Voltage (PDA)



# Observations (speculations)

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- **Minimal difference between the averages and standard deviations and up to 75<sup>th</sup> percentile of the results.**
- **The PD magnitudes may have “weak” dependence on load in the 90<sup>th</sup> and 95<sup>th</sup> percentiles, but as these are the most “damaged” windings then the volatility is most likely due to the type and extent of stator winding deterioration.**



# Questions

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1. Are PD results statistically dependent on voltage? In other words, should voltage be considered an independent variable? **YES, relatively strong correlation**
2. Are PD results statistically dependent on rated or operating load (MW/HP) ? In other words, should load be considered an independent variable? **Not really, perhaps a weak correlation about the 90<sup>th</sup> percentile.**



# Summary

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- **Impact of Load to PD results**
    - As found before, operating kV has a big impact on the Qm distribution.
    - Some impact from machine MW load, but it is much less significant and inconsistent.
    - PD Alert levels are mainly determined by voltage, pressure, and sensor type/installation. Though there is a load effect, it is weak.
    - It is understood that the main variable that explains most of the variation is the type and extent of deterioration in each stator – and this is not captured in these analyses.
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# Next steps

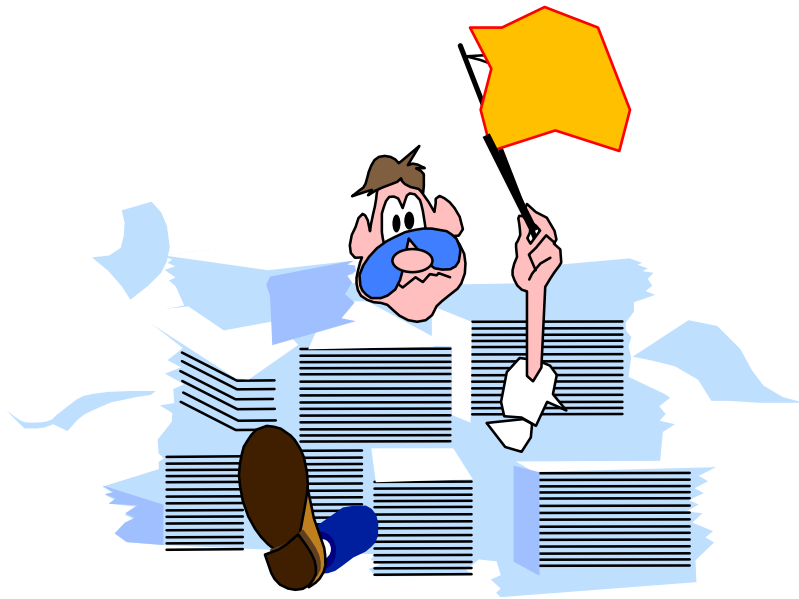
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- Evaluate for gas-cooled machines
- Evaluate closer at the >50MW rated machines



# Yellow flag raising

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- Doubling
- High PD
- Investigate

**PD is a symptom of failure mechanisms**

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# Thank you

And good luck keeping your machines  
running