Partial Discharge Testing: A Progress Report

Hydrogen vs Air-Cooled Machines

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Qualitrol - Iris Power

QUALITROL® Defining Reliability

IRIS POWER A QUALITROL Company

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)**
  - hydrogen (**7 kV/mm)**
- PD results in small current 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™

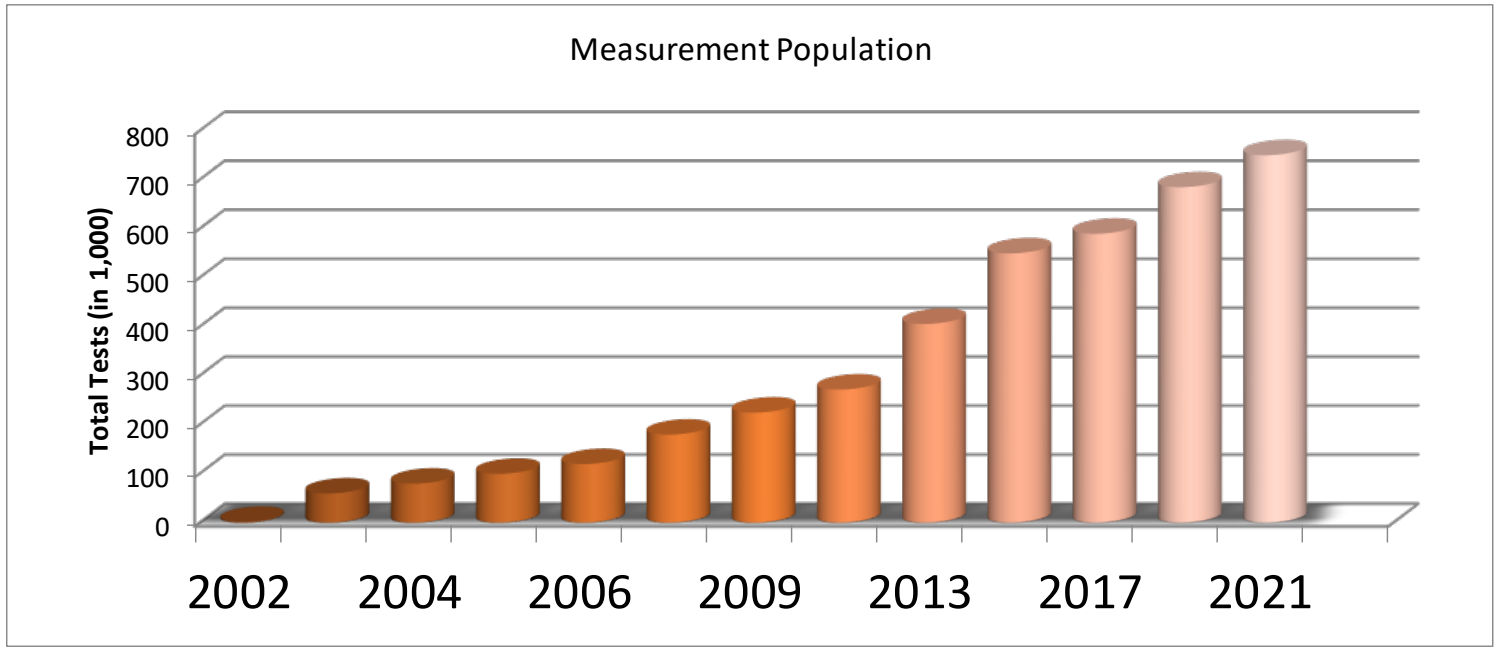
Portable instruments only
•27,000 coupler installations
• 8,500 machines in database

Data Analysis (> 750,000)

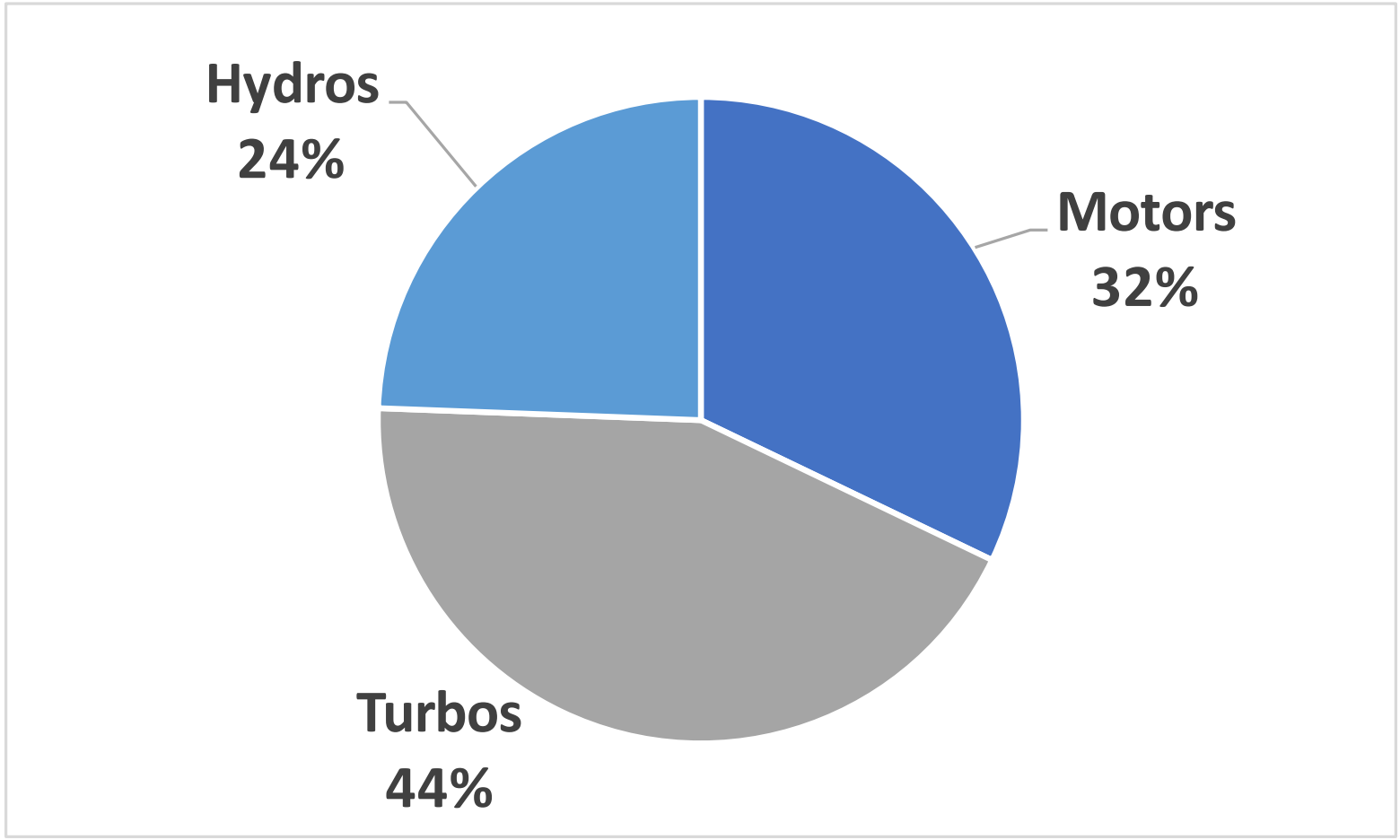
- Full load hot tests online
  - VHF and disturbance separation
- Data separated by
  - Coupler installation type
  - insulation
  - voltage class
  - gas coolant pressures
  - manufacturer

Statistical Database

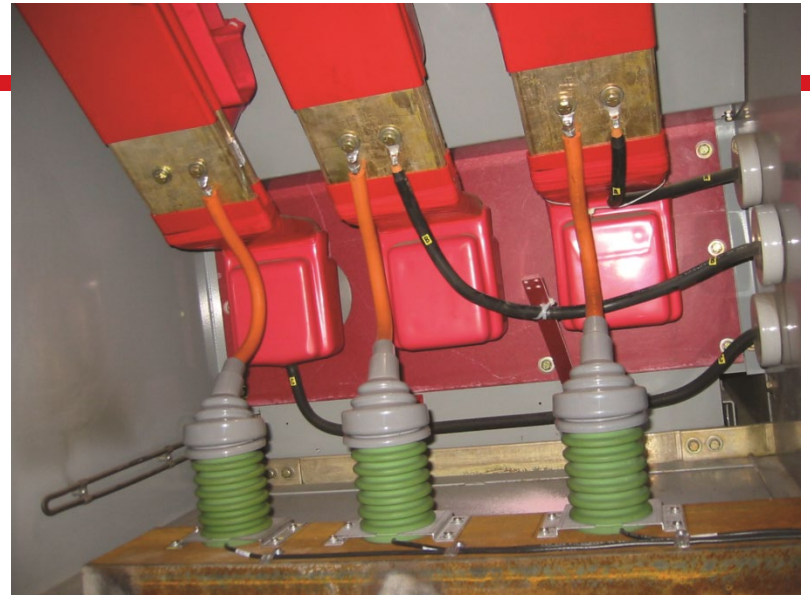
- Population
  - 750,302 measurements for 2021 database
  - High temperature and high load measurements



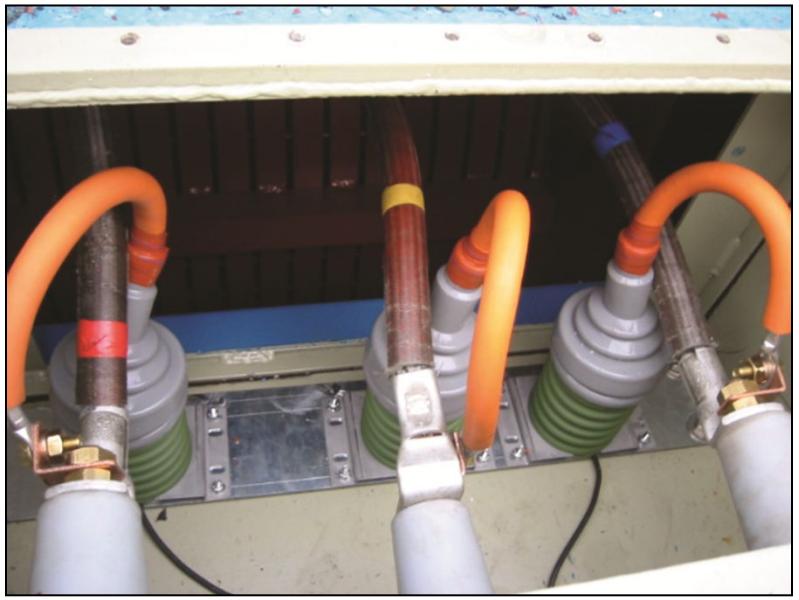
Data collected through 2021



80pF sensors



Turbos



Motors

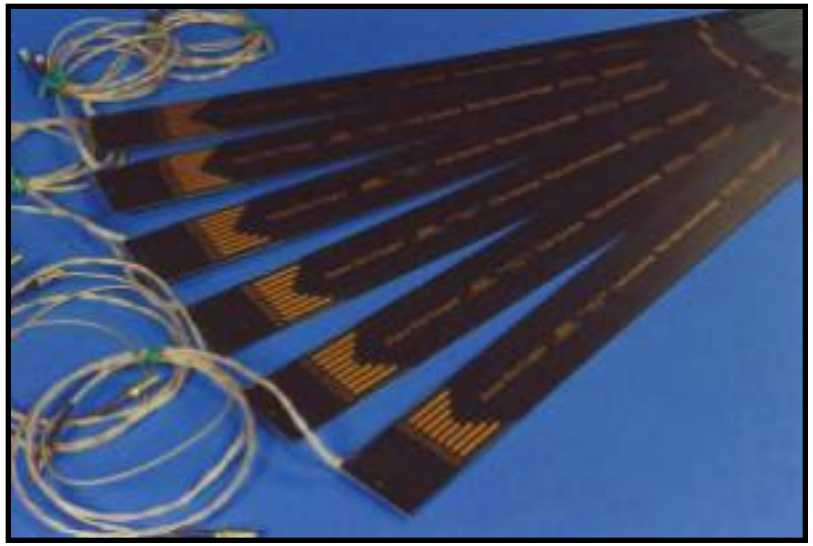
80pF sensors at the Terminals

kV	≥6 <10	≥ 10-<13	≥ 13-<16	≥ 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

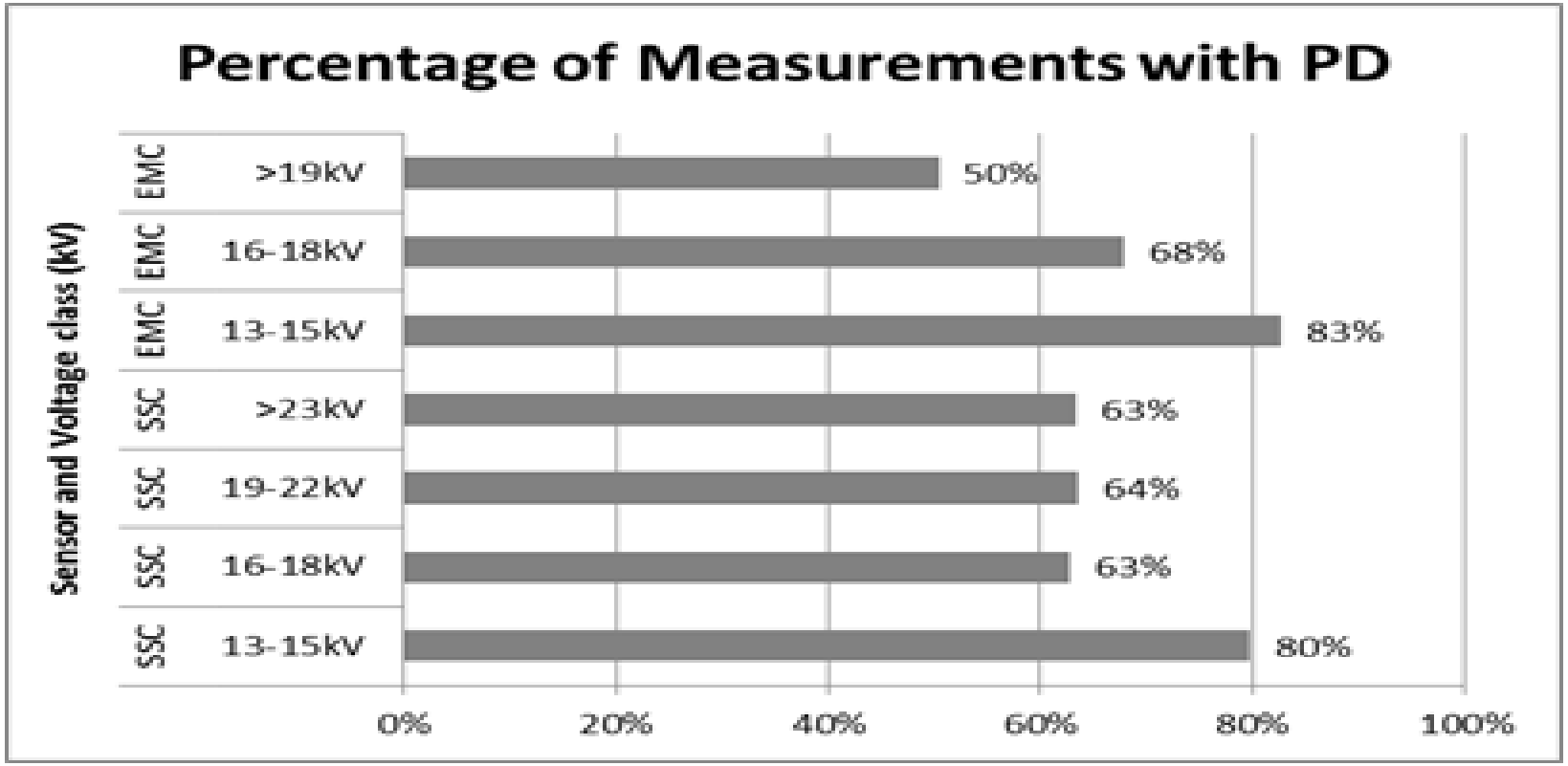
- Hydrogenerators (PDA)
- Hydrogen-cooled Bus
- Air-cooled SSC
- Hydrogen-cooled SSC



Air vs Hydrogen

- Hydrogen at elevated pressure is much more effective at cooling the rotor winding than atmospheric pressure hydrogen
- At the same pressure and temperature, air is a slightly better insulating medium than hydrogen
- PD suppression in H_2-cooled machines is due to operation at elevated pressures (20 – 75 psig)
- Operation in hydrogen minimizes thermal aging due to absence of oxygen

Does PD Occur in H_2-Cooled Machines



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

Air-cooled, 80 pF sensors

	Operating Voltage (kV)		
Cumulative Probability (%)	13-15 kV	16-18 kV	> 19 kV
25%	45	42	45
50%	111	85	90
75%	239	186	191
90%	488	346	507
95%	730	506	798

H_2-cooled, 80 pF sensors

	Operating Voltage (kV)									
	13-15 kV			16-18 kV				19 kV and higher		
H_2 pressure (kPag)	76-138	145-207	Over 207	76-138	145-207	214-345	Over 345	145-207	214-345	Over 345
< 25th	27	19	13	48	33	25	6	42	21	12
< 50th	69	44	35	121	58	45	17	84	50	33
< 75th	154	90	77	256	205	111	38	152	100	76
< 90th	331	189	184	409	544	245	129	191	155	256
< 95th	695	351	469	439	969	373	302	237	192	883

Comparing Air with H_2 (80 pF)

16-18 kV		16-18kV			
		76-138	145-207	214-345	Over 345
25%	42	48	33	25	6
50%	85	121	58	45	17
75%	186	256	205	111	38
90%	346	409	544	245	129
95%	506	439	969	373	302

Air-cooled, SSCs (slot PD)

	Operating Voltage (kV)	
Cumulative Probability (%)	13-15 kV	16-24 kV
25%	0	0
50%	10	1
75%	33	10
90%	83	60
95%	126	115

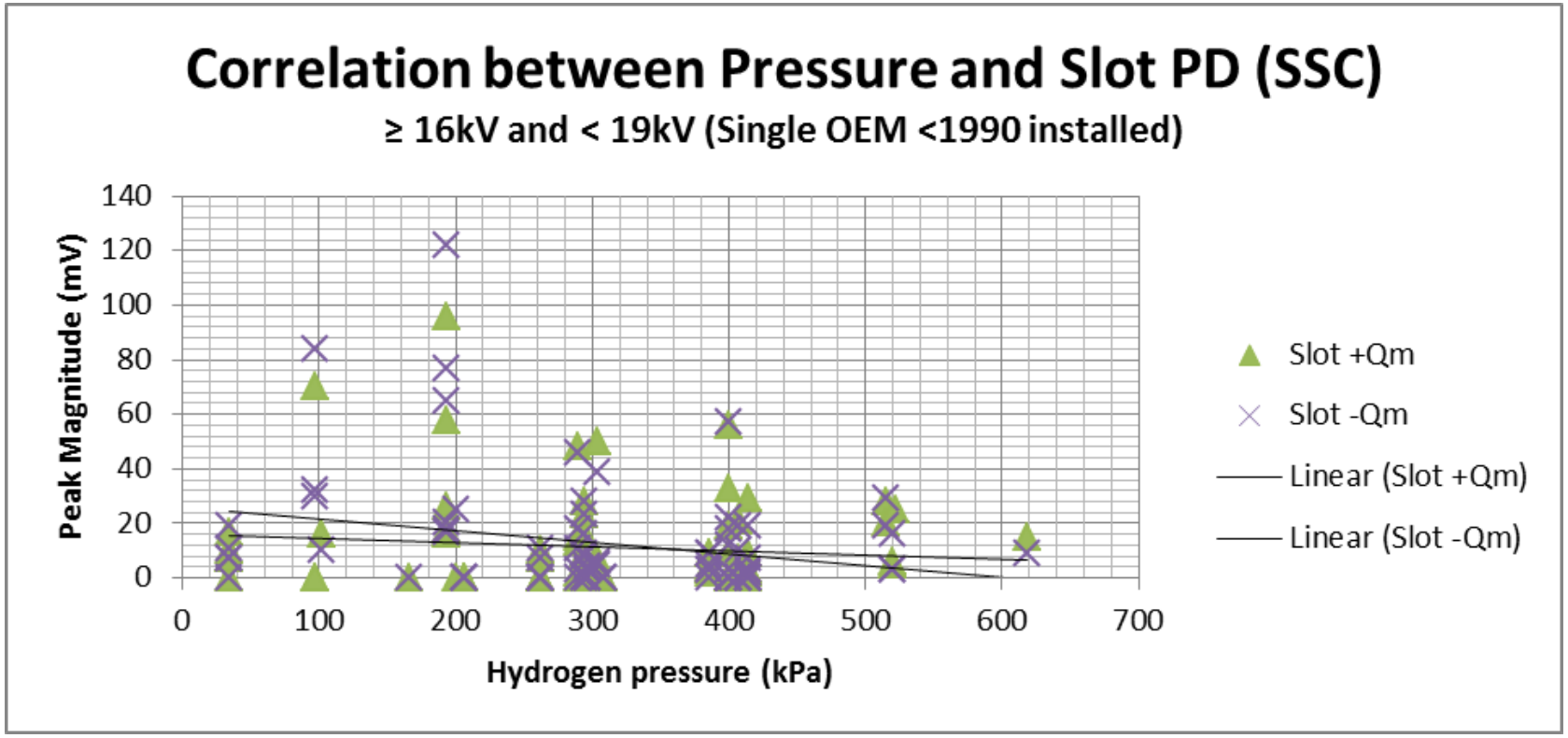
H_2-cooled, SSCs (slot PD)

	Operating Voltage (kV)										
	13-15 kV			16-18 kV			19-22 kV			23-27kV	
H_2 pressure (kPag)	76-138	145-207	>207	75-207	214-345	>345	75-207	214-345	>345	214-345	>345
< 25th	0	0	2	0	0	0	2	0	0	0	0
< 50th	5	0	8	2	2	1	9	4	2	3	2
< 75th	20	13	17	15	10	4	23	16	9	12	7
< 90th	47	48	34	44	34	15	84	42	22	33	20
< 95th	60	86	47	77	47	22	237	67	36	93	30

Comparing Air with H_2 (SSC)

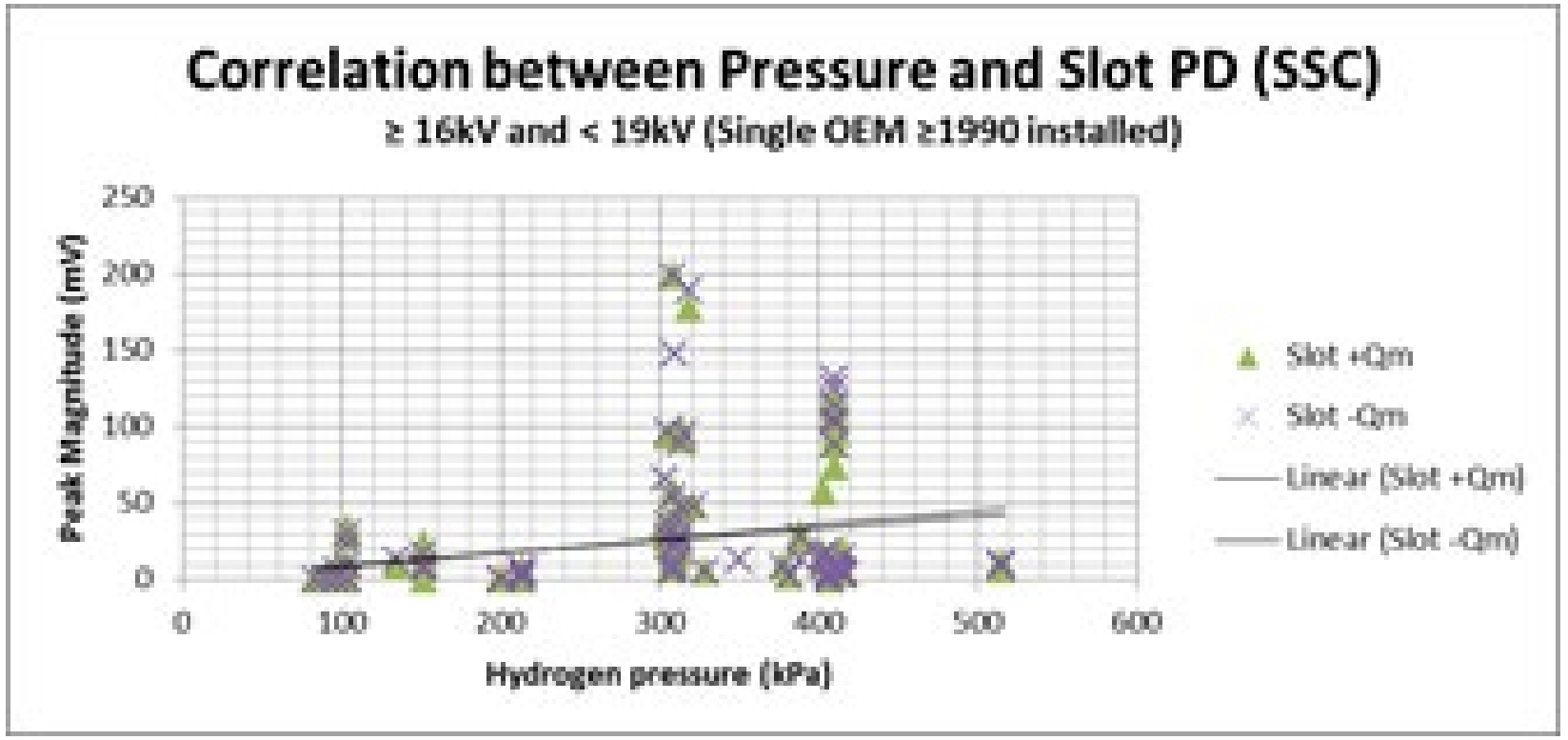
13-15 kV		13-15 kV		
		76-138	145-207	214-345
25%	0	0	0	2
50%	10	5	0	8
75%	33	20	13	17
90%	83	47	48	34
95%	126	60	86	47

PD in Hydrogen



Old windings <1990, no evidence of correlation

PD in Hydrogen



Newer windings >1990, slight correlation

Observations

- PD occurs in H_2-cooled machines
- In general, as the H_2 pressure increases, the Qm values decrease
- Vintage of machine plays a role
- The 80 pF sensor data is more corrupted with noise from the machine terminals, thus the pressure effect is less obvious
- Pressure effect more evident from SSCs

Summary

- Proper use of the statistical tables is beneficial to determine stator winding insulation condition
- Correlation with visual inspection indicates if the Qm is higher than 90% of similar machines, stator insulation problems are likely
- In all cases, the trend of a single asset is still the most reliable for condition monitoring
- In H_2-cooled machines, PD mainly a symptom of loose coils in the slot, endwinding contamination and delamination
- Thermal ageing and problems related to PD-related ozone are significant factors in air-cooled machines

Thank you

And good luck keeping your machines running