Stator Slot Couplers (SSCs)
Basic principles & use

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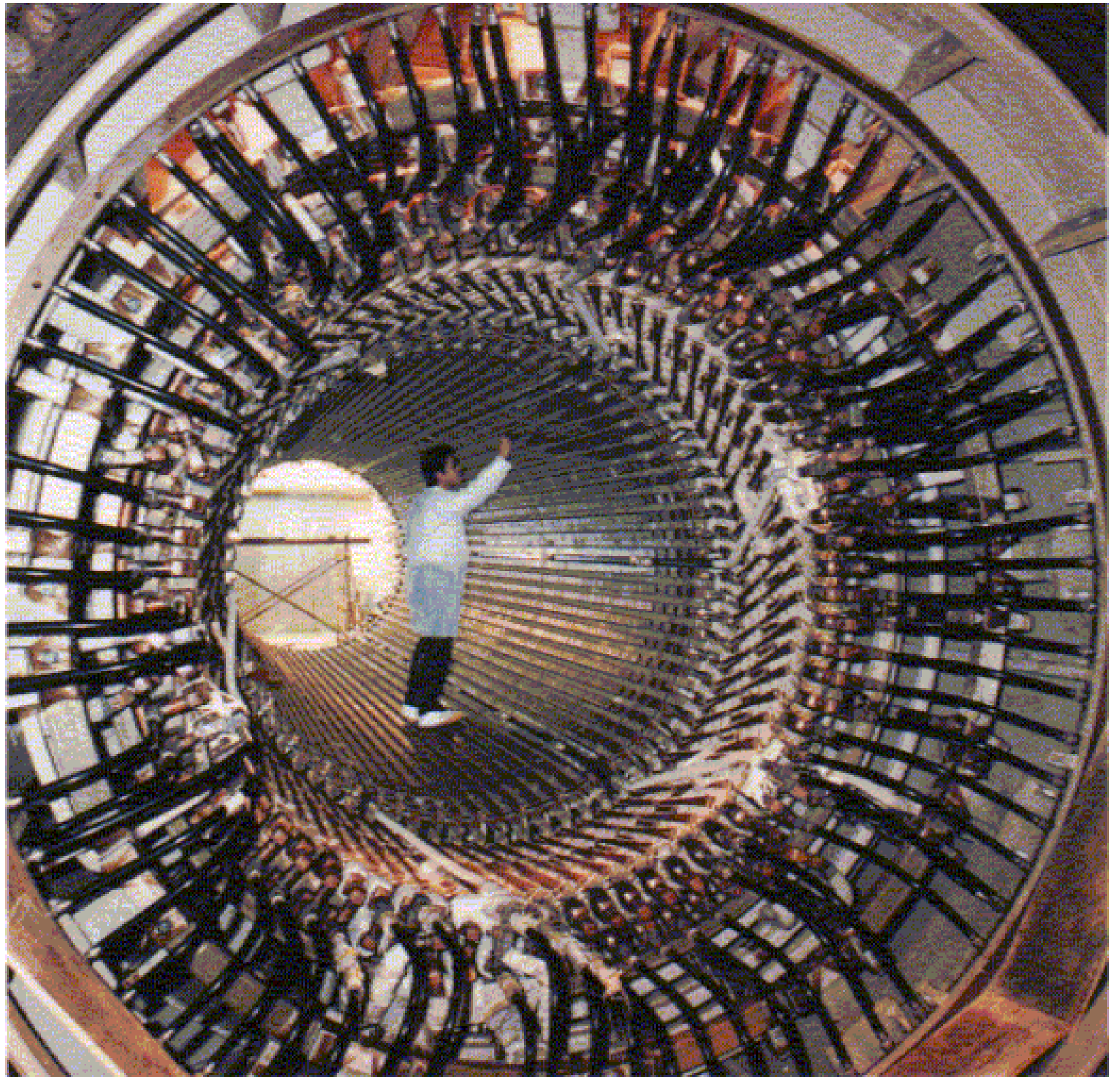
October 13, 2020

Outline

- Purpose of PD testing
- What the SSC is
- How the SSC detects PD & rejects noise
- Instrumentation
- Which machines to apply SSCs
- Examples of test results

Stator winding insulation problems - 2nd most frequent reason for machine failure



What Is Partial Discharge?

- Small electrical sparks in air-filled cavities in or adjacent to HV electrical insulation
- Occur because breakdown strength of
  - air **(3 kV/mm)**, H_2 **(7 kV/mm)** < solid insulation **(~300 kV/mm)**
- PD creates small voltage pulses
  - PD monitoring measures these small pulses
- Properly interpreted, PD is a useful tool to aid maintenance planning

PD a Symptom or Cause of Many Failure Processes

- Poor impregnation of coils: (voids)
- Overheating of coils: (delamination)
- Looseness of windings in slot: (slot discharge)
- Deterioration of semiconductive or grading coatings: (slot or endwinding discharge)
- Thermal Cycling: (voids next to copper)
- Contaminated windings: (electrical tracking)
- PD will not find stator endwinding looseness, problems solely at the neutral end, foreign metallic objects or water leaks due to crevice corrosion

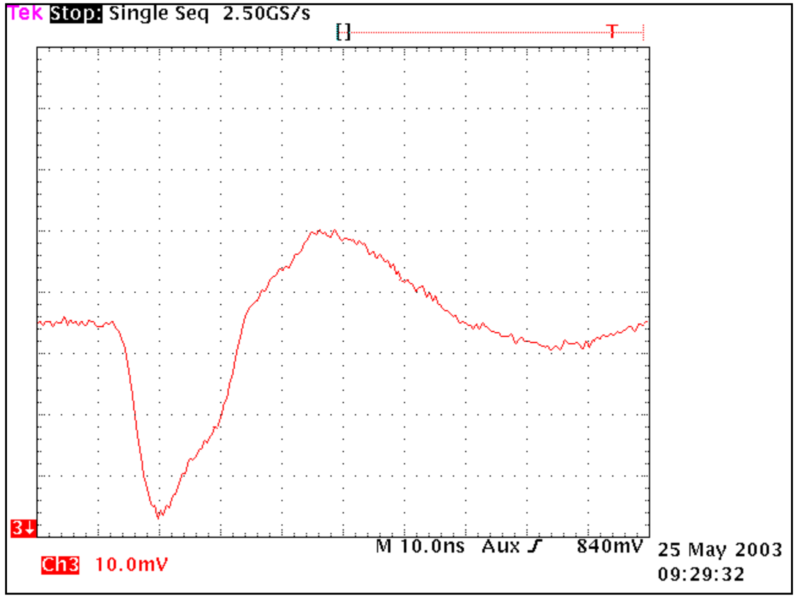
Improper impregnation - voids

Loose windings

- Can affect all machines
- If winding is not maintained tight in slot, abrasion between bar/coil surface and core iron can occur
- Leads to loss of semicon, higher electrical stress and PD

PD Pulse Characteristics

- Extremely fast rise-time current pulse = short pulse width
- Rise-time at discharge origin ~ 1 to 5 ns
- Using f=1/T (~50 to 250 MHz)
- Measure PD in high frequency spectrum



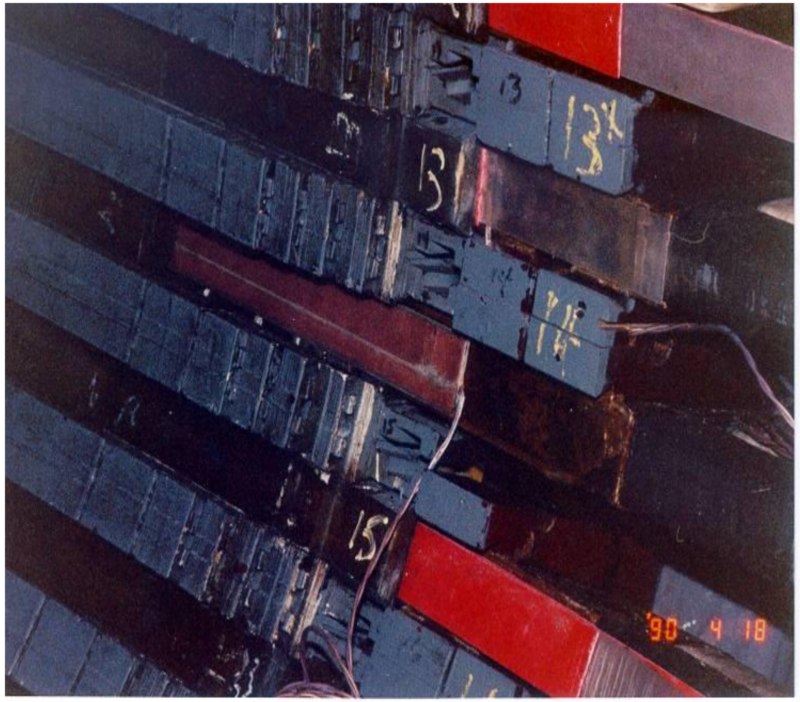
Separating Electrical Noise from PD

- In on-line test, electrical interference from ‘noise sources’ such as transmission line corona, sparking electrical connections, slip ring sparking, power tool operation
- This noise masks stator winding PD – non specialists may assume stator is close to failure, when high levels of relatively harmless noise present – false indications
- sensors and instruments need to separate electrical noise from PD
- Thus very low risk of false indications; users can perform and interpret results with only 2 days training

PD Sensors

- Epoxy-Mica Capacitors (EMCs)
  - Directly connected to HV bus or terminals
  - 80 pF creates a HPF with cutoff of 40 MHz
  - Motors-1 per phase
  - TGs – 2 per phase
  - Complies with sensor reliability requirements of IEEE 1434 and IEC 60034-27-2

Stator Slot Coupler SSC

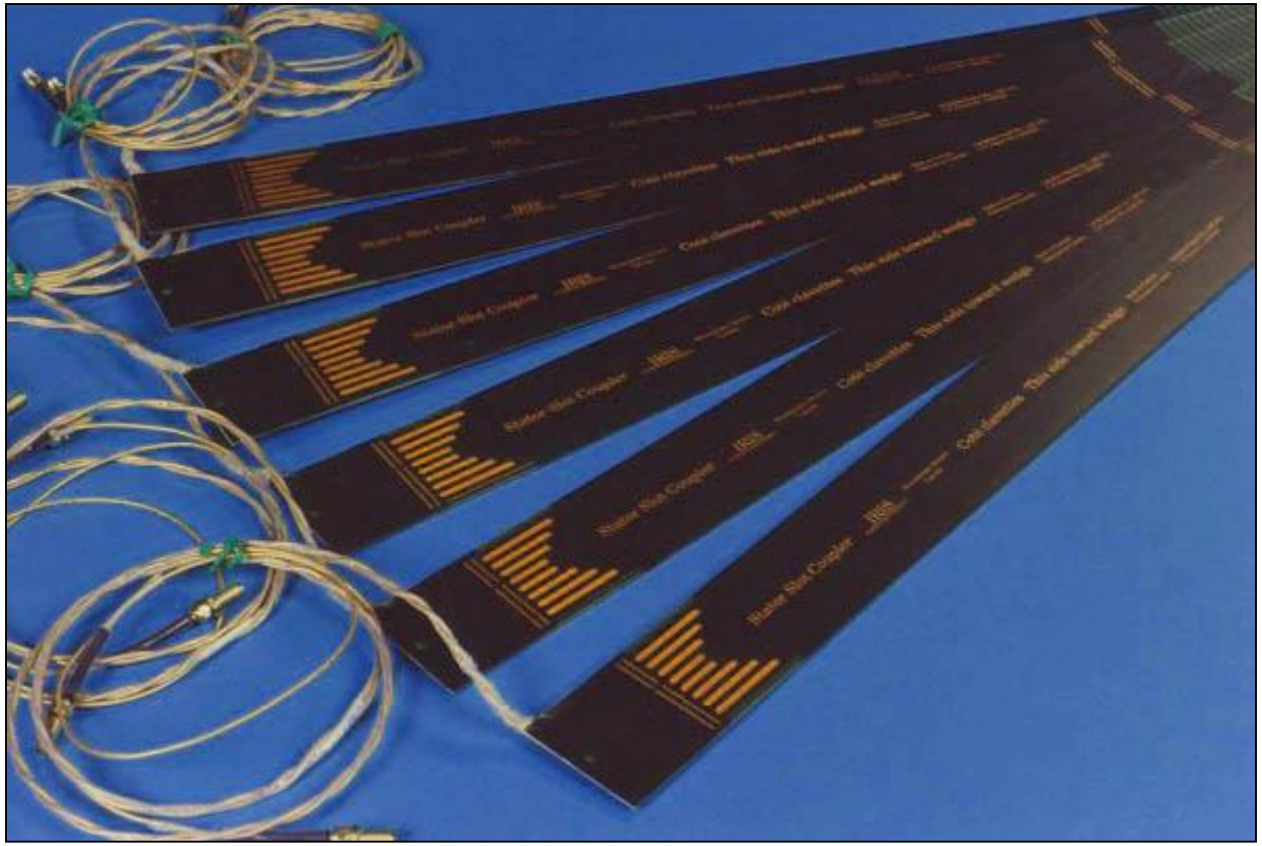


- Developed at Ontario Hydro in late 1980s
- Wide band (10 – 1000 MHz directional coupler
- No HV connection (need external phase ref.)
- Installed under wedge or between bars
- Use pulse shape to reject noise
- Limited "view" of winding

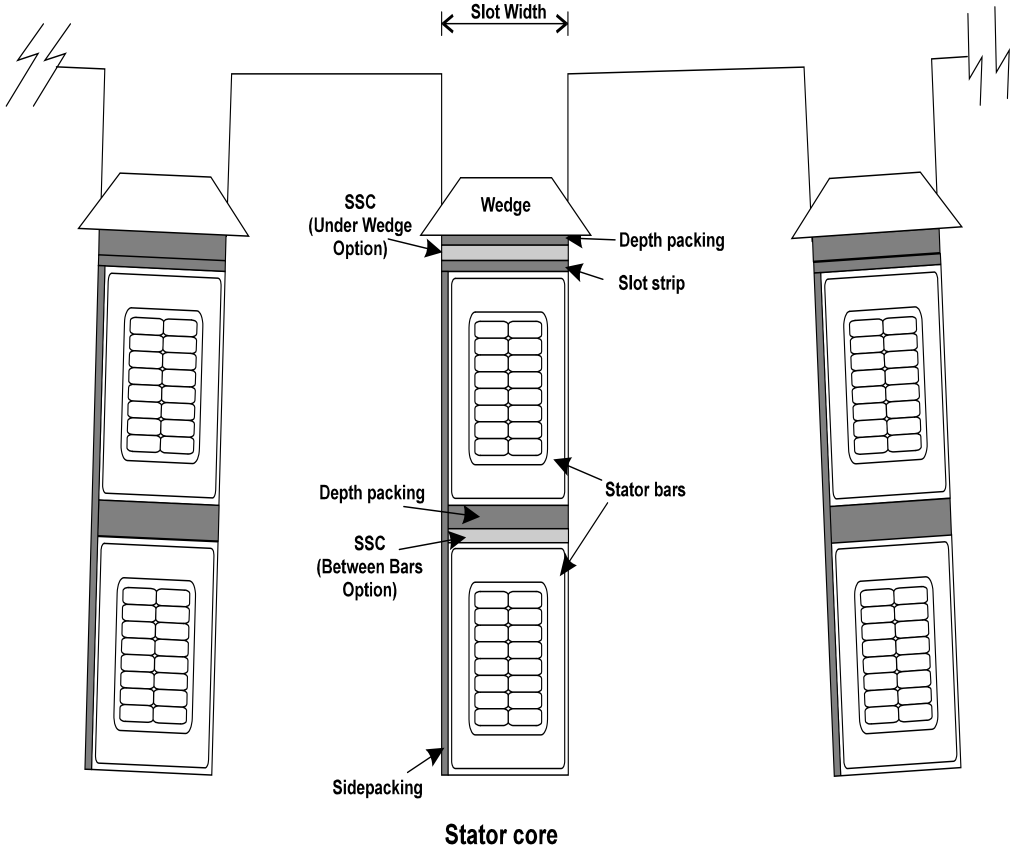
Why install SSC?

- On large machines arcing/sparking on core may be present
- Better suppression of sparking noise at the generator terminals

Stator Slot Coupler SSC

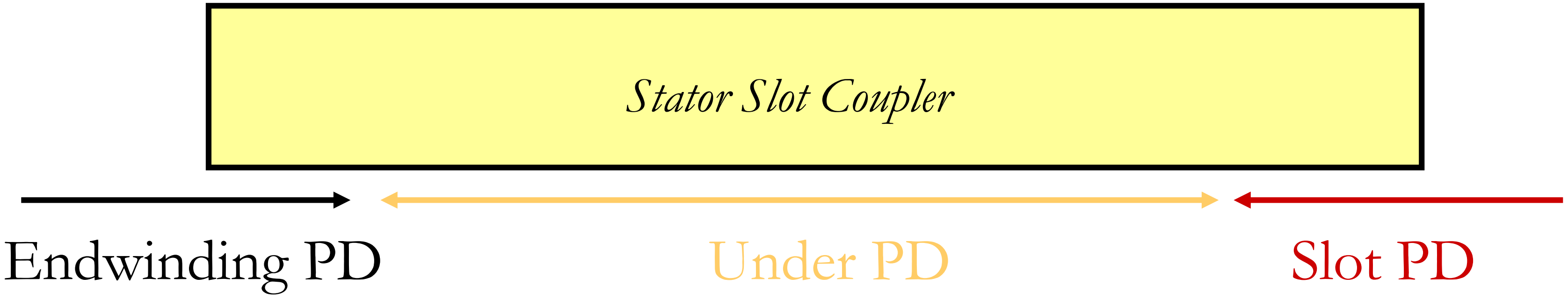


Where are SSCs installed

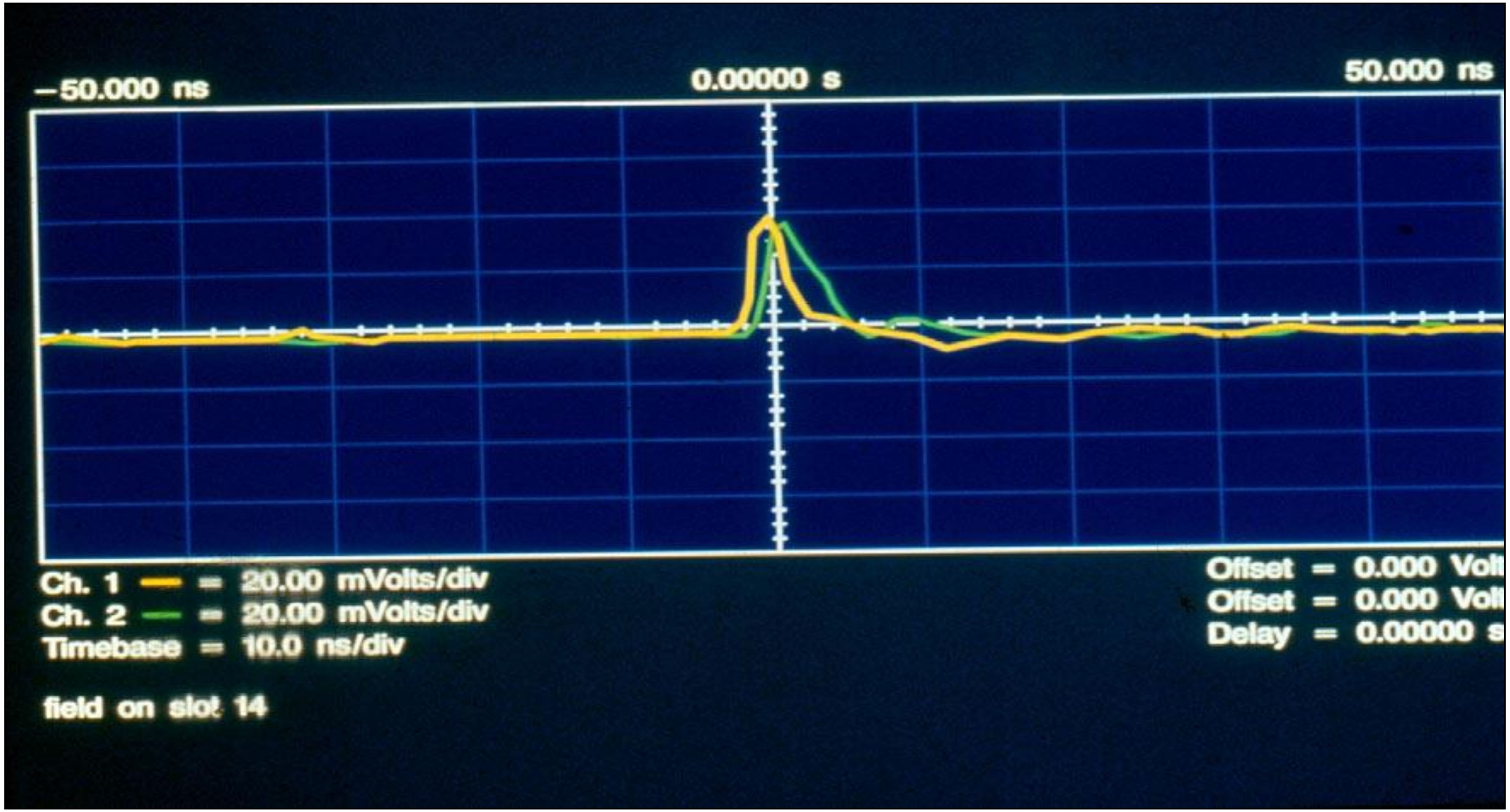


- Typically, SSCs are installed at the collector end of the machine
- SSC leads are routed in contact with grounded surfaces to a feedthrough plate
- Normally install two couplers per phase on 2-pole machines

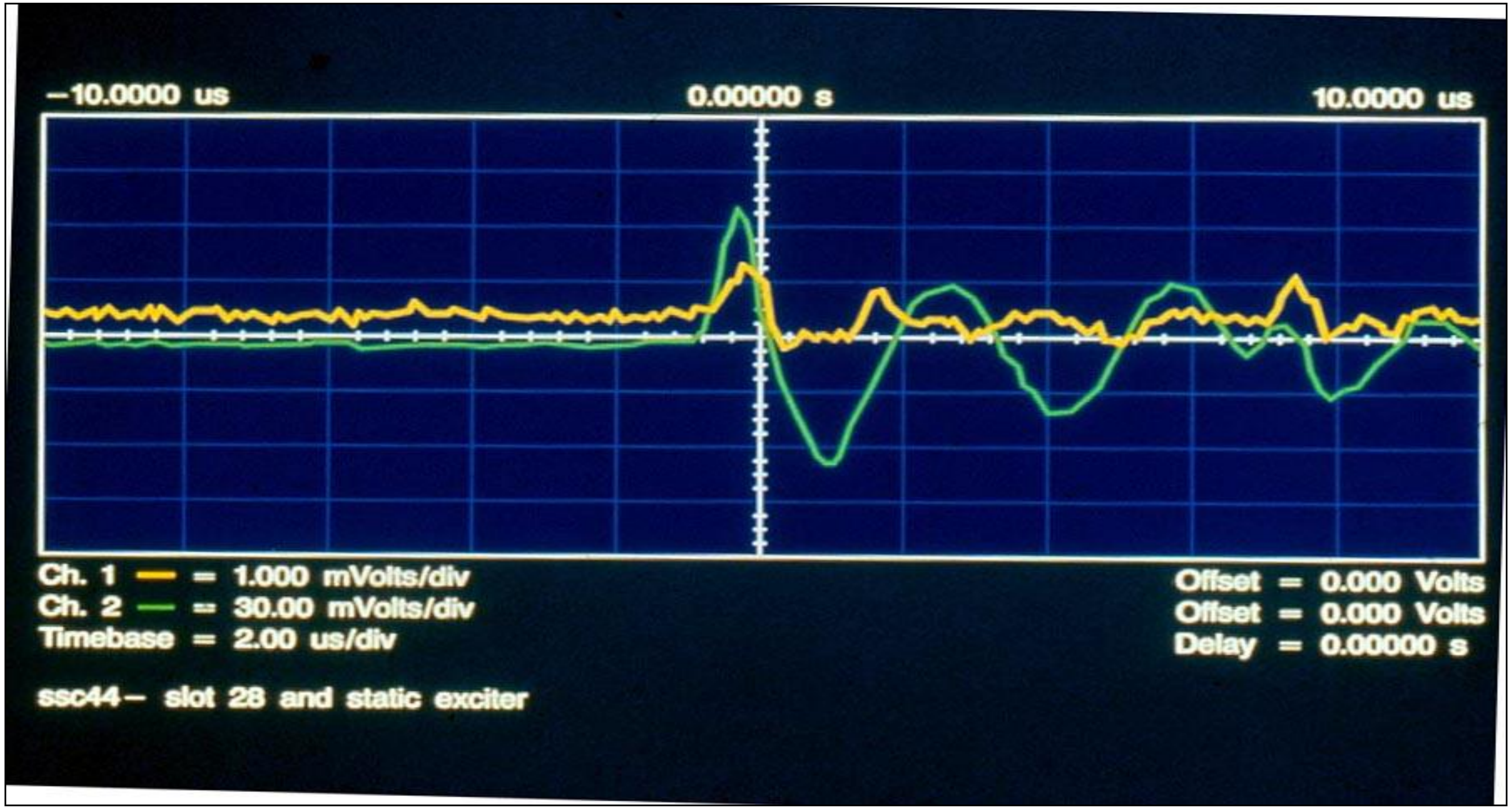
Directional - SSC



PD pulses are unipolar and have a width < 6 ns



Noise pulses are oscillatory and have a width >6 ns



Noise separation with SSCs

- Partial Discharge Signals:
  - Detected as 1-5 ns rise-time pulses
  - TGA-S separates PD from Noise based on Pulse characteristics

- Noise Signals:
  - > 8 ns rise-time as Wide pulses
  - > 20ns as Noise

Instruments

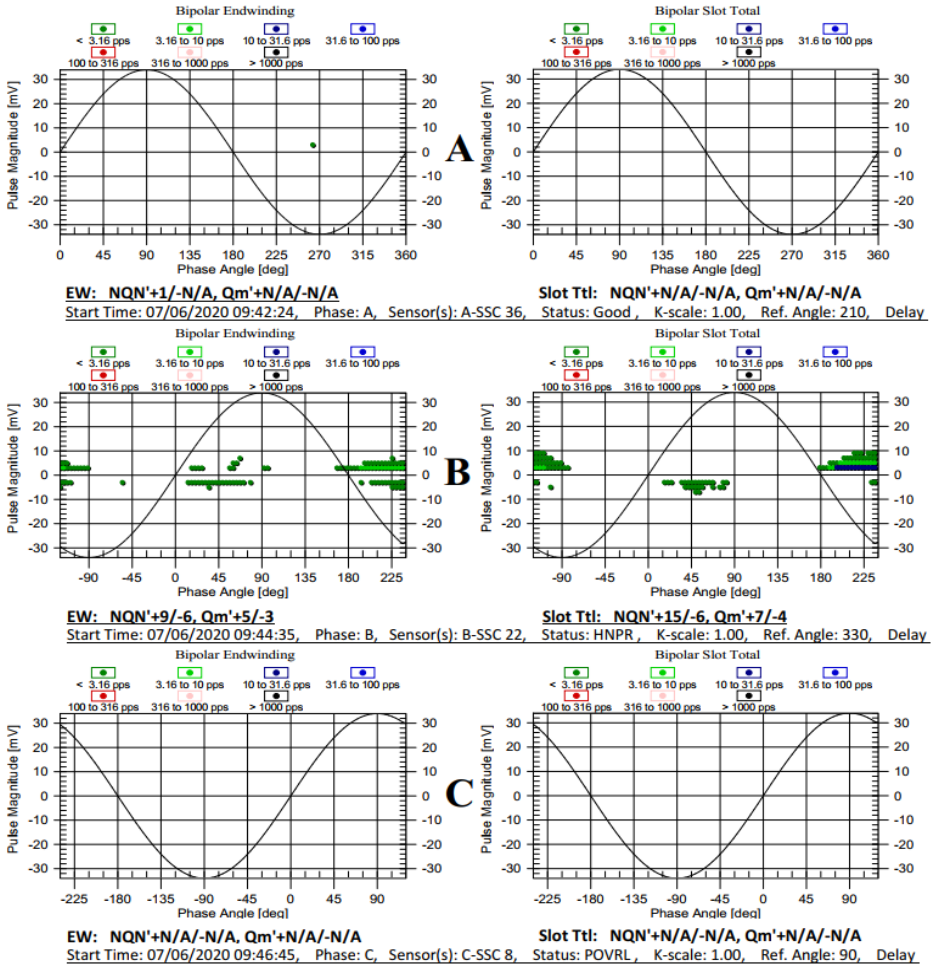
GuardII – continuous monitoring

TGA-S – periodic monitoring

Which machines to apply SSCs to

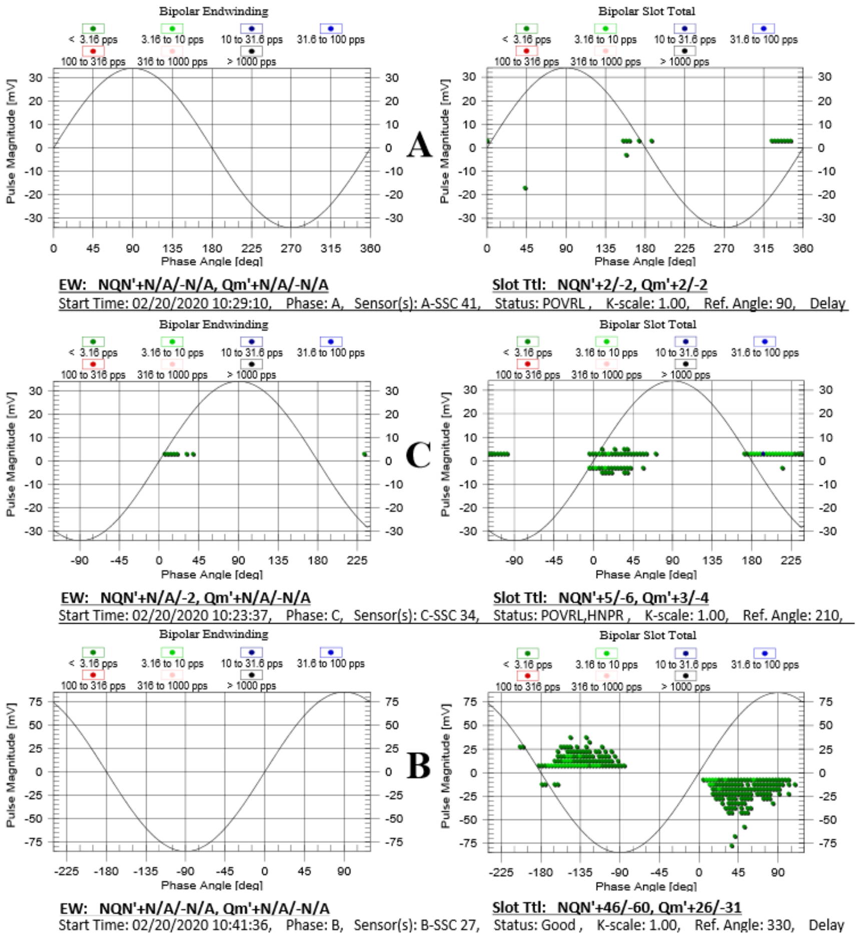
- In principle, SSCs are preferred for H_2-cooled generators rated > 100 MVA
- However,
  - Magnitude of noise pulse tends to increase as a function of V and I, so most installations are on much higher capacity machines
  - Installation of SSCs requires rotor removal, not always practical and occurs less than once/decade

Test result – example 1



- 18.5 kV, 830 MW, H_2-cooled (60 psig) turbogenerator
- Endwinding (EW) PD on plots at right
- Slot (S) PD on left

Test result – example 2



- 18.5 kV, 830 MW, H_2-cooled (60 psig) turbogenerator

Separate database for SSCs

Rated V	13-15kV				16-18kV			19-22kV			23-26kV	
(kPa)	76-138	145-207	214-345	> 345	75-207	214-345	>345	75-207	214-345	> 345	214-345	> 345
H2 (psi)	11-20	21-30	31-50	> 50	11-30	31-50	> 50	11-30	31-50	>50	31-50	>50
25%	0	0	0	0	0	0	0	0	0	0	0	0
50%	1	1	2	1	2	0	0	8	1	1	0	0
75%	16	8	16	6	12	5	3	34	14	6	16	6
90%	57	37	41	15	32	30	8	149	47	21	56	16
95%[2]	97	85	53	32	49	56	13	629	68	39	117	30

Slot (S) PD

Rated V	13-15kV				16-18kV			19-22kV			23-26kV	
H2 (kPa)	76-138	145-207	214-345	> 345	75-207	214-345	>345	75-207	214-345	> 345	214-345	> 345
H2 (psi)	11-20	21-30	31-50	> 50	11-30	31-50	> 50	11-30	31-50	>50	31-50	>50
25%	0	0	0	0	0	0	0	0	0	0	0	0
50%	0	0	1	0	0	0	1	0	0	1	0	0
75%	1	1	5	1	3	1	4	1	3	6	1	3
90%	10	6	13	7	11	6	9	8	11	16	13	7
95%	20	10	23	27	17	16	16	10	17	31	51	16

Endwinding (EW) PD

Summary

- SSCs were developed in the late 1980s to overcome noise issues in large turbogenerators
- The SSC is a directional coupler with a 10 – 1000 MHz bandwidth
- SSCs are installed either under the slot wedge (retrofit) or between top and bottom bars (rewind)
- No contact with HV conductor; signal outputs different than for 80 pF sensors
- Statistical analysis of SSC data requires separate databases