

PARTIAL DISCHARGE SUMMARY BENCHMARK DATA

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The following summarizes the analysis of the PD levels, given by Qm number, for all data collected with Iris equipment up to the end of the year 2015 with over 550,000 results. Since it has been well established that it is ambiguous to compare PD results obtained using different types of sensors [3], data analysis requires separation of the database based on sensor type. The two basic types of sensors used in the data collection are: 80pF capacitors (cable-type and epoxy-mica type) and stator slot couplers (SSC). Furthermore, data will be separated based on gas cooling pressure and operating voltages.

CAPACITORS – (AIR-COOLED MACHINES)

The most widely employed sensors are the 80pF couplers used on motors, hydro-generators, and small turbine generators. There are two methods of sensor installation for the capacitive couplers, the directional (TGA) and the differential (PDA) methods.

Directional Method (TGA)

The directional method is used primarily on motors and small turbine generators and occasionally on small hydro-generators.

Qm values for air-cooled machines with directional capacitive couplers (TGA)

Rated kV	2-5	6-9	10-12	13-15	16-18	> 19 ₁	
25%	9	25	45	54	38	63	25% of the results have Qm levels below this value
50%	21	66	98	120	76	101	50% of the results have Qm levels below this value
75%	63	158	210	261	162	231	75% of the results have Qm levels below this value
90%	214	336	412	520	329	626	90% of the results have Qm levels below this value
95%	363	521	643	770	570	935	95% of the results have Qm levels below this value

As shown here, the majority, 75%, of the results obtained with the directional mode installation (BUS) of capacitive couplers are below 210mV for machines rated less than 12kV, 261mV for machines rated 13-15kV, 162mV for 16-18kV, and 231mV for those >19kV.

Additionally, there is at least a doubling of the Qm levels between the 75% and the 90%, which supports the definition of *rapid deterioration* as doubling over a twelve-month interval [28]. There are a few machines with PD much higher than the 90th percentile with Qm levels >500-935mV. These machines are suspected to have significant deterioration.

Differential Method (PDA)

The differential method is used primarily on large hydro-generators having an internal circuit ring bus.

There are two major differences in the directional and differential installations: one is the method of time-of-arrival noise separation and the second is the actual location of the couplers. Since both time-of-arrival noise separation techniques work similarly, this difference should have little impact to the test results.

However, the difference in the sensor locations can greatly affect the results. A differential (PDA) installation in a larger hydro-generator uses sensors normally placed within one meter of the junction between the incoming phase bus and the first coil/bar in the circuit. A sensor at this location will be extremely sensitive to any pulses originating within the coil/bar since the magnitude of the pulse will be amplified when it reaches the impedance mismatch between the bus and the coil/bar. Thus, it is reasonable to assume the results obtained with the couplers at this location will be higher than when the couplers are located outside the machine housing typical of

directional (TGA-BUS) installations. However, when comparing the directional (TGA) results to the differential (PDA) results, though there are some minor variances, there is little significant difference between the statistical summaries for windings rated less than 16kV. Thus, it is safe to say that for a 13.8kV winding,

regardless of installation type, the PD levels should be less than ~250mV and those machines with PD higher than 500mV need further investigation.

Qm values for air-cooled machines with differential capacitive couplers (PDA)

Rated V	6-9 kV	10-12 kV	13-15 kV	16-18 kV	> 19 kV	
25%	25	45	54	38	63	25% of the results have Qm levels below this value
50%	66	98	120	76	101	50% of the results have Qm levels below this value
75%	158	210	261	162	231	75% of the results have Qm levels below this value
90%	336	412	520	329	626	90% of the results have Qm levels below this value
95%	521	643	770	570	935	95% of the results have Qm levels below this value

CAPACITORS – (GAS-COOLED) (TGA)

Since the occurrence of PD is extremely dependent on the electrical breakdown point of the gas medium, PD results from air-cooled machines are typically higher than machines cooled with either hydrogen or pressure carbon dioxide. Therefore, it is not advisable to compare the results from machines using different gas mediums. Since most hydro-generators (PDA installations) are air-cooled, all of the tests for gas-cooled machines with capacitors were obtained using a TGA instrument and directional sensor installation. Most of the hydrogen-cooled machines have high rated loads and frequently suffer from problems with the core iron arcing. PD or noise activity at the machine terminals, outside the hydrogen environment, can make stator winding insulation condition difficult to interpret. As a result, stator slot couplers (SSC) are the recommended sensors in these applications to avoid misdiagnosis resulting from the capacitive sensor detecting core-iron problems in addition to stator winding problems.

Qm values for non air-cooled machines with directional capacitive couplers (TGA)

Rated V	13-15kV ₂				16-18kV				> 19kV		
	H2 (kPa)	76-138	145-207	214-345	Over 345	76-138	145-207	214-345	Over 345	145-207	214-345
H2 (psig)	11-20	21-30	31-50	>=51	11-20	21-30	31-50	>=51	21-30	31-50	>=51
25%	28	21	16	27	17	33	21	9	43	22	10
50%	75	50	34	80	80	72	40	21	94	49	27
75%	157	98	67	197	146	3793	97	47	172	90	602
90%	346	183	179	600	268	9053	191	272	217	154	3982
95%	830	293	419	965	389	976	354	350	246	224	987

As expected, the PD results for gas-cooled machines are much lower than for the air-cooled machines. This is especially observable at higher pressures, where 75% of the tests for all operating voltages operated above 31psig are below 200mV and 90% generally below ~250mV, less than half of that observed on the air-cooled machines (Section 7.1.1). At the lower operating pressures, the PD levels are generally much higher, with a few machines having extremely high PD of Qm levels >600mV, which would require more tests and investigation.