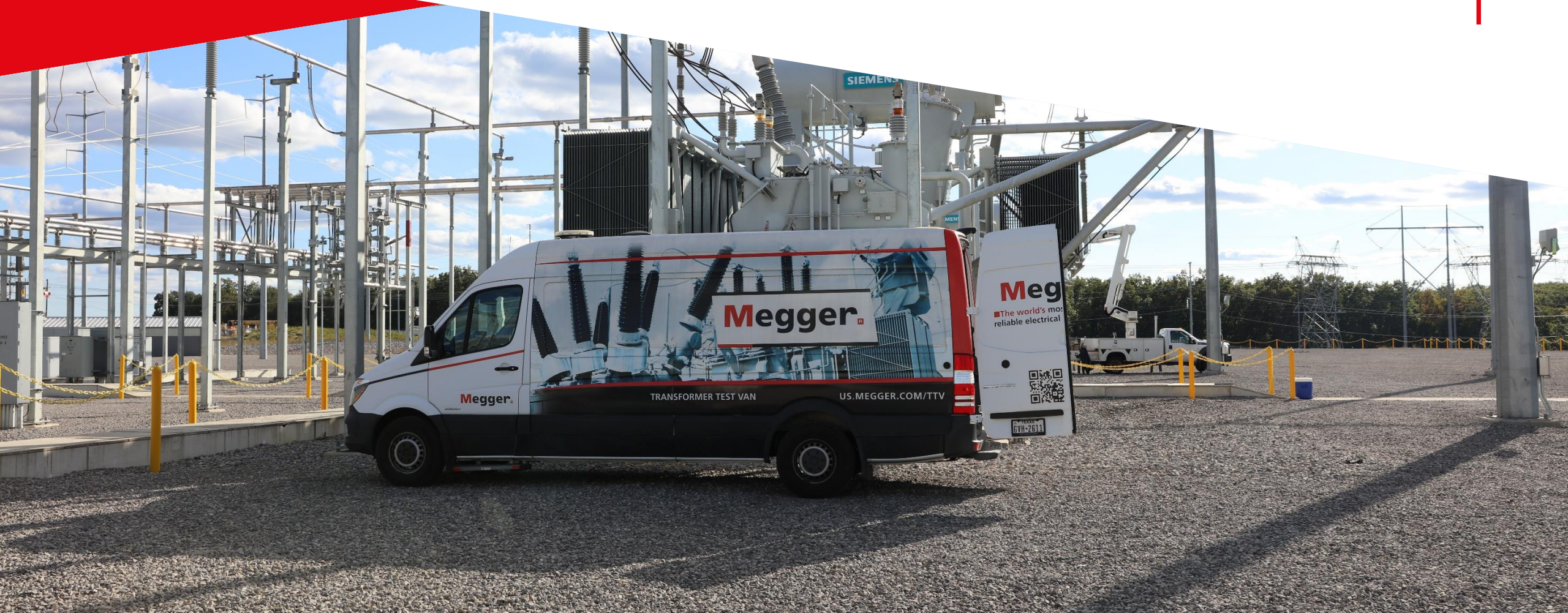
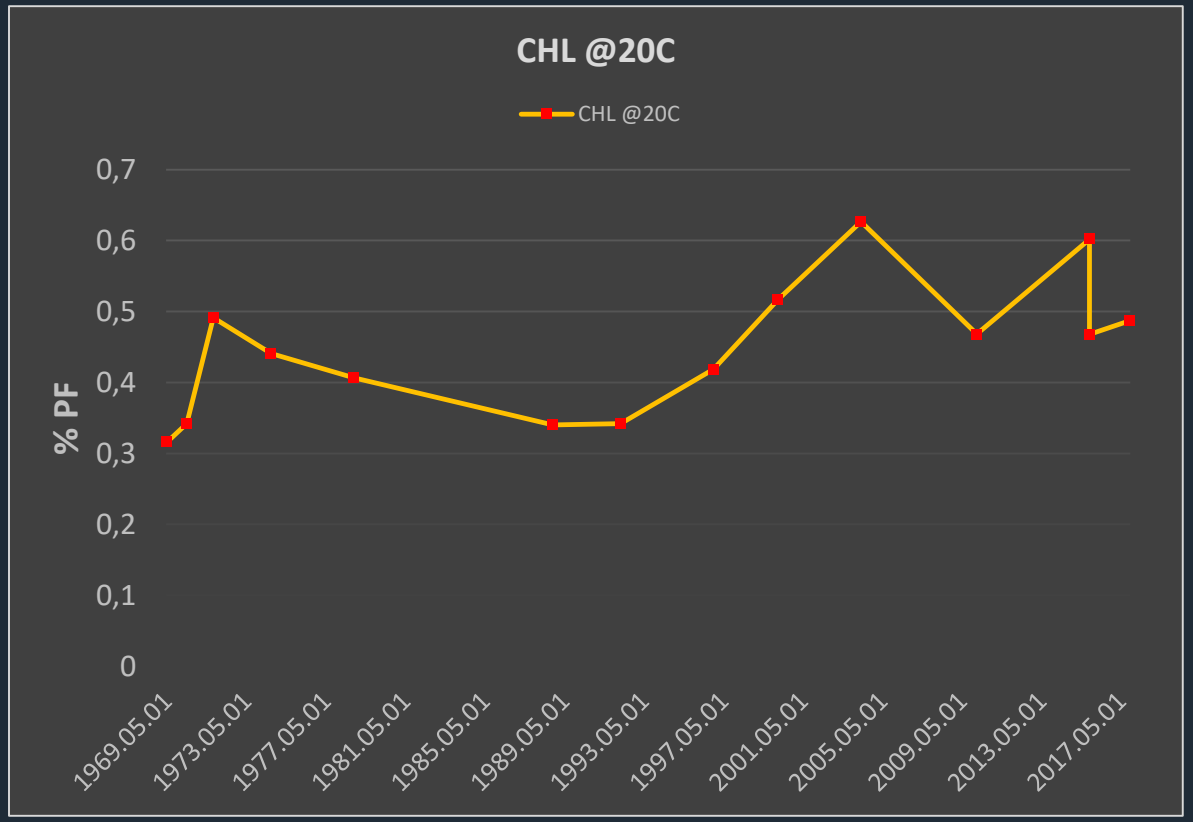
Benefits of 1 Hz tan δ testing for Insulation Condition Assessment



Line Frequency tan δ

- Performed at 50 Hz or 60 Hz
- Evaluate @ 20°C
  - Correct with tables
  - Limits set by standards
- Analysis improves with trending
  - Small PF increments not conclusive
- Early deterioration not noticeable



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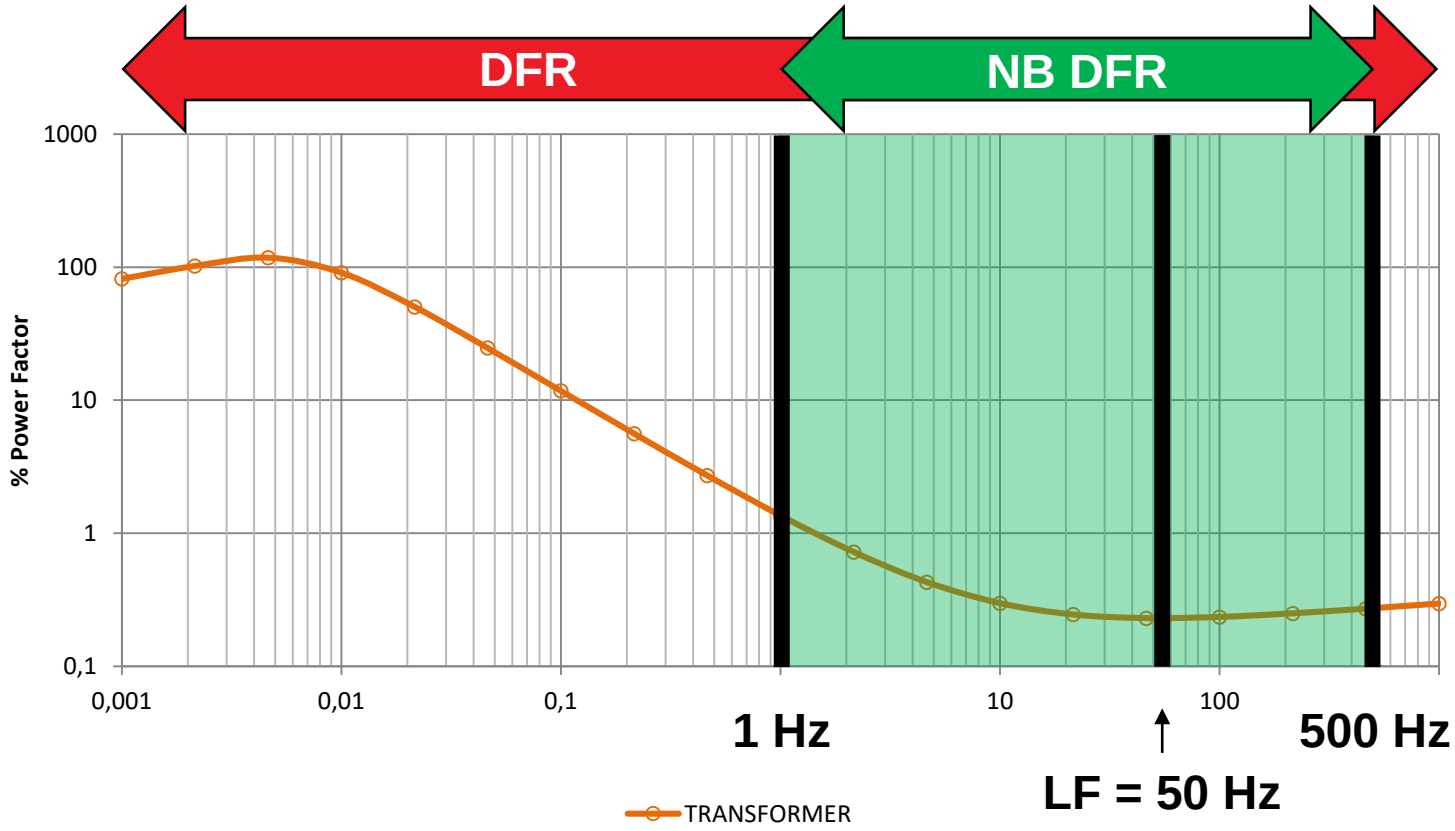
LF vs NB DFR vs DFR Range



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Case study 1

2002 69kV Bushings @ 11.5°C

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2002 69 kV Bushings @ 11.5°C

- C1 Results with Temperature Correction tables
- Everything is great! Minor deviation from nameplate
- What about 1 Hz?
  - LV phase C (X3) significantly different from sister bushings
- What does ITC say?

Bushing C1 Test **Test Mode:** Line Frequency + 1Hz + 505Hz | Temperature Correction Table | View Table Temp. Correction Factors

Connection Diagram			60Hz										
Test No.	NB DFR	Dsg.	Test Mode	TEST kV	Capacitance		Equivalent @ 10 kV		POWER FACTOR %			Δ %PF @ 20°C	%VDF
					C (pF)	Δ pF	mA	Watts	Measured	@ 20°C	IR		
14	✖	X1	UST-R	10.0	262.4		0.99	0.0241	0.24				
15	✖	X2	UST-R	10.0	261.7		0.99	0.0246	0.25				
16	✖	X3	UST-R	10.0	260.9		0.98	0.0313	0.32				

2002 69 kV Bushings @ 11.5°C

- LF shows investigate…
- 1 Hz deviation from sister bushings even more extreme

Bushing C1 Test **Test Mode:** Line Frequency + 1Hz + 505Hz | ITC | View Individual Temp. Correction Factors

Connection Diagram

					60Hz									
Test No.	NB DFR	Dsg.	Test Mode	TEST kV	Capacitance		Equivalent @ 10 kV		POWER FACTOR %			Δ %PF @ 20°C	%VDF
					C (pF)	Δ pF	mA	Watts	Measured	@ 20°C	IR		
14	✖	X1	UST-R	10.0	262.4		0.99	0.0241	0.24	0.24	G	0.02	0.04
15	✖	X2	UST-R	10.0	261.7		0.99	0.0246	0.25	0.24	G	0.02	0.04
16	✖	X3	UST-R	10.0	260.9		0.98	0.0313	0.32	0.40	I	0.14	0.04

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Case study 2

2019 16 MVA 138 kV Transformer @ 25°C

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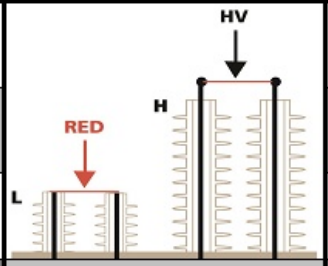
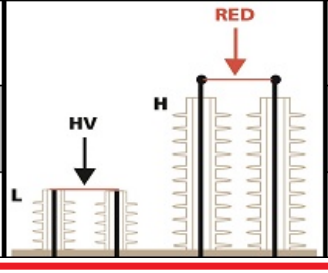
2019 16 MVA 138 kV Transformer @ 25°C

- Excellent LF tan δ for a new transformer
- …but 1 Hz looks a little high

Transformer Overall Test — **Test Mode:** Line Frequency + 1Hz | Temperature Correction Table | Enter Overall Correction Factors

Multiple Test

Test No.	NB DFR	Insulation Tested	Test Mode	Connections (Click image for detailed connection information)	TEST kV	Cap (pF)	60Hz DIRECT mA	60Hz DIRECT Watts	60Hz POWER FACTOR % Measured	60Hz POWER FACTOR % @ 20°C	60Hz POWER FACTOR % IR	%VDF
1		$C_{HG} + C_{HL}$	GST-GND		10.0	6,587.9	24.8	0.5383	0.22	0.21	G	
2	✖	C_{HG}	GSTg-RB		10.0	2,421.1	9.09	0.2081	0.23	0.22	G	
3	✖	C_{HL}	UST-R		10.0	4,146.5	15.6	0.3302	0.21	0.20	G	
4		C_{HL}'		Test 1 Minus Test 2		4,166.8	15.7	0.3302			Valid	
5		$C_{LG} + C_{HL}$	GST-GND		7.00	13,793.7	36.4	0.5496	0.22	0.21	G	
6	✖	C_{LG}	GSTg-RB		7.00	9,646.7	25.4	0.3888	0.22	0.21	G	
7		C_{HL}	UST-R		7.00	4,147.6	10.9	0.1637	0.22	0.21	G	

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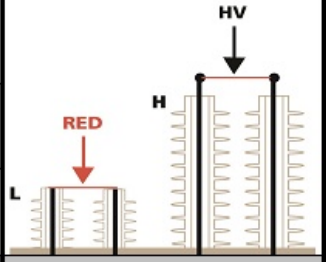
2019 16 MVA 138 kV Transformer @ 25°C

- With ITC, 1 Hz insulation is rated as aged
- …but this is a new transformer that has never been in service?!

Transformer Overall Test | **Test Mode:** Line Frequency + 1Hz | ITC | View Individual Temp. Correction Factors

Multiple Test

Test No.	NB DFR	Insulation Tested	Test Mode	Connections (Click image for detailed connection information)	TEST kV	Cap (pF)	60Hz DIRECT mA	DIRECT Watts	POWER FACTOR % Measured	POWER FACTOR % @ 20°C	POWER FACTOR % IR	%VDF
1		C_{HG} + C_{HL}	GST-GND		10.0	6,587.9	24.8	0.5383	0.22	0.22	G	
2	✖	C_{HG}	GSTg-RB		10.0	2,421.1	9.09	0.2081	0.23	0.23	G	
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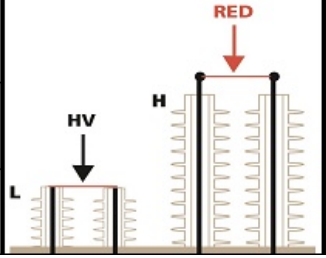
4		C_{HL}'		Test 1 Minus Test 2		4,166.8	15.7	0.3302			Valid	
5		C_{LG} + C_{HL}	GST-GND		7.00	13,793.7	36.4	0.5496	0.22	0.22	G	
6	✖	C_{LG}	GSTg-RB		7.00	9,646.7	25.4	0.3888	0.22	0.24	G	
7		C_{HL}	UST-R		7.00	4,147.6	10.9	0.1637	0.22	0.22	G	

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2019 16 MVA 138 kV Transformer @ 25°C

- C_{HL} DFR:

Results @ 60Hz, 20°C		Analysis results		
Capacitance pF	%PF	%PF @ 60 Hz & 20°C	Moisture %(wt/wt)	Cond. (pS/m) @ 25°C
4124	0.216	0.216	1.6	1.30
		< 0.30 % As new	< 1.0 % As new	< 0.37 pS/m As new
		0.30 - 0.50 % Good	1.0 - 2.0 % Dry	0.37 - 3.7 pS/m Good
		0.50 - 1.0 % Deteriorated	2.0 - 3.0 % Moderately wet	3.7 - 37 pS/m Service aged
		> 1.0 % Investigate	> 3.0 % Wet	> 37 pS/m Deteriorated

- 1.6% moisture
  - High for new transformer that has not been in service
- Oil conductivity of 1.3 pS/m
  - also high for new transformer

2019 16 MVA 138 kV Transformer @ 25°C

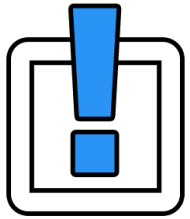
- Customer has **no moisture limit for transformers < 150 kV**
- Customer has **limit for moisture in oil of < 10 ppm (per IEEE)**
- Two separate oil samples extracted @ 26C and taken to a lab
  - Results: **15ppm** & **16ppm**
  - Result: Failed commissioning for this class of new transformer

Overall Conclusions – 1 Hz Power Factor

- Same connection as LF tan δ test

- 1 minute additional test time
  - PowerDB automatically tests without additional configuration

- Immediate assessment at any temperature – no trending required
  - Validate expected LF measurements
  - Confirm questionable LF results
  - Detect early signs of insulation changes when LF looks acceptable



Overall Conclusions – Three step insulation evaluation

- tan δ @ 50 Hz
  - 10kV 50/60Hz corrected to 20°C
- 1 Hz
  - 250V 1Hz corrected to 20°C
- Definitive Analysis with DFR
  - 1mHz to 1kHz

Questions?

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