Megger

Diagnostic Test:

1-500Hz Narrow Band Dielectric Frequency Response

Megger Valley Forge Corporate Center, 2621 Van Buren Ave Norristown PA 19403-2329 USA
T 1-866-254-0962 F 610-676-8625

Registered to ISO9001:2008 - Certificate No. 110006.01

www.megger.com

General

For approximately 25 years, dielectric frequency response (DFR) has been investigated and proven to provide an accurate method of determining both the moisture condition of paper + oil power transformers and bushings. Together with general insulation testing, DFR provides enhanced insulation condition of the transformer under test.

The DFR method of testing involves measuring the insulation response at different test frequencies and uses the resultant curve to determine the level of moisture, as well as the presence of impurities. This is done by comparing the curve to a reference (ideal) insulation model curve.

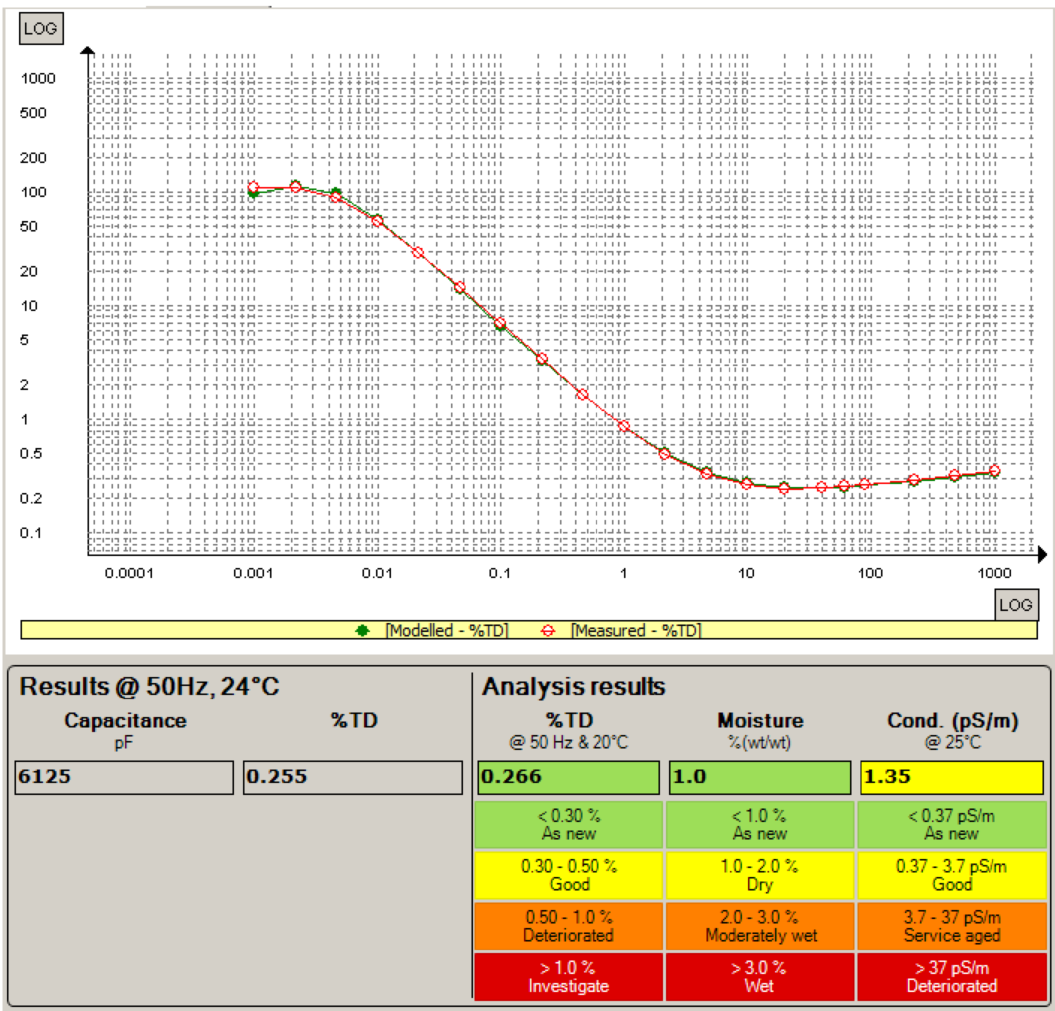

Figure 1 – Example of DFR Curve | IDAX300 | .001Hz – 1000Hz 200V DFR Result & Analysis

Megger

Although a complex process, modern software and hardware have automated DFR testing and the method is now accepted internationally – as evidenced by its inclusion in the CIGRE TB445 as an accepted method for moisture determination. IEEE is presently in the process of completing a new guide for use of DFR in transformer moisture assessment for both factory and field testing, which should be completed and available by 2019. Instruments like the Megger IDAX300, which was the first commercially available unit to perform this test, is a valuable tool in this determination of moisture content.

Narrow Band DFR Testing

Standard 10KV PF(DF) test sets are now available with expanded capabilities. Their main application is line frequency 10KV PF(DF) testing (which is still the international standard for AC insulation quality), but some units include the ability to perform PF tests at frequencies from 1 to 500Hz which can be defined as a **narrow frequency band dielectric frequency response** test. We are now able to provide a shorter duration DFR test which gives us additional information into the overall insulation condition of the transformer or bushing.

This reduced frequency band does not provide the measured level of moisture (we cannot determine what percentage of moisture is present with this test), but it does point to the presence of moisture and/or impurities in the insulation. When we perform the testing, we focus on the paper portion within a transformer which exists between the main high voltage winding to the low voltage winding. We can use the curve shaped result as a sign of the condition of the insulation.

In the figure below, we see the typical shape for a new transformer, (Ch-l) where the curve is considered generally flat. The 60Hz result is 0.34%, the slope around line frequency is slightly positive and the maximum PF at 1 Hz is under 1%. We consider this insulation to be in excellent condition.

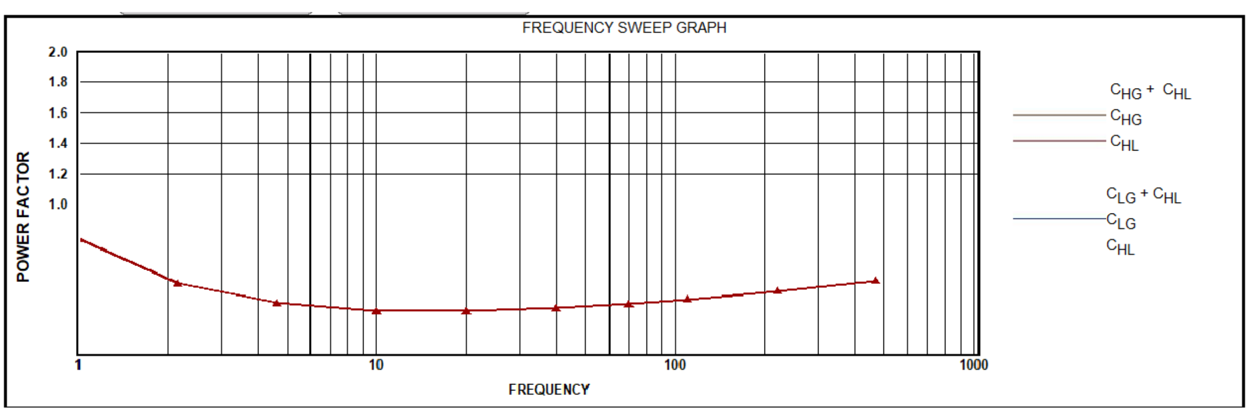

Figure 2 – Sample Narrow Band DFR | New Transformer | DELTA4000 | Scaled to max 2% PF

Case Study – Thailand

As evidence of the value of narrow band DFR, we have the following case study from a test performed on a transformer located in Thailand at a power utility in September 2018. The transformer is no longer in service and is used for training power utility personnel in proper test methods. Prior to our testing, the transformer was considered as a working, service aged unit. This transformer would not be considered as a problem if it were in service according to the manager of this training center.

The transformer was built in 1972, which is at the end of its useful life (>50 years old). We have seen many transformers which are allowed to operate beyond their designed service life, so long as no indication of issues arise to question its reliability.

Picture 1
Test crew performing tests on transformer

Picture 2
Transformer Nameplate
Dyn11 – 500kVA
22kV to 400V

After determining that we had proper testing conditions, using a DELTA4000 for our testing we came up with the following 60Hz PF results:

Multiple Test	TRANSFORMER OVERALL TEST SET UP							Hookup Diagram	ITC	TRANSFORMER OVERALL TEST RESULTS						Set Individual Temp. Corr.
Test No.	INSULATION TESTED	Test Mode	Test Lead Connections				TEST kV	DFR	Capacitance C (pF)	POWER FACTOR %			DIRECT		%VDF	IR
			HV	Red	Blue	Gnd				Measured	@ 20°C	Corr Factor	mA	Watts		
1	$C_{HG} + C_{HL}$	GST-GND	H	L		G	10.00					0.740				
2	C_{HG}	GSTg-RB	H	L		G	10.00	✖				0.740				
3	C_{HL}	UST-R	H	L		G	10.00	✖	2,301.59	0.70	0.52	0.740	7.2282	0.5043	0.03	G

Figure 3 – EGAT – DELTA4000 60Hz 10kV Result

This transformer is considered to be in good condition, especially when taking the climate of Thailand together with the age of the transformer into consideration.

As an additional test to determine the condition of the paper + oil insulation, we were also able to conduct a narrow band DFR test (1-500Hz). Doing so added 7 minutes to the test time, but with no change in lead connections. The narrow band DFR provided us with the following result:

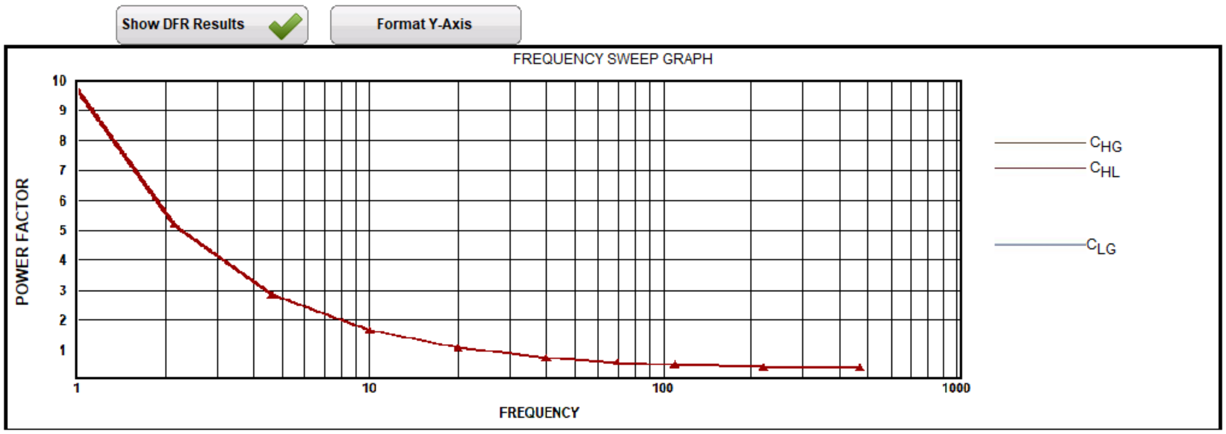

Figure 2 – EGAT – DELTA4000 | 1–500Hz 250V DFR Result | PF @ 50Hz – 0.52%

Comparing this result to a typical new transformer using same y-axis scale(0-10%) as above:

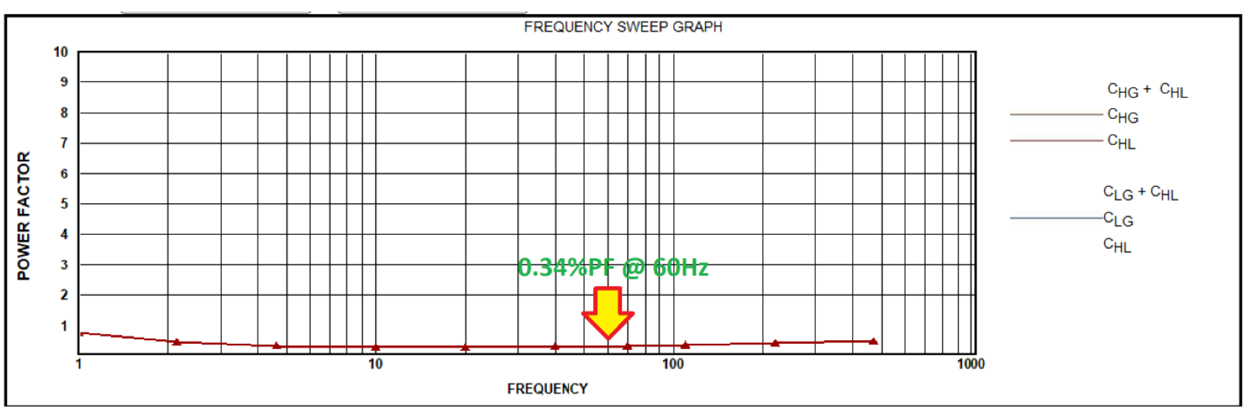

Figure 3 – AEP – DELTA4000 | 1-500Hz 250V DFR Result | PF @ 60Hz – 0.34%

When observing figures 2 and 3, there is a significant difference in the curve shape even though the 60Hz PF (DF) are within only 0.18%PF of each other. One sees an upward curve in the EGAT transformer where the AEP example transformer shows a virtually flat response.

Using this situation as an opportunity to explore possible issues with the EGAT transformer, we set about to perform an IDAX300 full DFR test the next day. This test required a similar connection setup, but with a different lead set and a 200V test voltage from a frequency band of 2mHz to 1000 Hz. Total setup plus testing time for this small transformer was approximately 30 minutes. (Note: It takes longer to make lead connections to larger high voltage transformers)

The IDAX result for the EGAT transformer as shown below agrees with the DELTA4000 at 1 Hz, and so both tests are considered reliable and accurate.

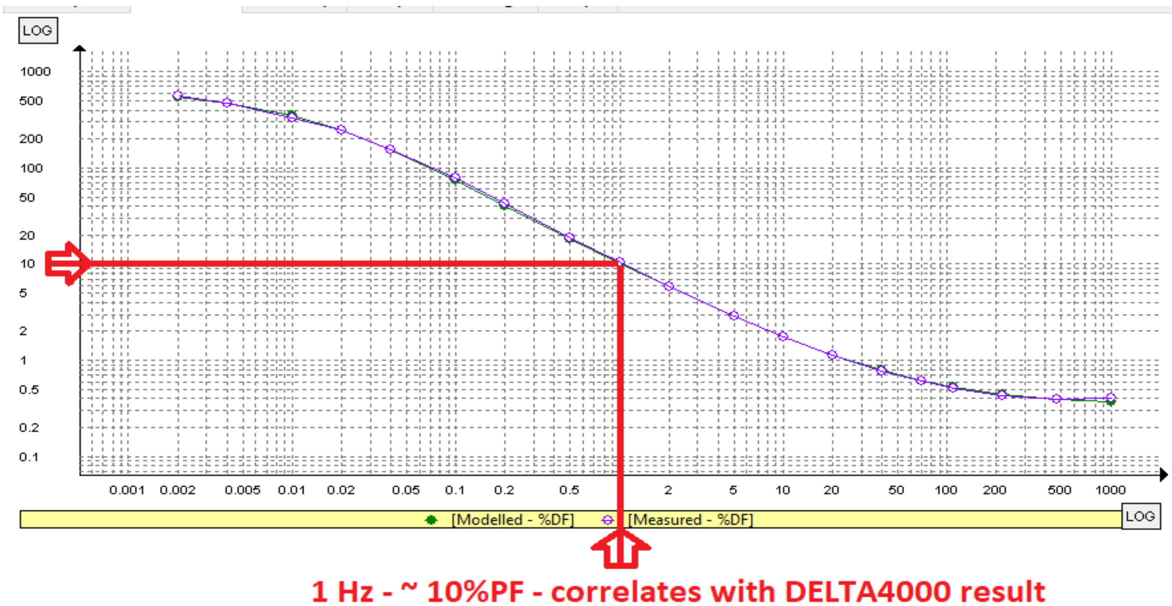

Figure 4 – EGAT – IDAX300 Curve | .002Hz – 1000Hz 200V DFR Result

As part of the IDAX300 test, we are given the moisture and oil conductivity result below, and we see the following:

Results @ 60Hz, 30°C		Analysis results		
Capacitance pF	%DF	%DF @ 60 Hz & 20°C	Moisture %(wt/wt)	Cond. (pS/m) @ 25°C
2304	0.651	0.482	3.4	8.86
		< 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

Figure 5 – EGAT – IDAX300 Analysis | 3.4% Moisture

IDAX300 with a wide band DFR test indicates that this transformer has a moisture issue in the paper insulation, which is not apparent in the 60Hz result. A content above 3% is considered WET, and this transformer has issues which are not apparent from the 60Hz PF result. If this transformer were to remain in service, this problem may get worse and result in a catastrophic failure, which is both a danger and a reliability concern. We also see that the oil conductivity is "service aged", and would require further mitigation efforts once the moisture issue was attended to.

The full DFR result concludes that the evidence of an issue from the narrow band DFR test is well founded. The additional test time of 7 minutes is considered excellent value, as no additional skill or equipment was needed.

Competitor Narrow Band DFR

We consider the **1-500 Hz** ability of the DELTA4000 and the TRAX+TDX to be more sensitive to insulation issues versus our competitors because others only offer **15-500Hz** for their narrow band DFR. As shown below, one can see a significant upward curve of results across the 1-15Hz portion, whereas, with only 15-500Hz, this upward curve shape is not as apparent. The difference is observed on the example below versus competitor's unit:

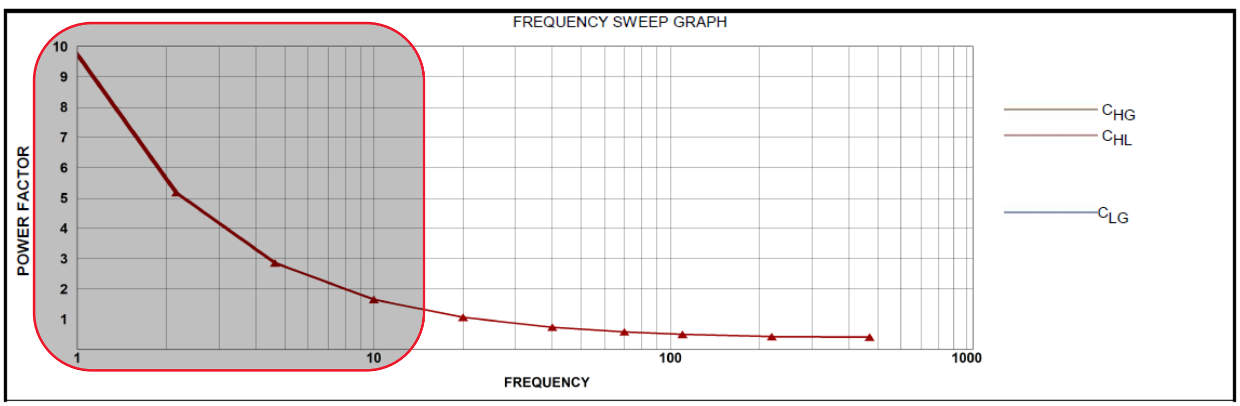

Figure 6 - Greyed out area not visible in competitor's unit. Remaining graph portion appears almost flat.

With competitor units, we are asked to look for the negative slope of the PF curve around line frequency (60Hz in this example), which is a valid method for determining an issue. This slope is not as easy to detect, and the wider 1-500Hz frequency DFR gives us clear evidence of an issue. Small changes around line frequency (for determination of curve slope) are more difficult to detect than with large changes as seen above. With lower frequency tests (below 15 Hz), we see clear evidence of moisture condition, even if we cannot determine what % moisture content we are at. As skill level is not consistent across different users, the 1-500Hz curve gives a clear indication of issues.

Conclusion

This case study shows the valuable information available within narrow band DFR testing and gives evidence of an issue by way of the change in curve shape as test frequency drops below line frequency. The lower (and higher) the test frequency one can perform the test at, the more sensitive the response is to issues. A numeric moisture value is not obtained until the wide band DFR is used to determine the extent of the issue, but the narrow band DFR result clearly points to an abnormal condition, even with a good line frequency PF result.

Value is therefore seen in performing narrow band DFR testing for the following reasons:

1. We are already testing at line frequency, so all the leads and connections are in place – no additional connections are required to perform the narrow band DFR test.
2. The additional time per test asset is only 7 minutes for the high to low winding (main paper insulation to be tested). We believe this to be an excellent cost/value proposition
3. The test is easy to perform, even for first time users.
4. We can predict the curve (response) to be an approximate flat line(<1%PF down to 1Hz for a new transformer) which is easy to note by most users versus this example where the curve increases to 10%PF at 1Hz.
5. This narrow band DFR test provides a base line for any future testing comparison. We can use both a curve shape and/or a trend change for looking for issues. We no longer need to only rely on the line frequency PF(DF) to detect future issues.
6. Competitors DFR (narrow band) instruments do not provide the sensitivity to issues unless the problem is more dramatic. This example shows a typical problem very clearly allowing the asset owner to be proactive in resolving a future issue. Using a competitor unit would not give clear evidence of the issue.

Figure 6 – DELTA 4310A

Figure 7 – TRAX 220 + TDX 120