Reducing risk of failure on HV instrument transformers in the transmission system

Megger

CASE STUDY

NB DFR on HV CVTs

Reducing risk of failure on HV Instrument transformers in the transmission system – application of narrowband dielectric frequency response (NB DFR) on HV CVTs

Background

- The utility's SCADA system indicated a loss of voltage in one phase.
- Because 765 kV CVTs provide the voltage information to all control, metering and protection systems at this location, the CVT (CVT-1) corresponding to that specific phase was immediately suspect

Summary:

- 10 kV capacitance and power factor (PF) tests at line frequency (Figure 1) confirmed insulation failure of C1 sections B2 and B3 of CVT-1 (Figure 2).

INSULATION TESTED	TEST MODE	TEST kV	Test Freq	L(H) CAP.(pF)		POWER FACTOR %			Equivalent @ 10 kV		%VDF
						MEAS.	@ 20°C	CORR.	mA	Watts	
B1-C1	GST-GND	10.00	60	29,776.85	pF	0.16			112.2635	1.8343	0.06
108-B3-C1-9117	GST-GND	10.00	60	18,205.73	pF	5.46			68.7714	37.8119	19.76
101-B2-C1-25721	GST-GND	10.00	60	44,625.85	pF	4.49			168.4252	75.6787	0.62
104-B4-C1-9120	GST-GND	10.00	60	25,942.91	pF	0.17			97.7748	1.6199	0.06

Figure 1: Megger delta control results of CVT-1's C1 sections B1 to B4
(Note elevated % PF results, significant discrepancies in capacitance between sections, and high, non-zero % VDFs, which indicate PF voltage dependencies, in sections B2 and B3).

- For additional insights, 250 V narrowband dielectric frequency response (NB DFR) tests, comprised of PF measurements made between 1 and 500 Hz, were performed on all 4 sections of CVT-1 (Figure 3).
- The customer reported this fairly obvious failure as an over-pressure event and replaced CVT-1 with CVT-1R.
- CVT-1R was similarly tested. Its acceptable capacitance and PF and NB DFR test results (Figures 4 and 5) serve as helpful, normative references for CVT test results.

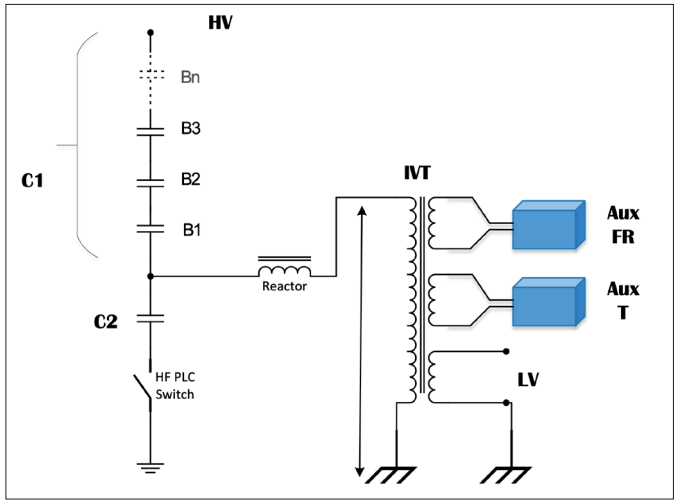

Figure 2: CVT simplified scheme

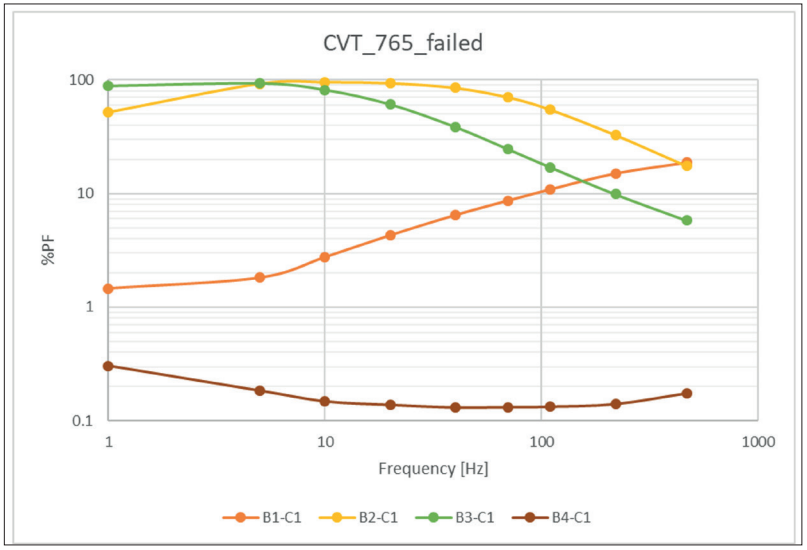

Figure 3: NB DFR plot of failed CVT 1's C1 sections B1 to B4
(Note the % PF at 60 Hz in the 250 V NB DFR test results above; comparing to the 10 kV % PF test results in Figure 1 confirms significant, abnormal voltage dependencies.)

INSULATION TESTED	TEST MODE	SUPPRESS.	TEST kV	Test Freq	L(H) CAP.(pF)		POWER FACTOR %			Equivalent @ 10 kV		%VDF
							MEAS.	@ 20°C	CORR.	mA	Watts	
B1-26502	GST-GND	Freq Variation	10.00	60	30,435.84	pF	0.08			114.7414	0.9714	0.05
C2-220469	GST-GND	Freq Variation	2.00	60	221,957.3	pF	0.11			836.5971	8.9591	0.05
108-B3-C1-26436	GST-GND	Freq Variation	10.00	60	26,710.64	pF	0.08			100.6802	0.8329	0.05
101-B2-C1-26524	GST-GND	Freq Variation	10.00	60	26,801.90	pF	0.08			101.0157	0.8430	0.04
104-B4-C1-26621	GST-GND	Freq Variation	10.00	60	26,903.76	pF	0.10			101.4393	0.9664	0.04

Figure 4: Acceptable capacitance and PF test results for replacement CVT-1R
(Note that a ratio test performed at 10 kV and a digital multimeter indicated acceptable ratio results.)

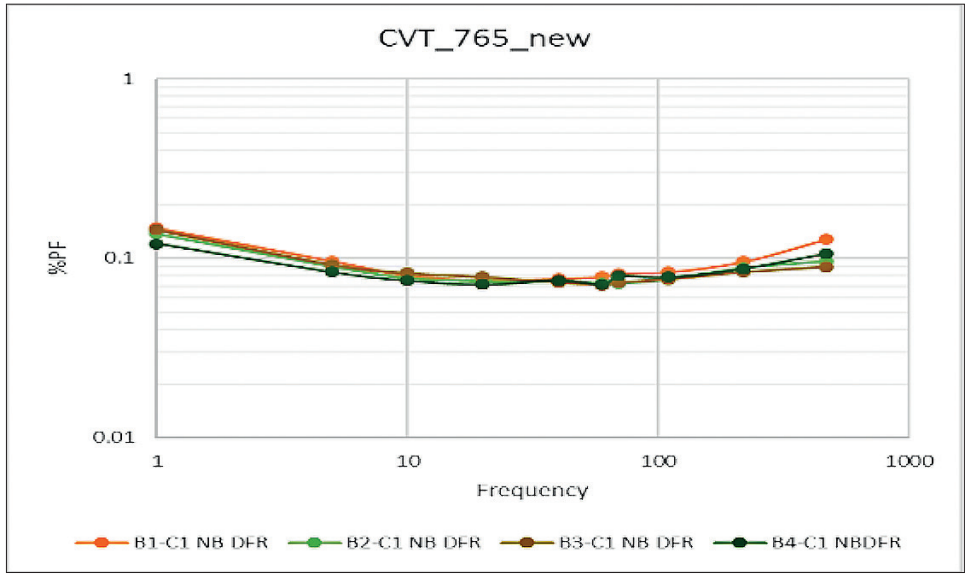

Figure 5: Acceptable NB DFR test results for replacement CVT-1R C1 sections B1 to B4

- While replacing CVT-1, the testing specialist noticed a stain on the surface of the adjacent phase CVT (CVT-2, Figure 6). CVT-2 was reporting an expected voltage in SCADA but given the failure of CVT-1 and convenient access to the testing equipment, capacitance and PF tests and NB DFR tests were performed on CVT-2 (Figures 7 to 10). Testing revealed insulation failure of CVT-2.

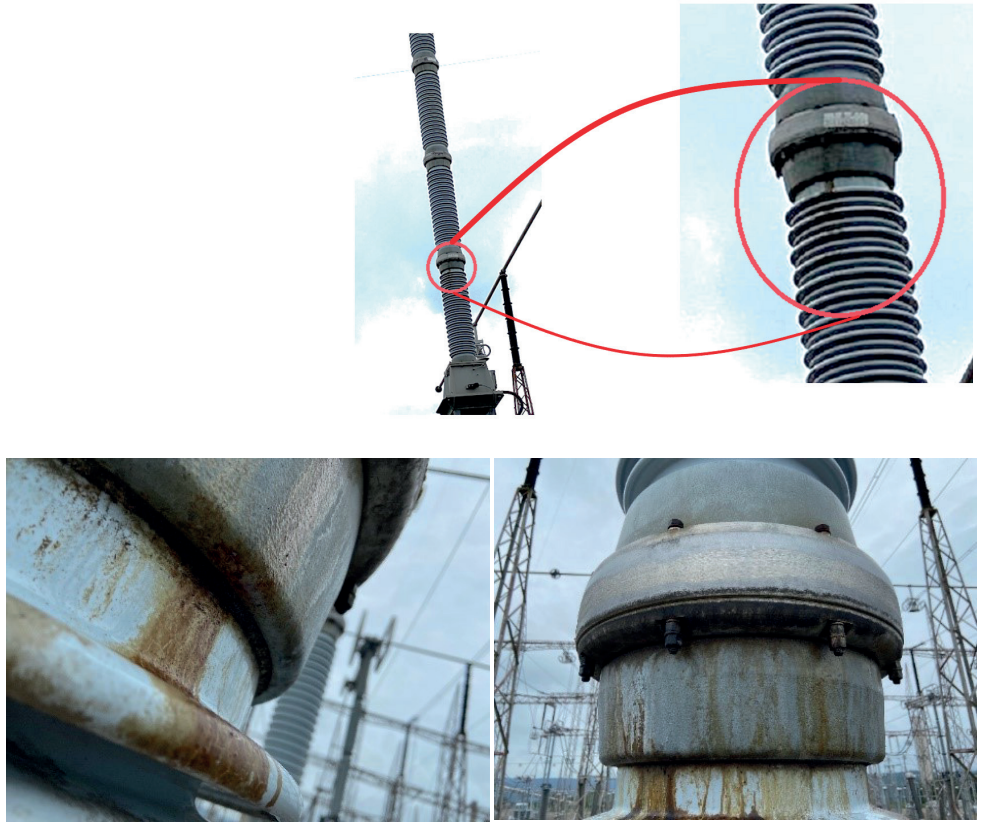

Figure 6: CVT-2 as found during visual inspection

(Note that a ratio test performed at 10 kV and a digital multimeter indicated acceptable ratio results.)

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TEST NO	INSULATION TESTED	TEST kV	Test Freq	L(H) CAP.(pF)		POWER FACTOR %			Equivalent @ 10 kV		%VDF
						MEAS.	@ 20°C	CORR.	mA	Watts	
1	B1 C1 cal 28963 +1.88%	10.00	60	29,509.65	pF	0.25			111.2432	2.7362	0.06

Figure 7: C1-B1 section capacitance and PF test results for stained CVT-2

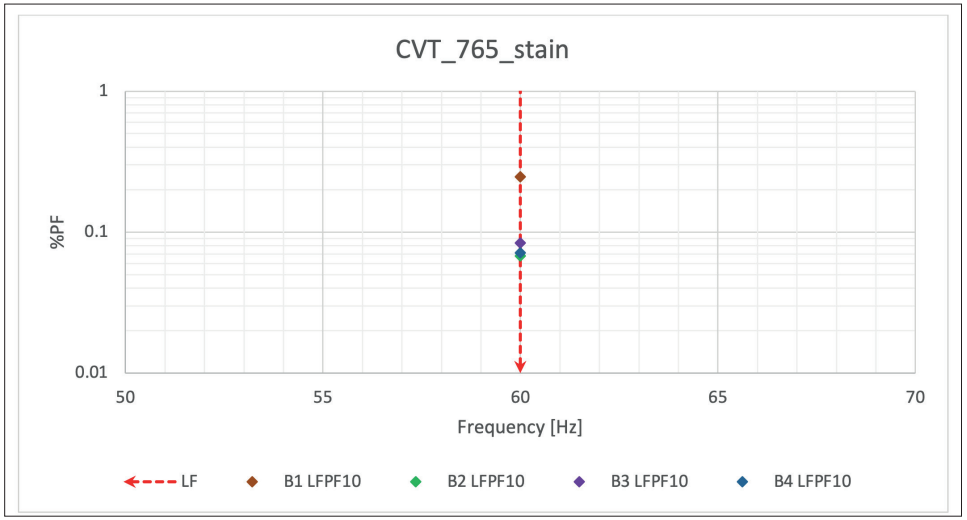

Figure 8: 10 kV line frequency % PF test results for C1 sections B1 to B4 of CVT-2

(Note the elevated % PF for C1-B1 section (0.25%) relative to the other 3 sections (~0.08%).)

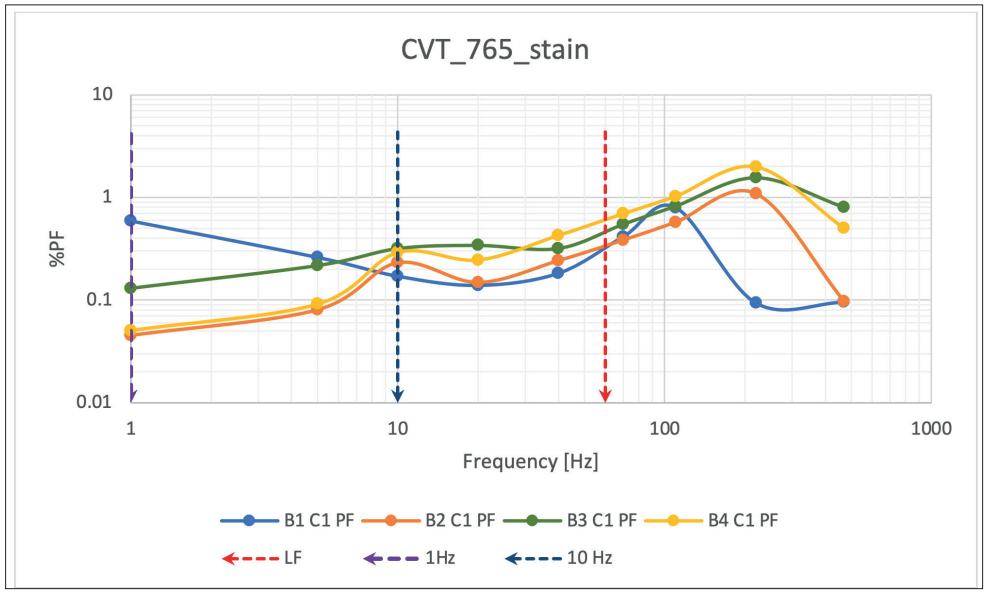

Figure 9: NB DFR test results 1-500 Hz on CVT-2

(Note that all units connected in series have been affected and the dielectric response presents an atypical response for all 4 sections. The 1 Hz test result of C1 section B1 revealed a different behaviour compared to the other sections and a PF tip-up test Figure 10, was performed to verify its voltage dependence.)

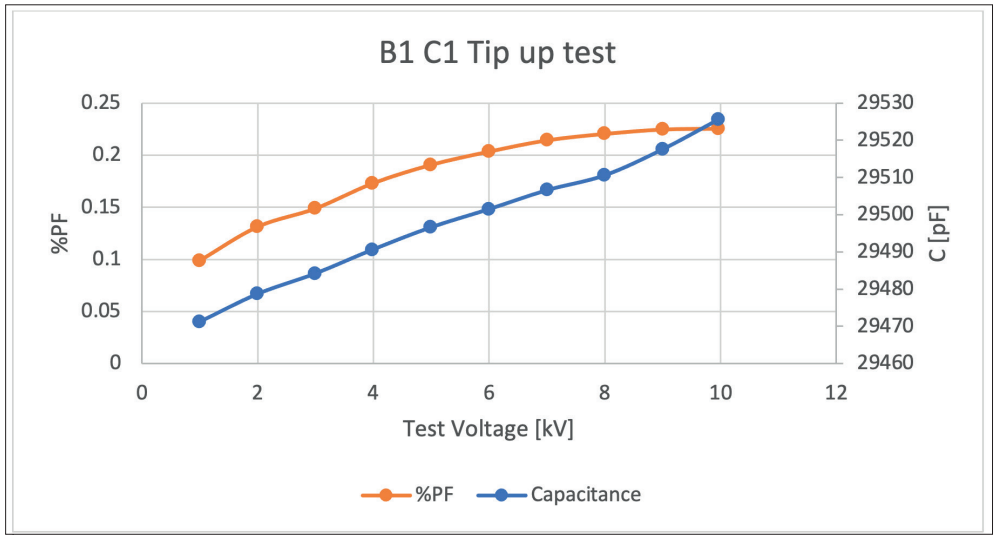

Figure 10: Power factor tip-up test results for C1-B1 section of CVT-2

Figure 11: Oil overflow due to puncture on top of C1-B1 section

- An ensuing teardown of CVT-2 confirmed significant damage to its C1 – B1 section (Figure 11). Specifically:
- A puncture was found in the C1-B1 section
- Oil was missing from the top portion of C1-B1 section.
- Its insulation integrity was compromised
- Ratio was not affected
- CVT-2 was also replaced.

Takeaways:

- A CVT in good condition should have a very low % PF value (at 20°C) <0.2% at 1 Hz (Figure 5).
- The utility performs monthly visual inspections but did not notice the oil leak between C1 sections of CVT-2. Testing averted its likely failure.
- NB DFR testing will be incorporated in the utility's future routine maintenance of CVTs.
- The Megger Delta4000 and TDX120 provide both basic (capacitance and PF) and advanced (NB DFR) diagnostic insulation testing. Atypical NB DFR results should be further investigated with a full dielectric frequency response (DFR) test using the Megger IDAX300.

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Product Reference:

DELTA:

- Dedicated capacitance and PF/DF test instrument (also exciting current):
- Narrowband DFR (NB DFR: 1 - 500 HZ)
- Individual Temperature Correction (ITC)
- Voltage Dependence Detection (VDD)

TRAX + TDX

- A multi-functional tester for transformer and substation equipment.
- Narrowband DFR (NB DFR: 1 - 500 HZ)
- ITC
- VDD

IDAX + VAX

- Megger's DFR test instrument – analysis of moisture content, PF/DF and oil conductivity
- Fast and reliable in high-interference environments up to 1.4 kV rms
- The result of 20+ years experience in the design(and expertise) of DFR test instruments
- Can perform DFR and NB DFR

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