POWER FACTOR/CAPACITANCE AND INSULATION RESISTANCE TESTING ISSUES ON 138 KV DRY TYPE CT

MAY WANG, BC HYDRO

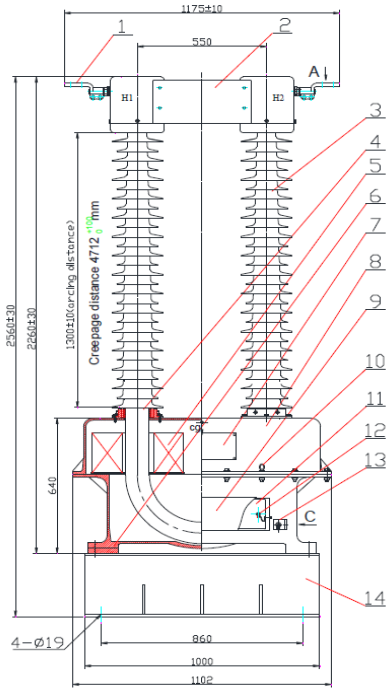
91ST International Conference of Doble Clients

doble®

Introduction

- BC Hydro has been using 138 kV dry type metering CTs. In many installations the locations are remote. These CTs are tested before shipping, prior to installation and post installation.
- During power factor/capacitance and insulation resistance testing, a few issues have occurred on some of the units.
- These test results perplexed both the testers and the engineers.
- The root cause of the issues needed to be determined.

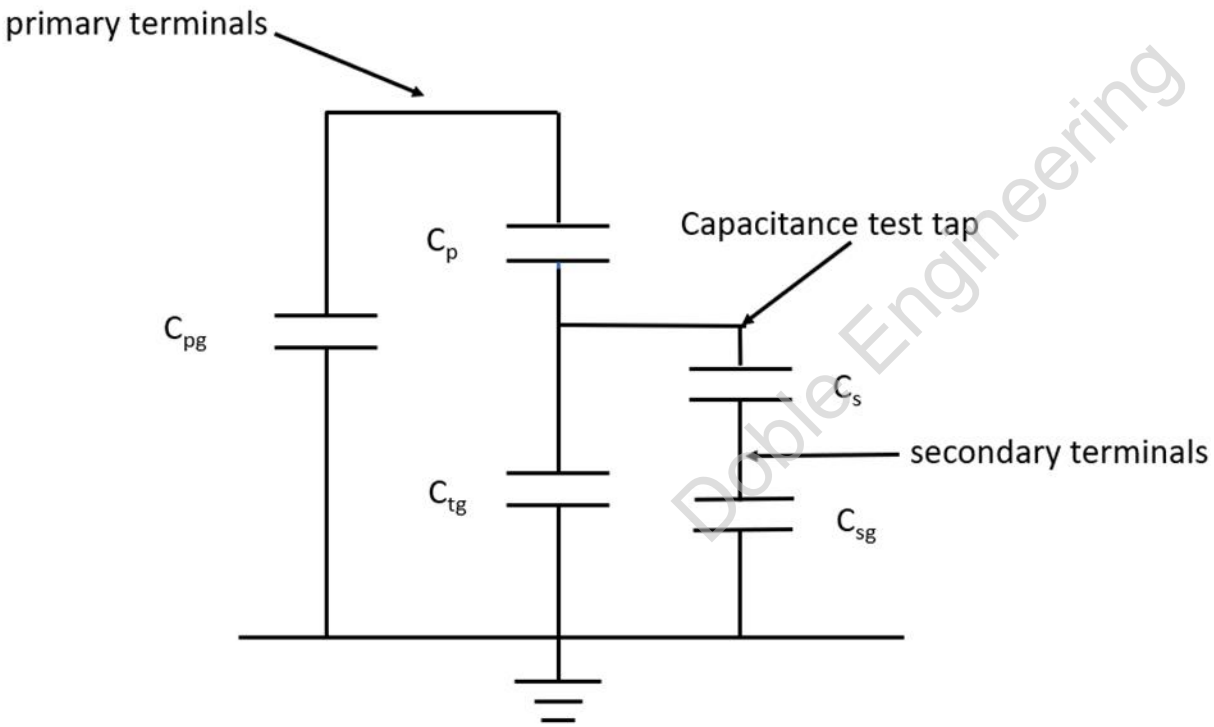
Dry Type CT Information and Description



No.	DESCRIPTION
1	Primary Terminal
2	Connection Cover
3	Sheds (Light Grey)
4	Primary Winding
5	Secondary Winding
6	Pedestal
7	Nameplate
8	Casing
9	Casing for Terminal Box
10	Lifting Lugs
11	Secondary Terminal Block
12	Capacitive Tap
13	Earthing Plate
14	Support

- Maximum system voltage:
  152 kV rms
- Primary continuous current:
  200×400×800 A
- Secondary continuous current:
  5 A
- Accuracy and rated burden:
  0.15B0.9
- Number of primary turns:
  1/2/4
- Number of cores:
  2

Dry Type CT Equivalent Circuit



C_p – capacitance between the HV primary terminal and capacitance test tap.

C_s – capacitance between the test tap and secondary winding terminal.

C_{sg} – stray capacitance from secondary terminals to ground.

C_{pg} – stray capacitance between the HV primary terminals and ground with tap guarded.

C_{tg} – stray capacitance between the test tap and ground.

C_{ps} – C_p in series with C_s.

$C_{t\text{-}grd}$ – C_{tg} plus C_s with the secondary terminal grounded.

Test Issues w/138 kV CTs

- Issue-1:
  - Each time tests were done the power factor/capacitance test results on C_s and C_{ps} were different, both capacitance and power factor values were changing. What caused these changes?
- Issue-2:
  - Our power factor/capacitance test results did not agree with the CT's FAT test data on C_s and C_{ps}. What test configurations should be used to compare with the FAT data?
- Issue-3:
  - Low insulation resistance readings on CT secondary terminals. What caused the problem?

Issue – 1: PF and Capacitance Changed Test to Test

- Each time tests done, C_s and C_{ps} C and PF values changed

Table 1 Sample Test Results

CT-2 AU20083	Shop pre-test results		Site test results		Capacitance Differences	PF Differences
	C (pF)	PF (%)	C (pf)	PF (%)	ΔC%	ΔPF%
C_s	70	-10	79	0.77	13	108
C_{ps}	33	0.09	48	0.12	45	39
$C_{t\text{-}grd}$	845	11	480	2.5	-43	-78
C_p	763	0.01	765	0.02	0.2%	38

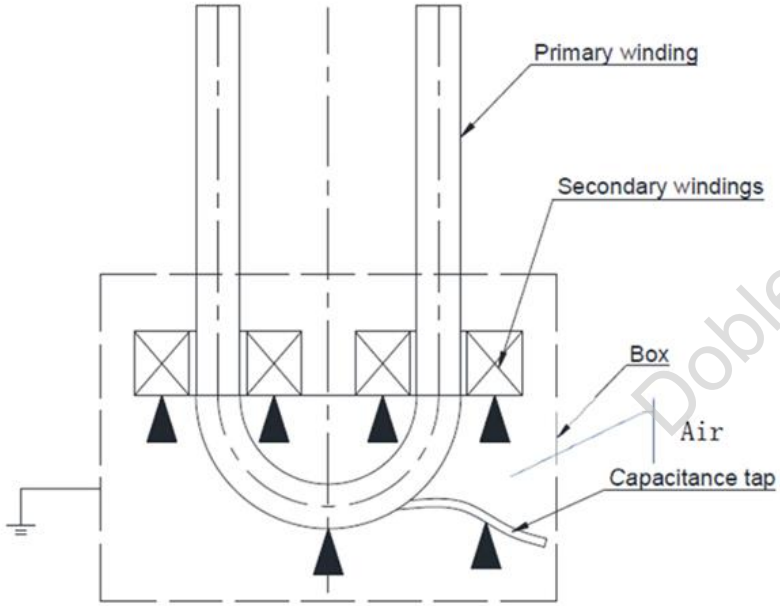
The Cause Of The Changes

- The power factor/capacitance results showed negative PF in some of the testing, indicating that there is another unstable shield in the CT
- The CT design/drawing does not have any other shield in the CT structure
- After checking the inside of the CT, again no other shield was found.

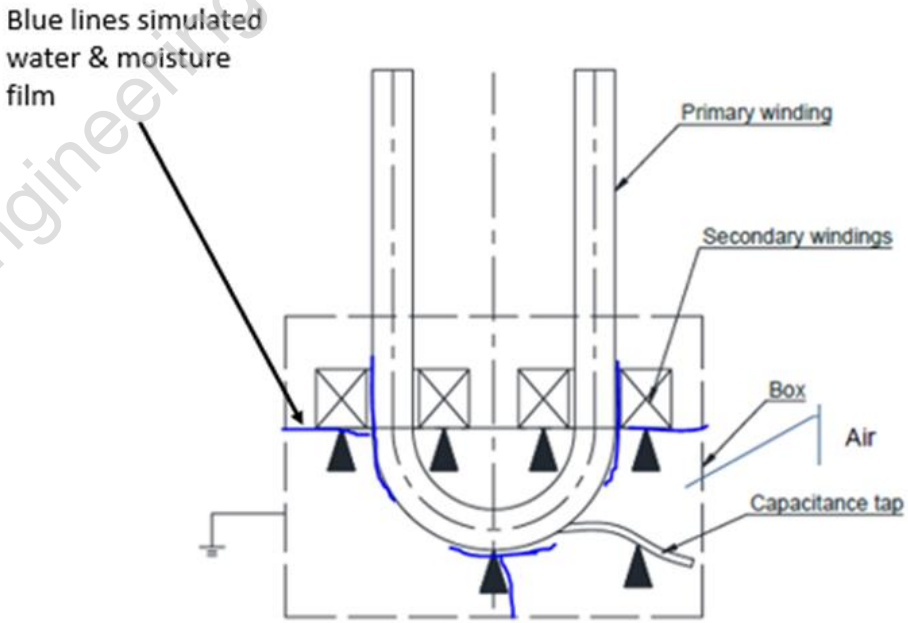
CT Internal Wet Condition

CT Internal Structure Drawing

Dry Condition

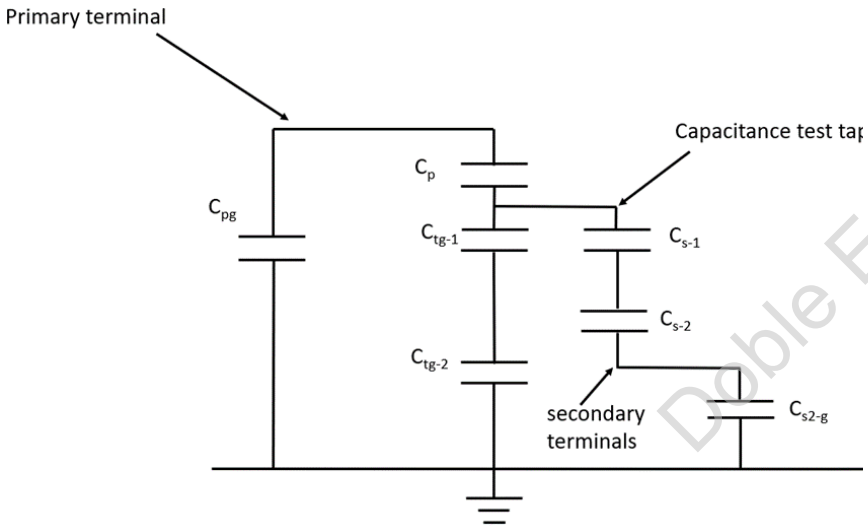


Wet Condition

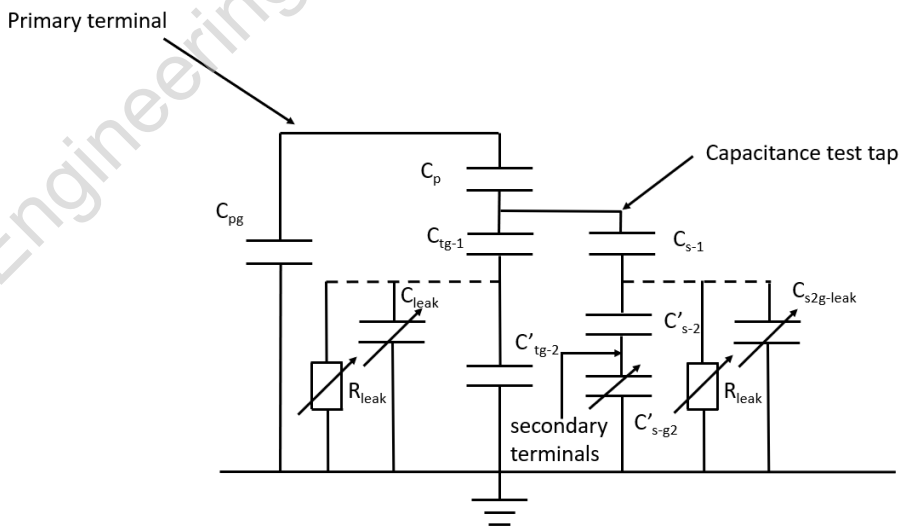


CT Equivalent Circuit

Dry Condition



Wet Condition



CT Simulation Test Results

Simulating testing	Simulated Wet Condition		Original (Drier) Condition	
	C (pF)	PF (%)	C (pF)	PF (%)
$C_{t\text{-}grd}$	724↑	4.3↑	495	3.1
C_{ps}	39↓	-1.3↓	47	-0.37

CT-2 AU20083	Shop pre-test results (wet)		Site test results (drier)	
Field Test Results	C (pF)	PF (%)	C (pf)	PF (%)
$C_{t\text{-}grd}$	845↑	11↑	480	2.5
C_{ps}	33↓	0.09↓	48	0.12

Issue - 1: Summary

- The changes of C and PF are caused by the water on the surface of the CT insulation forming conductive paths to the ground.
- The water forms an unstable conductive shield and causes the high PF and the capacitance value changes.
- If this problem occurs during the power factor/capacitance testing, ideally, the water should be dried and/or the water path to ground should be broken.
- Only drying out the terminal box of the CT will not solve the issue.
- The dry out procedure has to be done on the whole CT in an oven at a temperature of 40°C to 60°C (104°F to 140°F) for a minimum of 24 hours.

Issue - 2: Site Tests Disagree with FAT

CT-3 AU20085	On-Site Results		FAT Results		Comments
	Capacitance (pF)	PF (%)	Capacitance (pF)	Tanδ (%)	
C_p	753	0.01	758	0.02	Similar
C_s	78	0.80	502	3.3	Totally different
C_{ps}	47	-0.37	300	2.0	Totally different

Simulated FAT Test Conditions (Base Floating)

Test Configurations with Base Floating to Simulate FAT Test Configurations

Test Mode	ENG	UST	GAR	Floating	FAT		Measured on Site		FAT & Site Differences	
					C (pF)	Tanδ (%)	C (pF)	PF (%)	ΔC	ΔPF
Simulating FAT C_p	H1&H2	Cap tap, X&Y, base	-	-	758	0.02	758	0.05	0.04%	143%
Simulating FAT C_s	Cap tap	X&Y, base	H1&H2	-	502	3.3	498	3.3	0.88%	-1.3%
Simulating FAT C_{ps}	H1&H2	X&Y& base	-	Cap tap	300	2.07	298	1.99	-0.5%	-2.1%

Simulated FAT Test Conditions (Base Grounded)

FAT	Test config.	Test voltage (kV)	Test mode	Voltage applied to	UST	GAR	Ground	Float	Comments
C_p	C_p	10	UST	H1&H2	Cap tap	-	X, Y & base	-	To obtain ~FAT C_p
C_s	C_{sg}	2	GAR	Cap tap	-	H1&H2	X, Y & base	-	To obtain ~FAT C_s
C_{ps}	C_{psg}	2	GST	H1&H2	-	-	X, Y, base	Cap tap	To obtain ~FAT C_{ps}

Site Power Factor/Capacitance Test Results, Base Grounded, Updated Doble Test Configurations

CT S#		C_p		FAT $C_s \approx C_{sg}$		FAT $C_{ps} \approx C_{psg}$	
		FAT	Site	FAT	Site	FAT	Site
AU21042	C (pF)	781	792	515	503	308	350
	PF (%)	0.06	0.03	1.50	1.00	0.93	0.60
AU21045	C (pF)	773	784	521	510	309	353
	PF (%)	0.03	0.02	1.46	0.91	0.87	0.49

Issue - 2: Summary

- The investigation tests identified the closest power factor/capacitance test configurations to match the FAT results.
- Updated test configurations were defined for future tests with the CT base in the grounded condition.

FAT	Test config.	Test voltage (kV)	Test mode	Voltage applied to	UST	GAR	Ground	Float	Comments
C_p	C_p	10	UST	H1&H2	Cap tap	-	X, Y & base	-	To obtain ~FAT C_p
C_s	C_{sg}	2	GAR	Cap tap	-	H1&H2	X, Y & base	-	To obtain ~FAT C_s
C_{ps}	C_{psg}	2	GST	H1&H2	-	-	X, Y, base	Cap tap	To obtain ~FAT C_{ps}

Issue - 3: Low Insulation Resistance Readings On Secondary Terminals-1

Insulation Resistance Test Results (normally >2.2 GΩ)

Date (AU21049)	1 kV on X winding	1 kV on Y winding
Day 1	1.3 GΩ	>2.2 GΩ
Day 5	1.9 GΩ	>2.2 GΩ
Day 7	>2.2 GΩ	>2.2 GΩ

Power Factor/ Capacitance Test		C_p		C_s~C_{sg}		C_{ps}~C_{psg}		BCH C_s	BCH C_{ps}
		Factory	Measured	Factory	Measured	Factory	Measured	Measured	Measured
AU21042 (dry secondary for reference)	Cap (pF)	781	791.9	515	502.5	308	350.42	78.12	47.8
	PF (%)	0.06	0.03	1.5	1.0	0.93	3.6	1.1	0.9
AU210429 (wet secondary) >2.2 GΩ	Cap (pF)	783	793.5	528	743.8	312	430.43	74.2	38.11
	PF (%)	0.05	0.014	2.4	10.1	1.5	4.6	-4.0	-8.8

Issue – 3: Low Insulation Resistance Readings On Secondary Terminals-2

- Both insulation resistance and power factor/capacitance testing can show the moisture problems.
- Power factor/capacitance testing is more sensitive than insulation resistance testing to detect moisture.
- If the CT secondary winding is very wet (30 MΩ), the winding may not withstand the excitation voltage.
- High moisture levels may cause excitation test failure, increased ratio error etc.
- The moisture problems can go deep into the CT secondary windings resulting in long drying time.

Investigation Summary

- 138 kV dry type CTs are tested pre- & post-installation (power factor/capacitance and insulation resistance testing).
- Three issues have occurred on these dry type CTs during testing.
- This investigation addressed these issues.
- Analysis and simulation testing were carried out and the root causes were determined.
- The investigation provided technical information and testing configurations for future power factor/capacitance testing on this type of CT.

Thank you!

POWER FACTOR/CAPACITANCE AND INSULATION RESISTANCE TESTING ISSUES ON 138 KV DRY TYPE CT

MAY WANG, BC HYDRO

91ST International Conference of Doble Clients

doble®