

2022 International Conference of Doble Clients

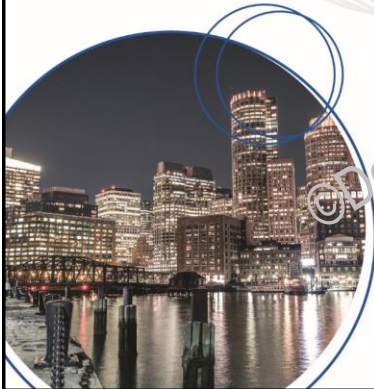
March 6-11, 2022 | Boston, Massachusetts USA

Field Test on cascade Current Transformer – Experiences and Development of Guidelines

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Field test on cascade Current Transformer (CT)



- Objectives:
 - Examine the component systems: Magnetic and Insulation circuits
 - Experiment with different field test procedures for the individual CT stack and the final assembly
 - Compare test results with factory test results
 - Propose guidelines for field test procedure and data analysis
 - Focusing on two section CT of dry type and based on three CTs

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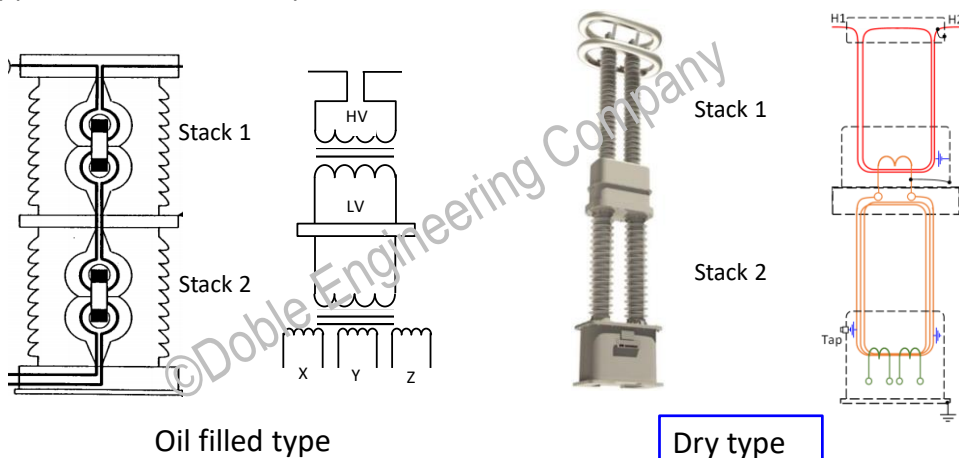
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Component system of cascade CT



- Typical Cascade style CT



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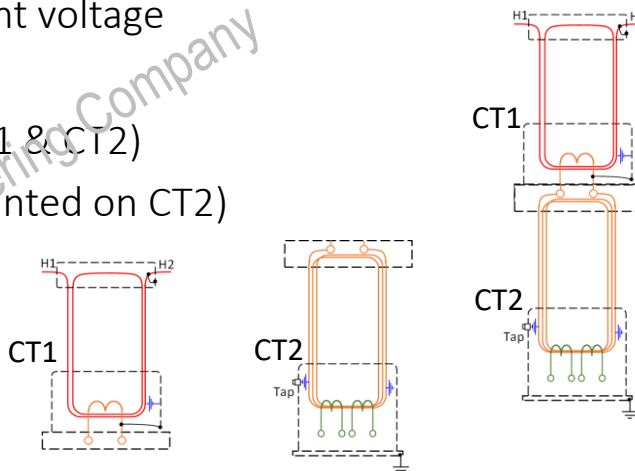
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Field test on cascade CT – Magnetic Circuit



- Winding Resistance → Demagnetization
- Excitation curve – Knee point voltage
- Ratio and accuracy
- ❖ On separate section CT (CT1 & CT2)
- ❖ On assembled CT (CT1 mounted on CT2)



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Field test on cascade CT - Insulation System



CT1

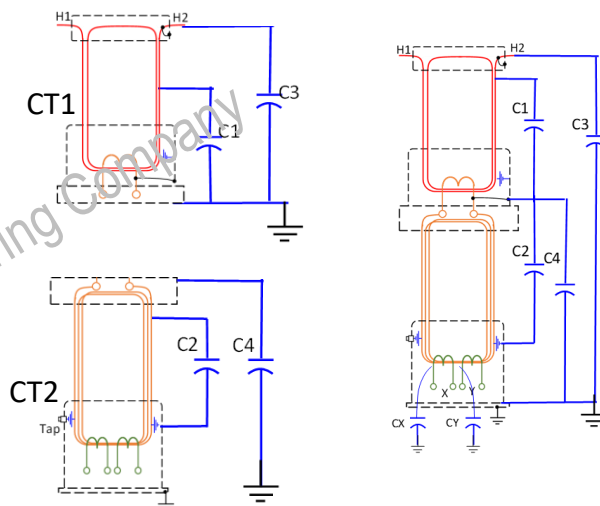
- C1: main insulation
- C3: Stray insulation (housing & ground plan)

CT2

- C2: main insulation
- C4: Stray insulation (housing & ground plan)

Secondary: CX, CY, CZ, CW

- ❖ On separate CT1 & CT2 and on assembled CT



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Field Test Results – Magnetic Circuit



- “Assembled” WR is lower than “Half” unknown cause.
- More difference of KP voltage in separate CT than in assembled CT. Need more study to confirm this.
- Normal Ratio.
- Assembled CT test compared better with factory test than separate CT1 & CT2.

Unit	Knee point (IEEE 30)		Secondary WR (mΩ@75°C)		Ratio	
	Sep.	Assembled	Sep.	Assembled	Sep.	Assembled
1 – CT1	58.84	-	141	-	100.034	-
1 – CT2 X	80.76	85.44	120	117	2	100.041
1 – CT2 Y	83.23	85.88	118	113	2.001	100.063
2 – CT1	59.88	-	150	-	100.03	-
2 – CT2 X	80.56	83.68	114	114	2	100.035
2 – CT2 Y	85.56	87.64	123	113	2	100.017
3 – CT1	62.4	-	165	-	100.028	-
3 – CT2 X	88.32	84.36	116	112	2.001	100.028
3 – CT2 Y	84.48	83.6	114	111	2	100.046

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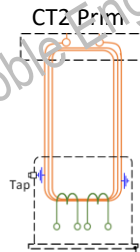
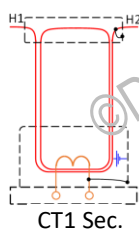
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Field Test Results – Magnetic Circuit



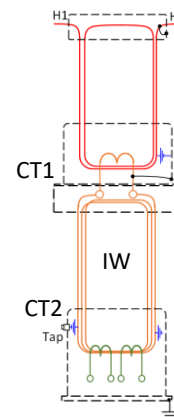
- Winding resistance (WR) of cascade CT intermediate

Unit	WR (mΩ@75°C)		
	CT1 Sec.	CT2 Prim.	Total - IW
1	141	367	508
2	150	366	516
3	165	410	576



$$\text{Total} = \text{CT1 Sec.} + \text{CT2 Prim.}$$

IW: Intermediate Winding



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Field Test Results – Insulation System



Separate

Assembled CT



Fig. 5

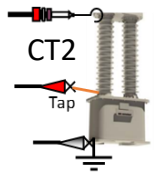


Fig. 6

Test Info		Unit 1			Unit 2			Unit 3		
Setup		PF (%)	C (pF)	°C	PF (%)	C (pF)	°C	PF (%)	C (pF)	°C
1	Fig. 5	0.05	533	17	0.05	542	18	0.05	539	17
2	Fig. 6	0.05	544	17	0.10	555	17	0.13	551	17
3		0.04	497	17	0.04	507	17	0.08	503	17
4	Fig. 7	0.08	304	10	0.09	308	7	0.10	305	6
5		0.02	234	10	0.01	240	7	0.03	236	6

Test #5 results are comparable to Factory's



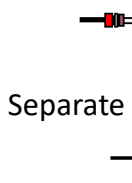
Fig. 7

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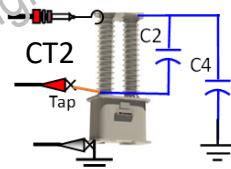
First Model of Insulation System



Unit 1	HV- H1,H2 (GST)		HV- H1,H2 (UST)		Stray CX (pF)
	PF (%)	C (pF)	PF (%)	C (pF)	
CT1	0.05	533			
CT2	0.05	544	0.04	497	47
CT (assembled)	0.08	304	0.02	234	70
CT (cal. series)		269			

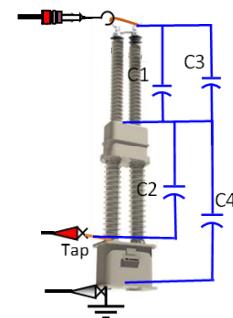


Separate



CT2

Assembled CT



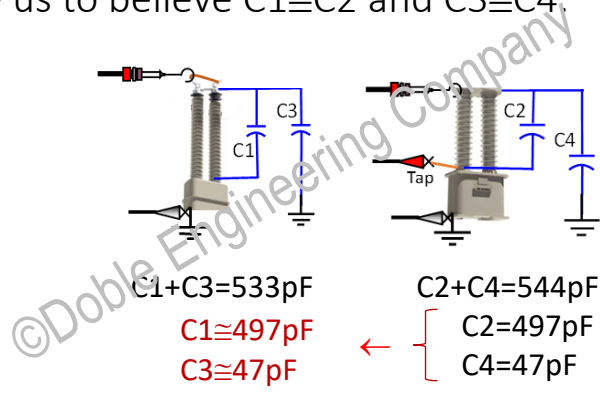
First thought, but this model is not backed up by the measurement.

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First Model of Insulation System



- CT1 & CT2 has similar size, dimension and GST capacitances, this make us to believe $C1 \cong C2$ and $C3 \cong C4$.

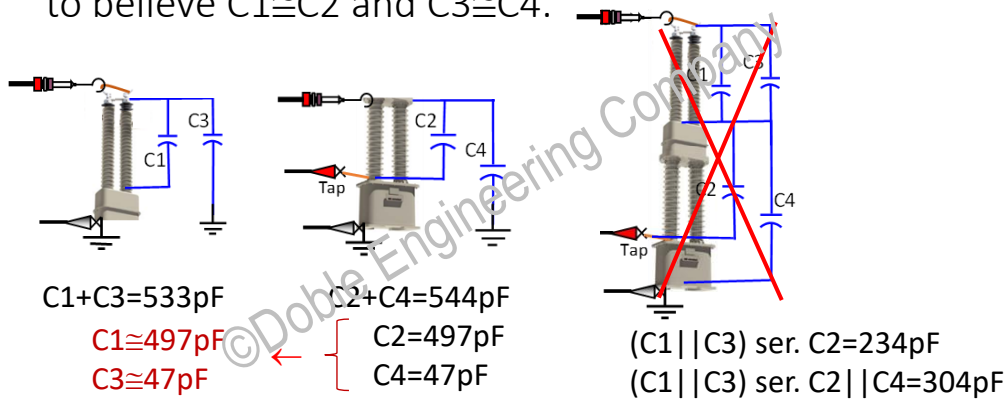


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First Model of Insulation System



- CT1 & CT2 has similar size, dimension and GST cap., this make us to believe $C1 \cong C2$ and $C3 \cong C4$.



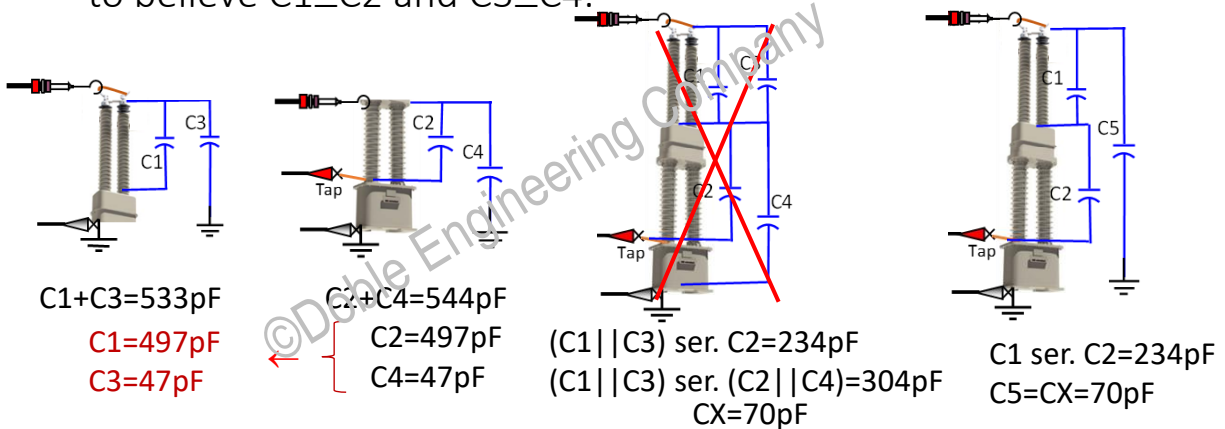
CX (stray)=70pF But WAIT! This model does not agree with the measurements

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Model of Insulation System



- CT1 & CT2 has similar size, dimension and GST cap., this make us to believe $C1 \cong C2$ and $C3 \cong C4$.



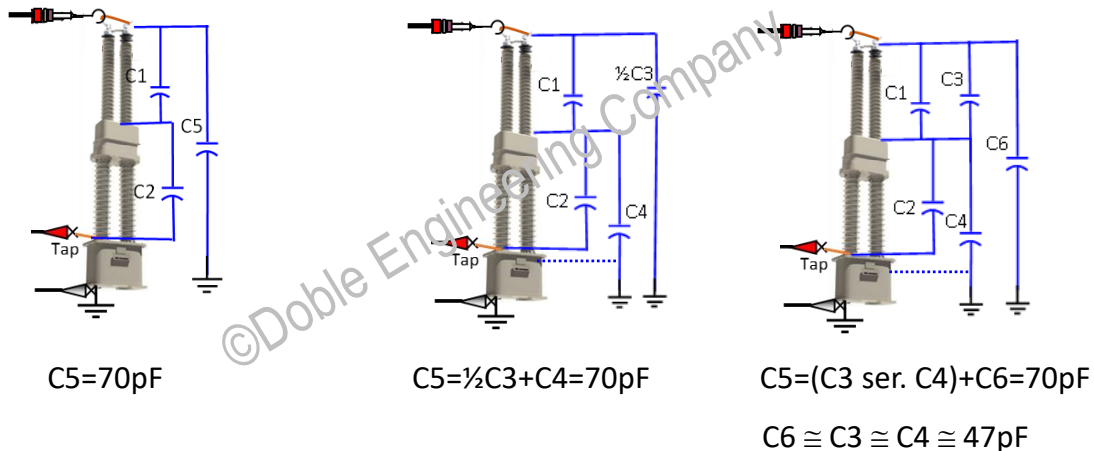
Note: Stray capacitance (C3, C4, C5) have two components (Housing + ground plan)

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Model of Insulation System



- Stray capacitance C5 is more complex than first thought

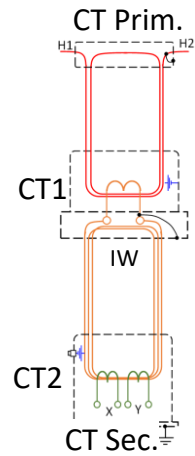
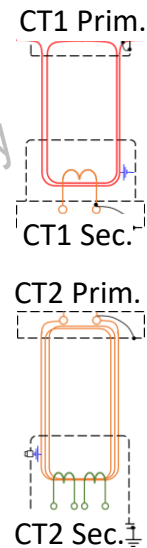


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Recommended Field Test – Magnetic Circuit



- Separate (CT1, CT2, etc.)
 - Winding Resistance → Demagnetization
 - Excitation curve – Knee point voltage
 - Ratio and accuracy
- Assembled (CT)
 - Winding Resistance → Demagnetization
 - Excitation curve – Knee point voltage
 - Ratio and accuracy



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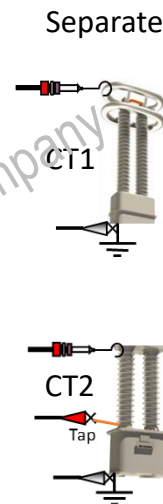
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Recommended Field Test – Insulation System



- Separate (CT1, CT2, etc.)
 - C1+C3, C2+C4, C2, etc.
- Assembled (CT)
 - (C1 ser. C2) + (C3 ser. C4), C1 ser. C2, etc.



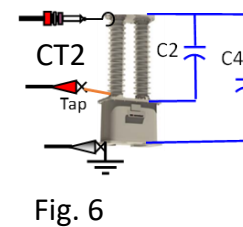
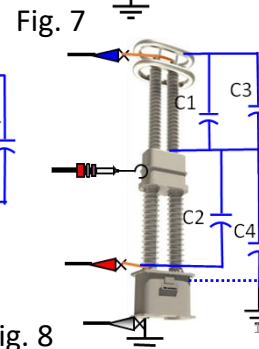
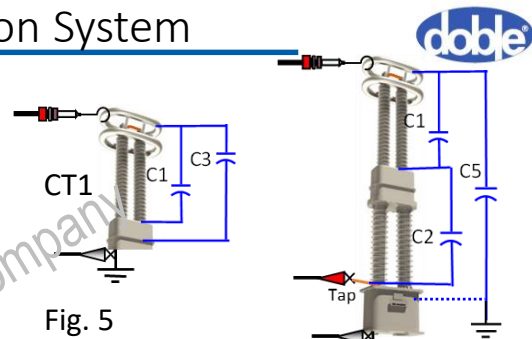
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Recommended Field Test – Insulation System

#	Test Setup	Mode	Measure
1	Figure 5	GND	C1+C3
2	Figure 6	GND	C2+C4
3		UST R	C2
4	Figure 7	GND	(C1 ser. C2)+C5
5		UST R	C1 ser. C2
6		GAR R	C5
7	Figure 8	GND	C1+C2+C3+C4
8		UST B	C1+C3
9		UST R	C2
10		GAR RB	C4



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Field Test Results – Insulation System



Results, re-arranged according to current understanding of the model

Test Info			Unit 1			Unit 2			Unit 3		
#	Setup	Unit	PF (%)	C (pF)	°C	PF (%)	C (pF)	°C	PF (%)	C (pF)	°C
1	Figure 5	C1+C3	0.05	533	17	0.05	542	18	0.05	539	17
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4	Figure 7	(C1 ser. C2)+C5	0.08	304	10	0.09	308	7	0.10	305	6
5		C1 ser. C2	0.02	234	10	0.01	240	7	0.03	236	6

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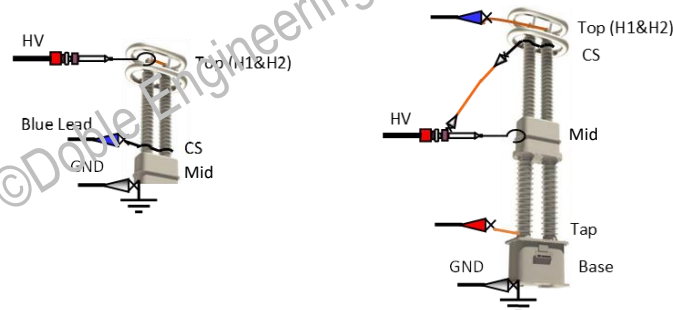
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Diagnostic Field Test – Insulation System



- Additional diagnostics tests can be done using a collar strap and details are beyond the scope of this presentation
- Using collar strap (CS) near the ground potential to guard out the influence of the housing surface.



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Conclusion



- Testing separate CT1, CT2, and assembled CT provide maximum information for:
 - Understanding the magnetic circuit and insulation system
 - Baseline for future condition assessment
 - Quality control
- In general, the field test results agree with the factory test results with more variation in Separate than Assembled CT.
- More differences in the knee point when comparing Separate to Assembled data
- More work is required for fully understand the cause of the differences.

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Questions?

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