CURRENT TRANSFORMER DOBLE TESTING TRIPPING UPSTRING BREAKER

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ABSTRACT

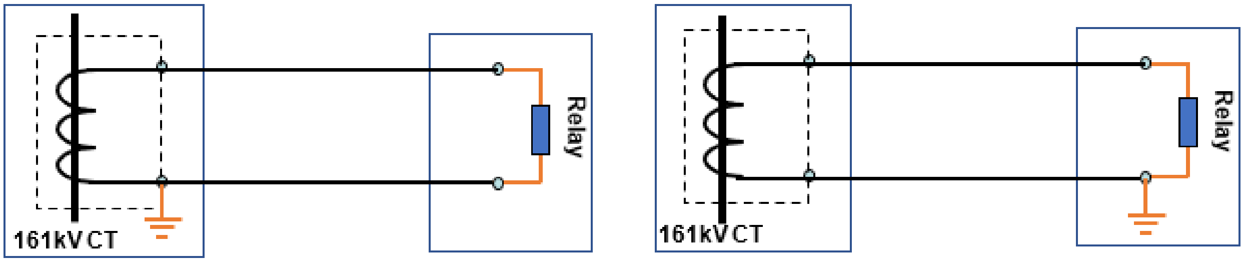
This paper will discuss testing methods for current transformers (CT) during routine maintenance. The current method recommended by Doble [1] is to disconnect the CT secondary side, which requires additional effort when there are labor shortages. Also, the authors will share an inadvertent outage that impacted several customers when a circuit breaker tripped by the electrical protection during an insulation test on a current transformer. A new test method has been investigated and should be implemented into a test program when performing a test on a current transformer.

INTRODUCTION

Measurement of the CT insulation quality is essential in monitoring the safety and reliability of electrical substations. Typically, the test is performed during planned outage and routine maintenance of the substation apparatuses. To shorten the outage duration and minimize the labor requirements, the CT secondary was not disconnected during testing; instead, we shorted and grounded all the CT secondary terminals in the junction box as shown in Figure 3. This practice has been used for more than 20 years without any incident, except for this one time resulting in tripping half of the substation. In addition, this paper describes an alternative method to test the current transformers and can be used to update the current grounding method.

SECONDARY CIRCUIT GROUNDING PHILOSOPHY

There are two philosophies to ground the CT secondary circuit in Rio Tinto's installations. In the new design, the secondary windings are grounded according to the IEEE C57.13.3-2014 standard [3], i.e. the ground is in the relay panel located in the control room in Figure 1b and therefore the ground could distance from the CT several hundred feet. In the old design, the CT secondary windings had been grounded in the junction box of the CTs located in the substation and connected to the station ground, shown in Figure 1a according to the old IEEE C57.13.3-1983.



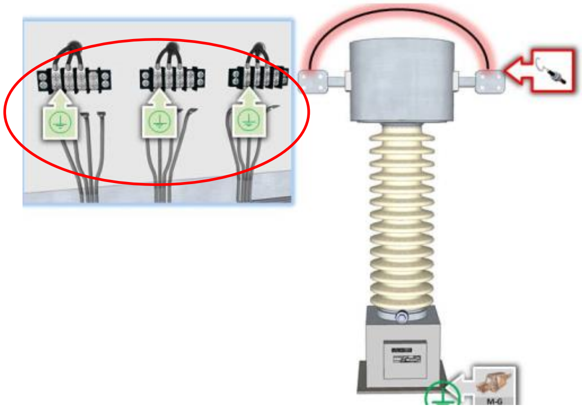
a) Ground at CT connected to station ground

b) Grounding at relay panel in control room

Secondary Grounding Methods for Testing CT Primary Insulation
Figure 1

TEST SETUP RECOMMENDED BY DOBLE [1]

- Isolate the CT primary terminals and shorted (H1/H2).
- Isolate the CT secondary terminals shown in the red circle of Figure 2.
- Grounding secondary terminal on each secondary winding (Ex.: X1, Y1, Z1), may be short-circuited too, but this is not necessary.
- Set up and perform the insulation test on HV primary.



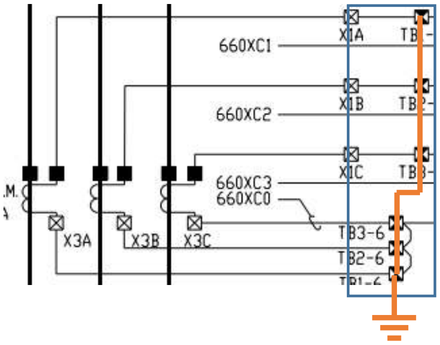
Test Setup Recommended by Doble
Figure 2

Note: This requires re-connection and functional verification after testing - disadvantage of this method

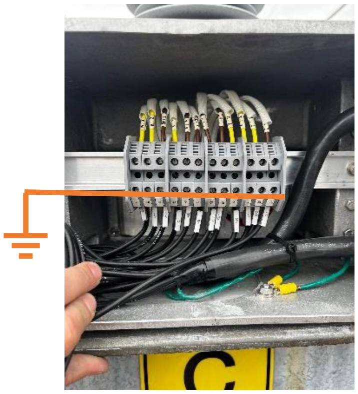
When the tests have been completed using Doble's procedure described above, we need to reconnect the secondary terminals and then perform the polarity test on each winding to follow the best practices recognized in the industry and to make sure that the connections are made correctly. For Rio Tinto, this practice requires a polarity tester in a different labor department located off-site. Obtaining this tester increases the complexity in work planning and the number of labor crews, and becomes unacceptable in a context of labor shortage.

COLLECTIVE PRACTICE OF MORE THAN 20 YEARS

For more than 20 years, the insulation tests have been performed by installing a short circuit on all secondary terminals and then connecting them to earth in the three-pole cabinet of all 3 current transformers in the substation (Figures 3 and 4). No verification of an existing ground in the secondary circuits is done. This method is described in detail as an in-house procedure [2] when servicing a current transformer. In the past, no events or disturbances have been observed and no incorrect insulation measurements were obtained using this procedure.



Circuit Diagram of Collective practice
Figure 2



Terminal View of Collective Practice
Figure 3

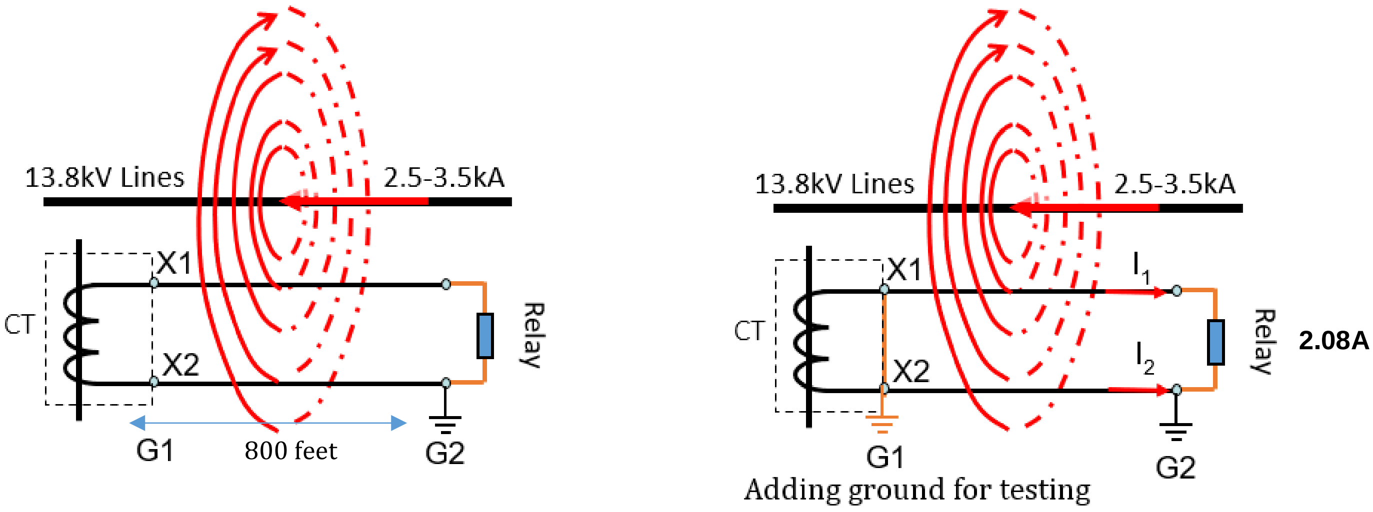
Tripping of the Circuit Breaker When Installing the Jumpers

During the routine maintenance of a current transformer in a substation, our existing procedure instructs us to install a shorting jumper and a ground directly on the three-pole terminals of the 3 current transformers. However, during the aforementioned inadvertent outage, immediately after shorting and grounding all secondary terminals, the testers received a call from the control room. The operator asked what actions had been taken because the electrical protection had operated and caused the 161kV circuit breakers to open. Maintenance personnel immediately removed the short-circuit and ground jumpers, then canceled the maintenance job on the current transformer. A root cause analysis was ordered to explain the cause of the tripping.

Investigation: Disadvantage of the In-House Method – Electromagnetic Induction

The electrical substation is approximately 800 feet from the protective relays located in the control room and has two power lines sandwiching the CT secondary circuits. The first power line is rated 13.8kV carrying the load currents between 2500-3500A (Figure 6a) and the second line is rated 161kV carrying about 100A (Figure 6b). The distance between the power lines and CT secondary circuit is about 40 feet and the power lines are in parallel for 800 to 1000 feet. In service condition, this installation has one ground on the CT secondary circuits located in the control room as shown in the terminal G2 (Figure 5a) and no ground at the current transformer side.

During test preparation, shorting and grounding jumpers were installed on the CT secondary terminal G1 located in the CT cabinet at the CT side. The additional ground formed two loops between the two grounds G1 and G2, (Figure 5b), then coupled with the magnetic field coming from the adjacent power lines carrying high load currents. This resulted in two current circulations I_1 and I_2; the current I_1 went through the protective relay before reaching G2 causing the electrical protection system to operate and ultimately trip the 161kV circuit breaker. Based on historical relay data, 2.08 amps circulated in the relay (see Appendix). Several customers were affected by this inadvertent outage.



a) In Service Condition **b) During Test Preparation**

Circuit Diagram of CT and Adjacent Line
Figure 4

a) 13.8kV Power Line **b) 161kV Power Line**

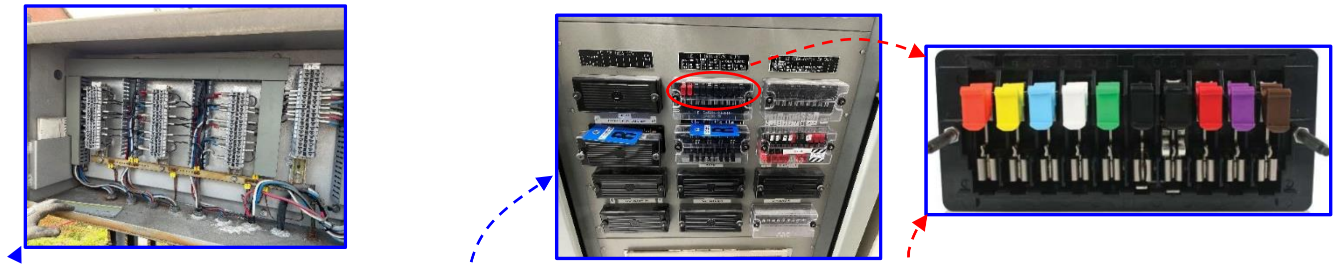
Line in Parallel with the CT Secondary Circuits Running to the Control Room
Figure 6

EXPERIMENTED METHOD AND RECOMMENDATION FOR MAINTENANCE TESTING

We analyzed the typical electrical circuit of a current transformer and how the Flexitest switch is connected to identify that the ground of secondary circuits W, X and Z were connected in the three-pole junction box at the CT side in substation (Figure 7a) and the other circuit Y was grounded in the protection cabinet in the control room (Figure 7b).

The operating principle of Flexitest switches is to provide a safe and reliable means for in-service testing of relays. Therefore, in the open position, they completely isolate the relays from the CTs to prevent a current circulation from any sources, and at the same time they short the CT secondary terminals and preserve the grounds on CT secondary circuits as shown in Figure 8.

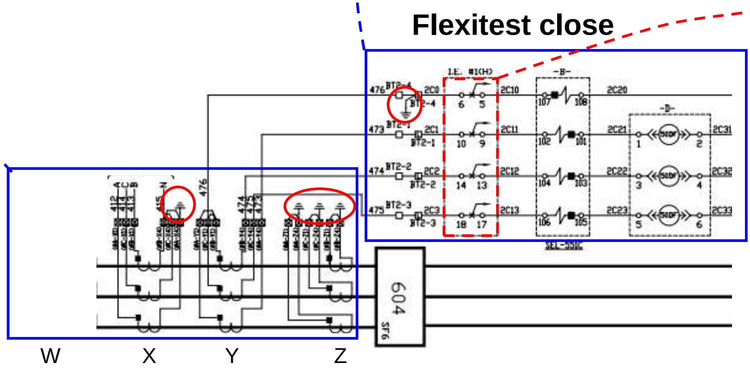
For the next step, we decided to perform the insulation test on the CT HV primary winding without disconnecting the burden circuit from the CT secondary while simultaneously using the Flexitest switches to isolate the burdens (relays) as shown in Figure 8. This was to check for any impact on the test results. The final step was to make sure that the testers didn't forget to close the Flexitest switches before returning the CTs to service. For this, we added control steps in the safety procedure while making and releasing the securing safety zone. We then repeated all the standard insulation tests on CTs using this test setup. All insulation test results (%PF and capacitance) were acceptable and consistently comparable to the previous method tests, as shown in Table 1.



a) Junction box at CT side where W, X and Z are grounded

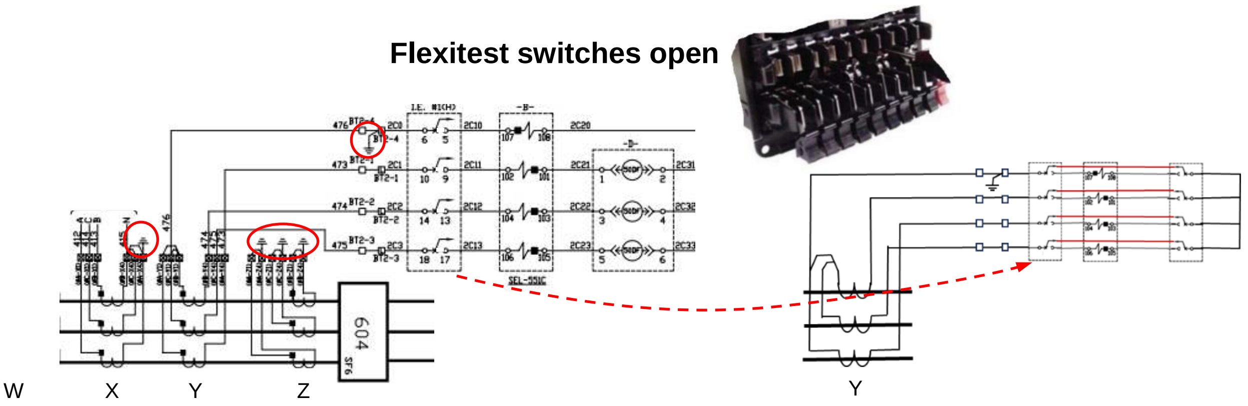
b) Relay panel in control room

c) Flexitest switches in close position



d) Circuit diagram of CTs and protection system

In-service Condition of Protection System Components
Figure 7



a) All four CTs and Y CT to Flexitest **b) Y CT to Flexitest bypassing relays**

In-testing CT Condition of Protection System Components
Figure 8

Table 1
Recommended Test Voltages

			Old method (2012)				New method (2023)			
Phase	**Insul.**	**kV**	**mA**	**Watts**	**%PF**	**Cap**	**mA**	**Watts**	**%PF**	**Cap**
A (T6135)	C1	10	4.114	0.071	0.160	1091	4.087	0.097	0.263	1084
	C2	2	Not performed				6.803	0.115	0.187	1805
B (T6136)	C1	10	4.047	0.069	0.160	1074	4.017	0.076	0.202	1066
	C2	2	Not performed				7.234	0.197	0.293	1919
C (T6137)	C1	10	4.027	0.93	0.159	1068	3.998	0.092	0.231	1061
	C2	2	Not performed				6.609	0.149	0.226	1753

CONCLUSIONS

This paper demonstrates that it is possible to keep the CT secondary windings connected during maintenance testing, by not physically disconnecting the wire from the CT secondary terminals. This practice has been used for several years in our facilities. During the inadvertent outage, a tripping of the electrical protection had occurred in a particular configuration involving electromagnetic induction. This event allowed us to improve our existing procedure by using the Flexitest switches to remove the relays from the circuit, to short the CT secondary windings and at the same time to preserve the existing ground on the CT secondary. This methodology complies with the principle of isolating and grounding the CT secondary, as written in the DTA Connection Diagram. However, the pictogram suggests physically disconnecting the wires, which leads the field tester to confusion. Rio Tinto proposes adding an option of using the Flexitest to the pictogram of the DTA Test Connection Diagram.

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REFERENCES

[1] Chapter 5, ***Doble Test Procedures***, 72A-2244-01 Rev. C, Copyright, 2009, Doble Engineering Company

[2] PEN-00000115 "Essais Doble sur un Transformateur de Courant (TC) (Incluant Manufacturier RHM)," ***Rio Tinto****'s* ***Test Procedure***, 2022

[3] C57.13.3-2014, ***IEEE Guide for Grounding Instrument Transformer Secondary Circuits and Cases***

[4] Avis Technique, "MALT des Transformateurs de Courant et de Potential," *Rio Tinto's* ***Technical Advice***

BIOGRAPHIES

Hugo Simard, P.E., works as an Electrical Engineer for Rio Tinto Aluminum in Strategic Expertise Group, and has over 25 years of experience in asset management and on transformer, hydroelectric generator, and aluminum rectifier substation. He is an active participant in the Doble community and he is the Chairman of the Rotating Machinery committee. He has also published numerous technical papers. He is an IEEE member and a registered professional engineer in Quebec. He got his Bachelor's from the University of Québec in Chicoutimi, Canada, in 1997.

Long Pong works as a Senior Principal Engineer in the Doble Client Service Department. He has over 30 years of experience in power utility and has published numerous technical papers pertaining to condition assessment, troubleshooting and new test techniques of power electrical apparatus. Before joining Doble in 2000, he was employed at Alcan-Energie Electrique and Hydro-Quebec. He is an IEEE member and a registered professional engineer in North Carolina. He got his Bachelor's of Electrical Engineering from École Polytechnique de Montreal, Quebec, Canada, in 1988

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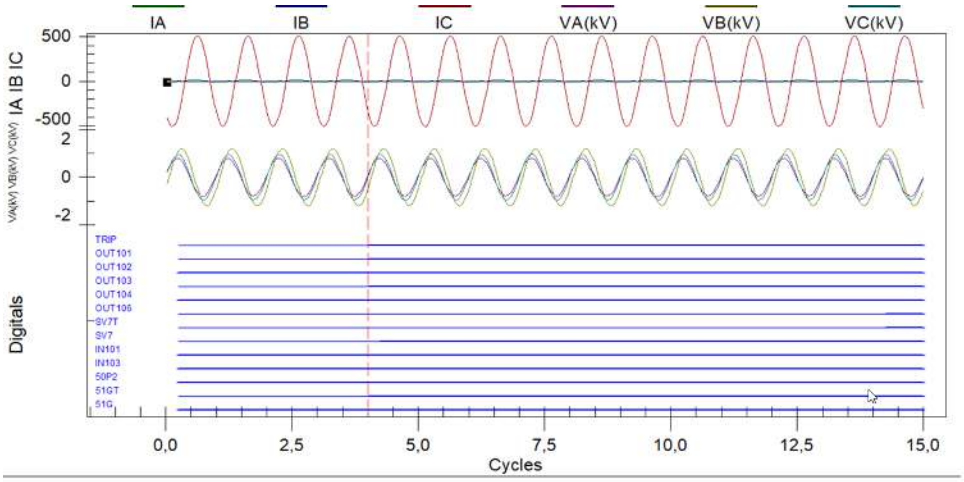
APPENDIX

351 (50S) Relay, 500A PHC Primary Current During Event



Un courant de 500 ampères a été vu sur la phase C au primaire, ainsi on sait qu'un courant de 2,08 ampère a circulé au secondaire dans le relais 351 (TC 1200:5) Puisque le courant a persisté pendant 10 cycle suite à l'état ouvert du disjoncteur, (50S) Le relais 351 a alors déclenché la sortie 106 qui fais déclencher la protection différentielle de la barre C. (87D)

Voici l'hypothèse :

En appliquant court-circuit au ground sur la phase C, les électrotechniciens ont créé un différence de potentiel entre le ground de la BJ tripolaire et le ground de la salle de commande.
Ainsi, une tension de quelques volt entre la BJ tripolaire et la salle de commande aurait pu engendré un courant d'environ 2 A puisque l'impédance de la boucle est faible.