



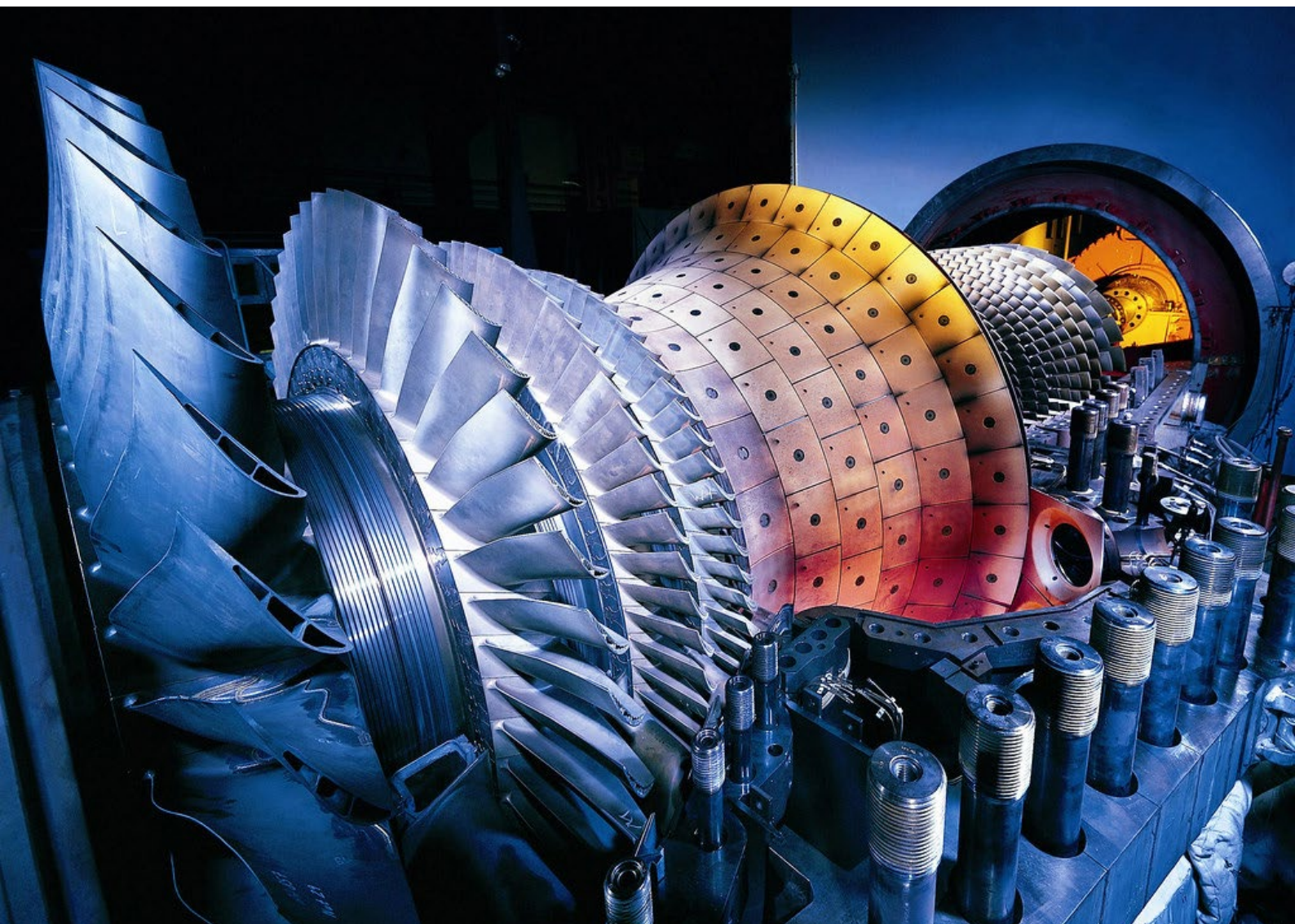
Report: Review of Generator Protection Performance

**13003045 Under-Frequency Event of 23 October 2025
Tauhara (TAB) and Te Huka (TAC) Geothermal Generation**

Transpower New Zealand Limited

28 August 2026

→ The Power of Commitment



Project name		Under-Frequency Event					
Document title		Report: Review of Generator Protection Performance 13003045 Under-Frequency Event of 23 October 2025 Tauhara (TAB) and Te Huka (TAC) Geothermal Generation					
Project number		13003045					
File name		13003045 Under-Frequency 23 Oct 2025					
Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
Approved	6.0	Dr Abraham Alvarez	Steven Nutt		Graham Skelly		28/08/2026

Gutteridge Haskins & Davey Limited CN 05528602

Contact: Steven Nutt, Technical Director | Power Systems
 49-51, Grey Street
 Newcastle Upon Tyne, NE1 6EE, UK
 E Steven.Nutt@ghd.com | www.ghd.com

© GHD 2026

This document is and shall remain the property of GHD. The document may only be used for the purpose for which it was commissioned and in accordance with the Terms of Engagement for the commission. Unauthorised use of this document in any form whatsoever is prohibited.

Executive summary

On 23 October 2025 at 17:42 (NZ), an under-frequency event (UFE) occurred on the New Zealand power system, with the National grid frequency momentarily reaching approximately 49.20 Hz. The event followed the return to service of the 220 kV Wairakei–Tauhara (WRK–TAB) overhead line from a planned maintenance outage: the circuit was energised from Wairakei (WRK) and circuit breaker CB662 at Tauhara was closed. This resulted in the near-simultaneous tripping of the Tauhara Geothermal (TAB) and Te Huka Geothermal (TAC) generating units. The conditions at the moment of closure, and commentary on them, are set out in Section 2.4.

GHD was engaged by Transpower as System Operator to review the performance of the generator protection at both sites. This report presents the evidence obtained from the relay records (COMTRADE and SEL event files), the protection setting lists, the protection event logs, and the control-room logs. The two principal findings are:

- **TAB (Tauhara):** One of the two current transformers (CTs) feeding the generator differential element measured the current as expected, while the other did not i.e. the CT measurements diverged, consistent with current transformer saturation. This difference between the two CT measurements is the primary cause of the event: it produced a false differential current on phase 3. The operation of the 87G differential protection was an effect of that CT measurement difference, and not a response to a true internal fault. GHD found no other protection pick-up, unrelated to the differential protection, that would have tripped the TAB unit.
- **TAC (Te Huka):** Contrary to the initial understanding (reflected in the Electricity Authority's draft determination, section 3.15) that TAC tripped on rate-of-change-of-frequency (RoCoF), the relay record shows that the 51V (voltage-restrained overcurrent) element picked up on the circuit-breaker closure but did not itself trip, and that the 81RXT (RoCoF) element subsequently picked up during the disturbance. GHD is not able to provide definitive evidence of which element issued the TAC trip, owing to the missing data set out in Section 6; Section 5 presents GHD's assessment based on the recorded events.

It was the CT behaviour that caused the TAB unit to trip: the protection operation resulted from the false current reading and not from an internal fault, and therefore the under-frequency event would not have happened without the false current reading. GHD further notes that the relay internal timestamps are not a reliable common reference (the two TAC relays differ by approximately three seconds for the same event). Using the circuit-breaker closure as a common zero-origin reference, TAB picks up at approximately 200ms and trips at approximately 250ms after closure, and the TAC 81RXT pick-up coincides with the TAB trip consistent with a working hypothesis that the loss of TAB drove the subsequent behaviour at TAC. This causation cannot be established conclusively for the reasons set out in Section 5.

Contents

1.	Introduction and Background	1
1.1	Purpose of this report and Scope	1
1.2	Event Description	1
1.3	Draft determination context	1
2.	Data Reviewed	2
3.	Methodology	2
3.1	Timing reference — zero (origin) alignment	2
3.2	Terminology	3
4.	Events Logic	4
5.	Tauhara (TAB) analysis of the differential operation	5
5.1	Confirmation of a differential (operate) current on phase L3	5
5.2	Evidence of CT divergence (saturation)	6
5.3	The differential element operated correctly for the signals it received	7
5.4	Relay OperDCBiasing Saturation setting	7
5.5	CT Saturation and Protection Operation	8
5.6	Standards and CT performance commentary	8
6.	Te Huka (TAC), analysis of the protection operation	9
6.1	ER report flag	9
6.2	First ER event 51V	9
6.3	Second ER event 81RXT (RoCoF)	11
6.4	Assessment of the source of the TAC trip	12
6.5	RoCoF commentary	13
6.6	Missing Data and limitations	13
7.	Discussion	15
8.	Conclusions	15
9.	Observations for consideration	16

Table index

No table of contents entries found.

Figure index

Figure 1 TAB GEN_SP_IL1	5
Figure 2 Differential current on L1, L2, L3 and differential pickups	6
Figure 2 TAB reconstructed 87G	6
Figure 3 TAB Current 87G and IL3 overlay	7
Figure 4 TAC SEL Relay Settings Definitions	9
Figure 5 TAC Event Capture ER Flag and 51V Operation Voltage and current	10
Figure 5 TAC Event Capture ER Flag and 51V Operation Current and Frequency	10
Figure 5 TAC second ER event (x axis approximately 49–53 s).	11
Figure 5 TAC second ER event (x axis approximately 49–53 s).	12

Appendices

Appendix A	Glossary of terms
Appendix B	Te Huka 3 PS Protection Log

Attachments

No table of contents entries found.

1. Introduction and Background

1.1 Purpose of this report and Scope

Transpower's System Operator requested a review of the performance of the generator protection at Te Huka and Tauhara power stations during the switching event of 23 October 2025. The scope of this review, as agreed in the GHD Offer of Service (ref. 13003045), is to:

1. Confirm whether current transformer saturation took place at Tauhara (TAB) and, so far as the data allows, identify the CT and location involved, with commentary on how CT saturation is usually mitigated by design for high fault current applications.
2. Confirm the differential protection that operated at TAB and whether its operation was correct given the signals it received, and consider whether, absent CT saturation, the protection would have operated during this switching event.
3. Provide commentary on the standards relating to the required performance of generator-protection current transformers.
4. Review the protection operation at Te Huka (TAC) and confirm whether the protection operated as expected, with commentary on the rate-of-change-of-frequency (RoCoF) protection settings and experience of RoCoF relays elsewhere.

In accordance with the agreed scope, **no modified protection settings are recommended**, and no transmission system analysis has been undertaken. Observations are provided for the System Operator's consideration in responding to the Electricity Authority's draft determination.

1.2 Event Description

The sequence of events, established from the control-room logs and relay records, is summarised below:

- The 220 kV WRK–TAB circuit was out of service on a planned maintenance outage. During this outage the Tauhara and Te Huka generation was operating at a single-circuit risk.
- The circuit was energised from Wairakei (WRK) and circuit breaker CB662 at Tauhara was closed, returning the circuit to service.
- On closure, the resulting current surge caused the TAB Tauhara unit to trip on generator differential protection and the TAC Te Huka unit to trip (see Section 5).
- The combined loss of TAB and TAC generation caused the under-frequency event, with the National frequency momentarily dropping to approximately 49.20 Hz.

The surge associated with the circuit closure persisted for a period substantially longer than any transmission fault-clearance time, which distinguishes this event from a close-in grid fault.

1.3 Draft determination context

The Electricity Authority Te Mana Hiko has issued a draft determination of causer for the 23 October 2025 UFE. GHD's review is a technical assessment of the protection performance based on the recorded data. This report does not address the question of regulatory causer, which is a matter for the Authority.

2. Data Reviewed

The following information provided by Transpower was reviewed in preparing this report:

Data source	Description / relevance
Generator relay records (COMTRADE)	REG670 generator protection records for TAB (e.g. TABG0010CHA10GS010F1_DR677), containing star-point and terminal current and voltage channels and relay word bits, sampled at 1000 samples/second.
SEL event records (CEV)	SEL relay event capture for TAC (e.g. CEV_10764), containing analogue traces and the ER report flag and element word bits.
Protection setting list	TABG-FES-1-000-ELE-LST-0003 Rev.1 Tauhara protection relay setting list, including the REG670 87G generator differential settings and the 51V voltage-restrained overcurrent settings.
Control-room logs	National Daily Operation Report (DOR, 20251023) and Grid Operators Log (GOL, 20251023); frequency excursion notice for the event.
Regional single-line diagrams	Annotated regional SLDs showing generation output, plant types and open circuit-breaker status at the event time.
PowerFactory case	Regional network case with the WRK–TAB circuit open and the correct angle across CB662, set up for unbalanced load-flow and dynamic studies (reference/context only).

3. Methodology

The generator differential element at TAB is defined in the setting list with an operate (differential) quantity equal to the vector sum of the two CT inputs:

$$\text{Operate current} = | I_{\text{terminal}} + I_{\text{star-point}} |$$

Accordingly, for each phase, the recorded differential current was reconstructed from the relay's own channels as the sum of the terminal-side and star-point-side currents. For the IL3 phase this is:

$$\text{TRMPSPIL3} = \text{GEN_TRM_IL3} + \text{GEN_SP_IL3}$$

Because this quantity is precisely the relay's operate-current input (not an approximation), it provides a direct link between the recorded CT currents and the differential element's decision to operate. The equivalent quantities for the white and blue phases (IL1, IL2) were also examined. Relay word bits (element start and trip flags) were then correlated in time with the analogue traces to establish the operating sequence. For TAC, the SEL ER report flag was decomposed into its constituent sources to identify which element operated at each instant, and the SEL-400G and SEL-700G event logs were reviewed alongside the event captures.

3.1 Timing reference — zero (origin) alignment

The internal timestamps of the relays were found not to be a reliable common reference for cross-relay comparison. For the same event, one TAC relay records a time of approximately 48.75 s while the other records approximately 51.75 s, and the TAB and TAC relays do not share a common time reference. To compare the operation of the different relays on a like-for-like basis, GHD therefore adopted a common **zero (origin) reference** defined by the instant at which the circuit-breaker closure is first observed as a disturbance in the recorded waveforms (i.e. the onset of the closure-induced waveform). All relative timings quoted in this report are measured from this zero-origin reference rather than from the relays' internal clocks.

3.2 Terminology

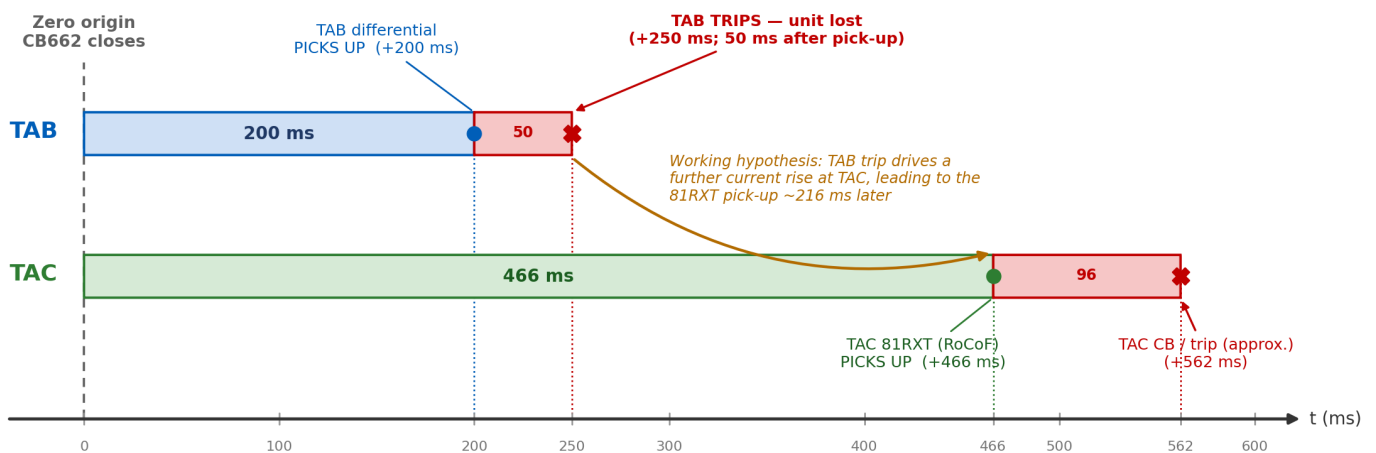
To avoid ambiguity, the following terms are used consistently in this report, and in Section 5 in particular: a protection element is said to have **picked up** (or **asserted**) when it starts; to have **dropped off** (or **de-asserted**) when it resets; and to have **operated** (or **tripped**) only when it issues an actual trip. A pick-up (assertion) does not, of itself, mean that a trip was issued.

4. Events Logic

Sequence of Events — Zero-Origin Timing Analysis

23 October 2025 Under-Frequency Event | Tauhara (TAB) and Te Huka (TAC) | GHD ref. 13003045

Reference point	TAB (Tauhara)	TAC (Te Huka)	Time from zero origin
Time 0 — CB662 close (disturbance onset)	17:42:51.79	16:42:48.795	0 ms (common origin)
Protection pick-up	17:42:51.99	16:42:49.261	TAB +200 ms TAC +466 ms
CB / trip (approx.)	17:42:52.04	16:42:49.874	TAB +250 ms TAC +562 ms



Note: relay internal clocks are not a common reference (TAB and TAC differ by ~3 s). All times are relative to a common zero origin defined by the CB662 closure disturbance. Causation (TAB trip → TAC behaviour) is a working hypothesis limited by missing data (see report §6).

The relative timing of the operations at the two sites is summarised in Figure 10. The upper table lists the raw relay timestamps recorded at each site for three reference points — the closure of circuit breaker CB662 (taken as Time 0), the protection pick-up, and the approximate circuit-breaker/trip — together with the corresponding offsets from the zero origin. Because the relay internal clocks do not share a common reference (the TAB and TAC records differ by approximately three seconds for the same event), the timeline beneath the table re-expresses these events on a single common axis, with the zero origin defined by the onset of the CB662 closure disturbance in the recorded waveforms.

On this common basis, the Tauhara (TAB) generator differential element picks up at approximately +200 ms after closure and trips approximately 50 ms later, at approximately +250 ms, at which point the Tauhara unit is lost. The Te Huka (TAC) 81RXT (rate-of-change-of-frequency) element picks up later, at approximately +466 ms, with the associated circuit-breaker/trip at approximately +562 ms. The interval between the TAB trip (+250 ms) and the TAC 81RXT pick-up (+466 ms) is approximately 216 ms. GHD's working hypothesis, indicated by the arrow in the figure, is that the loss of the Tauhara generation on the TAB trip produced a further increase in current and continued frequency fluctuation at Te Huka, which in turn led to the pick-up of the TAC 81RXT element. As set out in Section 6, this causal relationship is consistent with the observed sequence but cannot be established conclusively from the data provided, owing to the absence of circuit-breaker operation data and the short gap in the TAC record.

5. Tauhara (TAB) analysis of the differential operation

5.1 Confirmation of a differential (operate) current on phase L3

The reconstructed differential current TRMSPIL3 remained at approximately zero throughout normal operation and during the initial part of the surge, then developed a large, unidirectional excursion at the instant of operation. The corresponding quantities on the white and blue phases (IL1 and IL2) remained flat at approximately zero throughout and are therefore not reproduced here. The appearance of a genuine differential current on the IL3 phase only is consistent with the differential element starting and operating on phase L3 alone (GENPDIF_STL3), and not on the other two phases.

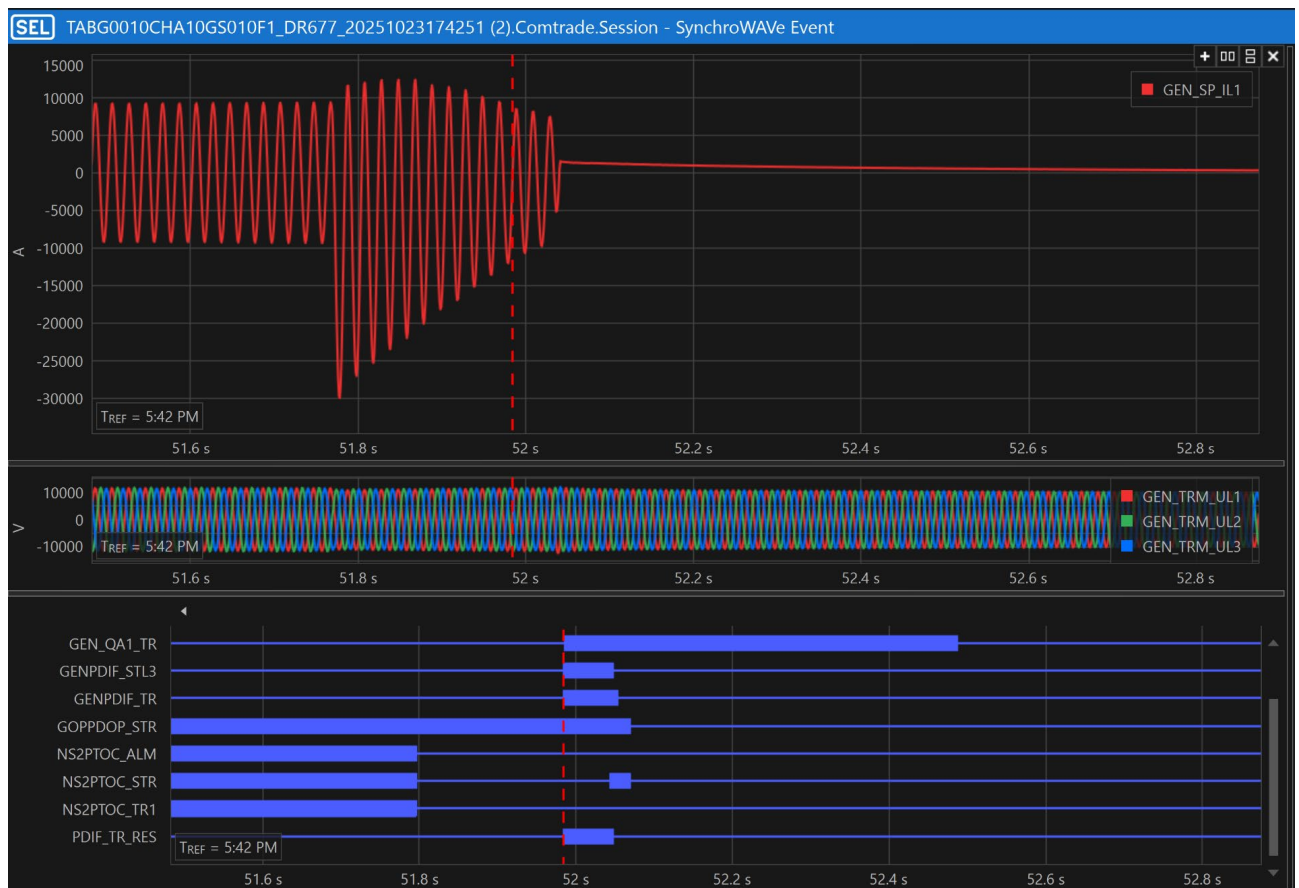


Figure 1 TAB GEN_SP_IL1

TAB GEN_SP_IL1 illustrative star-point current GEN_SP_IL1 (upper trace, context only; IL1 is not the operating phase). The lower digital panel shows the differential element start on phase L3 (GENPDIF_STL3) and the differential trip (GENPDIF_TR) asserting at the cursor, indicating operation at that instant with no intentional delay.



Figure 2 Differential current on L1, L2, L3 and differential pickups

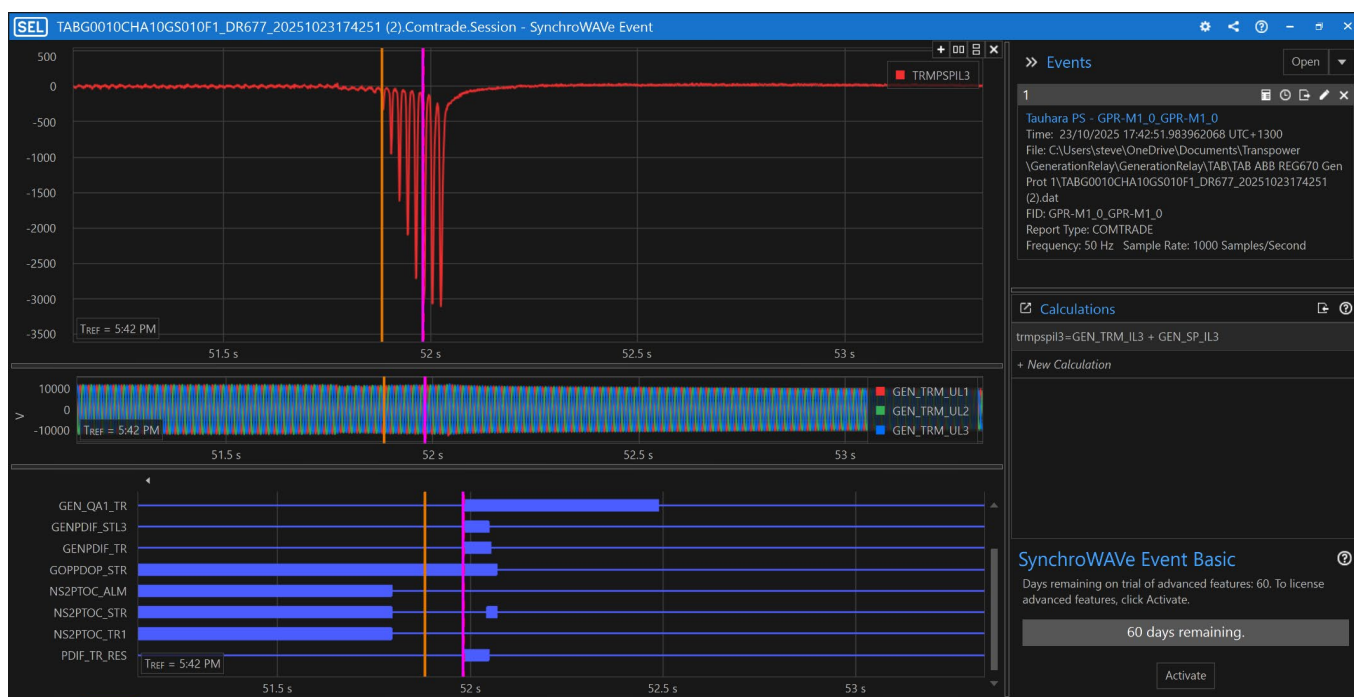


Figure 3 TAB reconstructed 87G

TAB reconstructed 87G: Operate current on the IL3 phase, $TRMPSPIL3 = GEN_TRM_IL3 + GEN_SP_IL3$. The differential remains at approximately zero during normal operation and then develops a large excursion at the instant of operation. The equivalent quantities on phases L1 and L2 were flat (≈ 0) and are omitted.

5.2 Evidence of CT divergence (saturation)

Overlaying the two CT inputs to the differential element on phase 3 the terminal-side current (GEN_TRM_IL3), the star-point-side current (GEN_SP_IL3) and their difference ($TRMPSPIL3$) shows the two currents tracking one another during the surge, so that their difference remains near zero, and then diverging. It is this divergence between the two CTs

one CT measuring the current as expected and the other not that produces the false differential current seen by the relay. Such divergence is the characteristic signature of current transformer saturation, in which one CT ceases to faithfully reproduce its primary current while the other continues to do so.

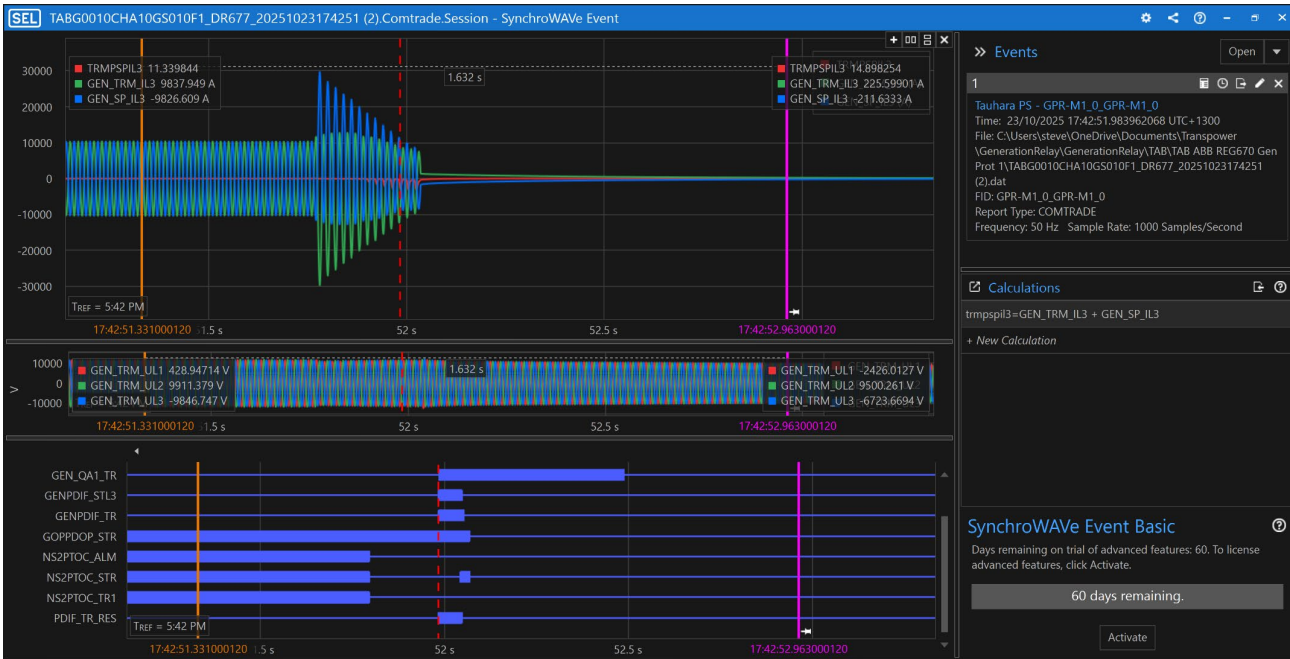


Figure 4 TAB Current 87G and IL3 overlay

TAB the two current transformer inputs to the differential element on phase L3 (terminal-side and star-point-side), together with their difference (TRMPSIL3) and the associated event sequence. The two currents track during the surge (difference ≈ 0) and then diverge, producing the differential current that operated the relay the characteristic signature of CT saturation.

This observation is consistent with the position reported by Contact Energy, namely that one of the current transformers on the TAB generator differential scheme reached saturation, producing a false differential current, while the neutral-side CT did not saturate. The recorded magnitude of the current experienced by the generator during the surge was of the order of twice the nominal current a magnitude below that expected for a close-in system fault, and one at which a generator-protection CT would not ordinarily be expected to saturate.

5.3 The differential element operated correctly for the signals it received

The REG670 87G element picked up and tripped on phase 3 in response to the differential current present at its inputs. On the evidence of the relay records, the element behaved in accordance with its settings and characteristic; there is no indication of a spurious or incorrect internal decision. In other words, given the (false) differential current presented to it, the relay operated correctly and without intentional delay.

5.4 Relay OperDCBiasing Saturation setting

The Tauhara protection setting list records the following for the REG670 generator differential (GENPDIF) element:

Setting	Value	Relevance
OperDCBiasing	Off	Manufacturer’s countermeasure used where poor CT saturation is anticipated. Disabled at TAB.
OpenCTEnable	Off	Open-CT detection feature; noted as not used to prioritise tripping.

OperCrossBlock	Off	Cross-block logic between phases.
Operate quantity	$ I_1 + I_2 $	Vector sum of terminal-side and star-point-side CTs (per phase).

The OperDCBiasing function is the manufacturer's feature intended to provide additional restraint where poor CT reproduction (saturation) may occur. At TAB this feature was set to Off. The description of the feature itself suggests that it would ordinarily be expected to be enabled for a generator differential protection where CT saturation is a credible concern; on the basis of the description, GHD would expect this setting to have been active. GHD has not been provided with a reason why the setting was Off for this generator. It is possible, and would be acceptable engineering practice, for the preference to be to mitigate saturation effects through appropriate CT specification instead (see Section 5.6) rather than by relying on the DC-biasing restraint; where that is the design intent, the CT specification becomes the primary safeguard. With the countermeasure disabled and, on the evidence available, the CT nevertheless saturating, the differential element had no additional mechanism to discriminate the false differential current arising from CT divergence and therefore operated on the difference current it observed. This is an observation on the configuration as recorded; in accordance with the agreed scope, GHD makes no recommendation to modify the setting.

5.5 CT Saturation and Protection Operation

The differential (operate) current on phases 1 and 2 remained at approximately zero throughout, and the operate current on phase 3 was near zero until the point at which the CTs diverged. On this basis, the evidence indicates that the differential current which caused the operation was produced by the divergence between the two CTs rather than by a true in-zone fault. It follows that, absent the CT divergence (saturation), no operate current of sufficient magnitude to cause a differential trip would have been presented to the element during this switching event. GHD further confirms that, from the records reviewed, there was no other protection pick-up at TAB unrelated to the differential protection that would have tripped the unit in the absence of the CT issue. GHD notes that CT saturation is a complex phenomenon and that a full forensic CT-performance analysis (for example, against the CT magnetisation characteristic and knee-point voltage) is beyond the data provided; the conclusion above is drawn from the recorded relay currents.

5.6 Standards and CT performance commentary

Current transformers used for generator differential protection are ordinarily specified (class and knee-point voltage) so as to avoid saturation for the range of through-currents and offset conditions expected in service, including the asymmetric (DC-offset) currents associated with faults and switching. The relevant international standards for protection-class CTs (for example the IEC 61869 series, and IEEE C57.13) define the accuracy classes and, for transient performance, the classes intended to secure correct reproduction under offset conditions. The observation that saturation appears to have occurred at a current of the order of twice nominal below the level expected for a close-in fault is consistent with the reviewed literature on false differential operation arising from CT core saturation and would ordinarily prompt a review of the CT specification and application against the duty at this location. Specifying the CT appropriately for the duty is, in GHD's view, the preferable means of mitigating saturation effects for this type of application. Where the CT specification for the TAB protection CTs is made available, GHD would be able to comment further.

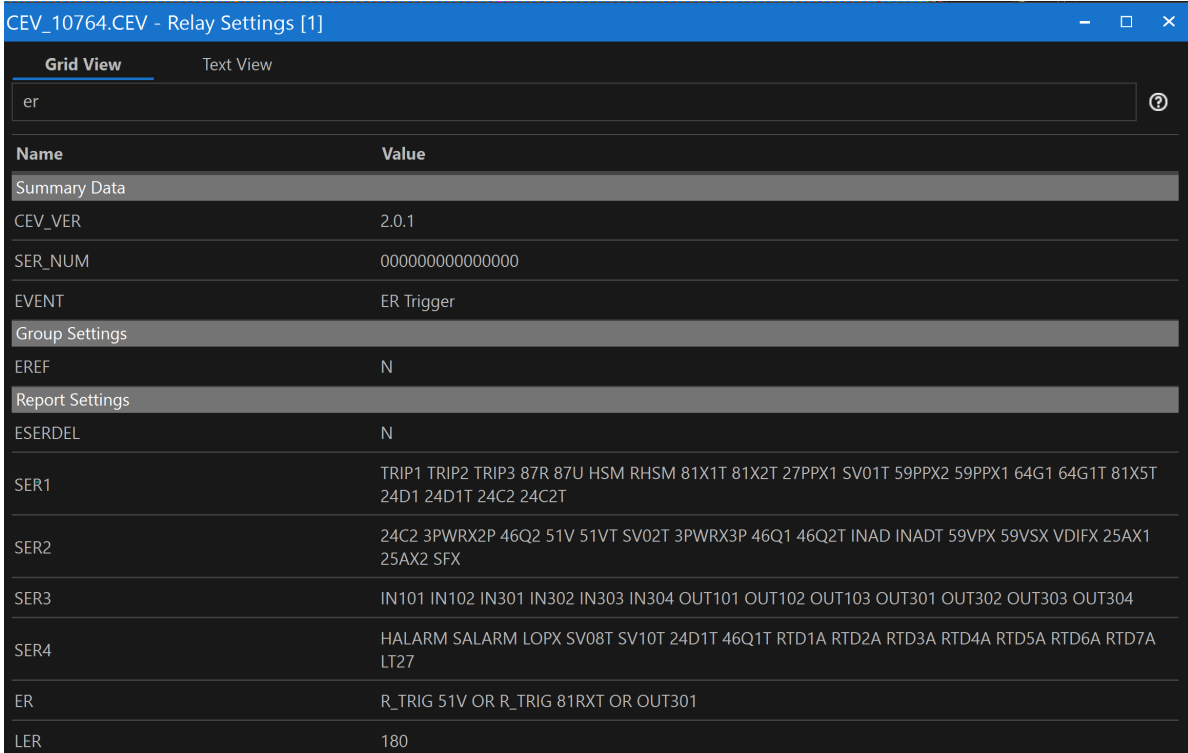
6. Te Huka (TAC), analysis of the protection operation

6.1 ER report flag

The initial understanding of the event (reflected in the Electricity Authority's draft determination) was that the Te Huka (TAC) unit tripped on rate-of-change-of-frequency (RoCoF) protection. Examination of the SEL relay settings shows that the ER report-trigger flag is not element-specific; it is asserted by any one of three sources:

ER = R_TRIG 51V or R_TRIG 81RXT or OUT301

Because the ER flag is common to the 51V (voltage-restrained overcurrent), 81RXT (rate-of-change-of-frequency) and OUT301 sources, the presence of ER alone does not identify which element picked up. TAC is provided with duplicate protection: a SEL-400G relay and a SEL-700G relay and both were reviewed. As set out below, the relay record contains **two separate ER events**: a first event associated with the 51V element, and a second, later event associated with the 81RXT (RoCoF) element.



Name	Value
Summary Data	
CEV_VER	2.0.1
SER_NUM	0000000000000000
EVENT	ER Trigger
Group Settings	
EREF	N
Report Settings	
ESERDEL	N
SER1	TRIP1 TRIP2 TRIP3 87R 87U HSM RHSM 81X1T 81X2T 27PPX1 SV01T 59PPX2 59PPX1 64G1 64G1T 81X5T 24D1 24D1T 24C2 24C2T
SER2	24C2 3PWRX2P 46Q2 51V 51VT SV02T 3PWRX3P 46Q1 46Q2T INAD INADT 59VPX 59VSX VDIFFX 25AX1 25AX2 SFX
SER3	IN101 IN102 IN301 IN302 IN303 IN304 OUT101 OUT102 OUT103 OUT301 OUT302 OUT303 OUT304
SER4	HALARM SALARM LOPX SV08T SV10T 24D1T 46Q1T RTD1A RTD2A RTD3A RTD4A RTD5A RTD6A RTD7A LT27
ER	R_TRIG 51V OR R_TRIG 81RXT OR OUT301
LER	180

Figure 5 TAC SEL Relay Settings Definitions

6.2 First ER event 51V

At the first ER event, the ER flag is asserted together with 51V, while the 81RXT (RoCoF) element and OUT301 are not asserted. The analogue traces show a rise in current accompanied by a slight dip in voltage. This combination (elevated current with depressed voltage) is the condition that the voltage-restrained overcurrent element (51V) is designed to detect: the voltage restraint increases the element's sensitivity when the voltage falls, as occurs for a disturbance in the vicinity of the generator. GHD is not able to confirm from the data whether the current rise and voltage dip met the 51V operating threshold as a numerical comparison against the setting; however, the 51V element is observed to have picked up (asserted), so it is reasonable to conclude that the threshold was met. There is no intentional pick-up delay applied to the 51V element in the relay. Importantly, the 51V element picked up (asserted) but did not itself trip and the associated 51V trip (51VT) did not assert.

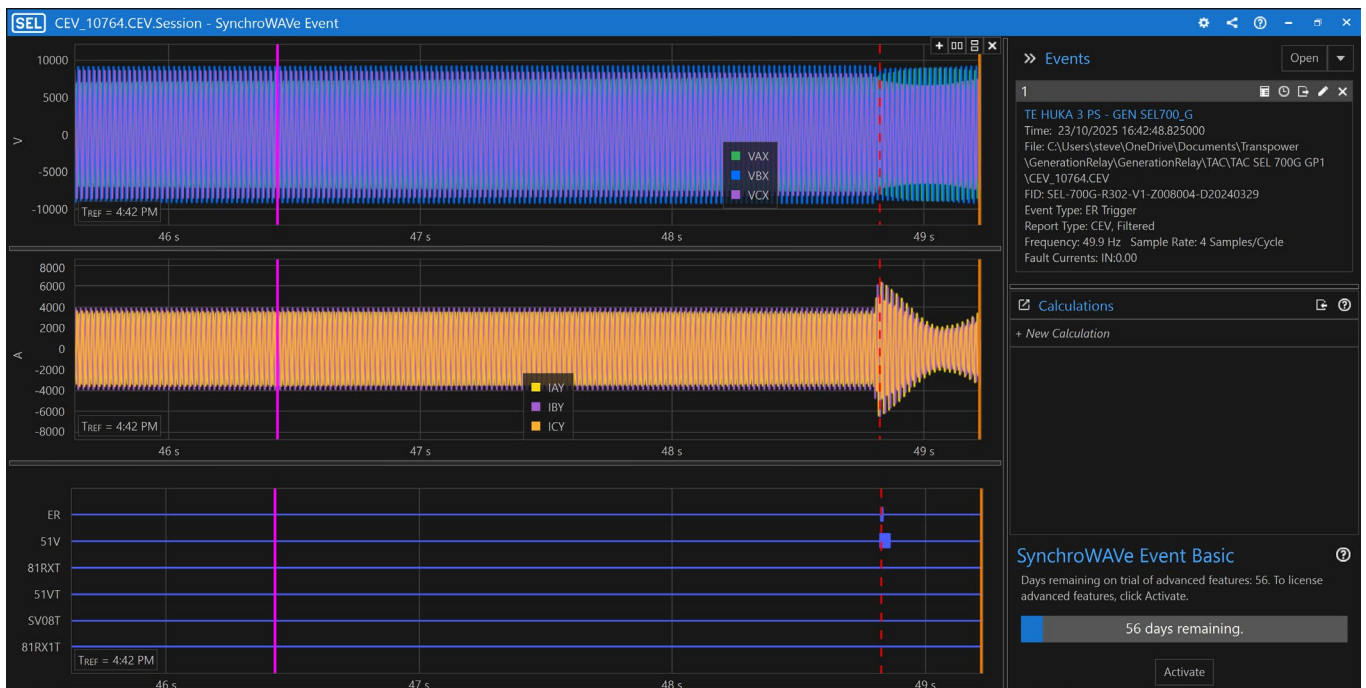


Figure 6 TAC Event Capture ER Flag and 51V Operation Voltage and current

Figures 5 show wide view of the first ER event (x axis approximately 45–49.25 s). The frequency drop occurs with the ER flag and 51V asserted, and without operation of the 81RXT (RoCoF) element or the 51V trip (51VT).

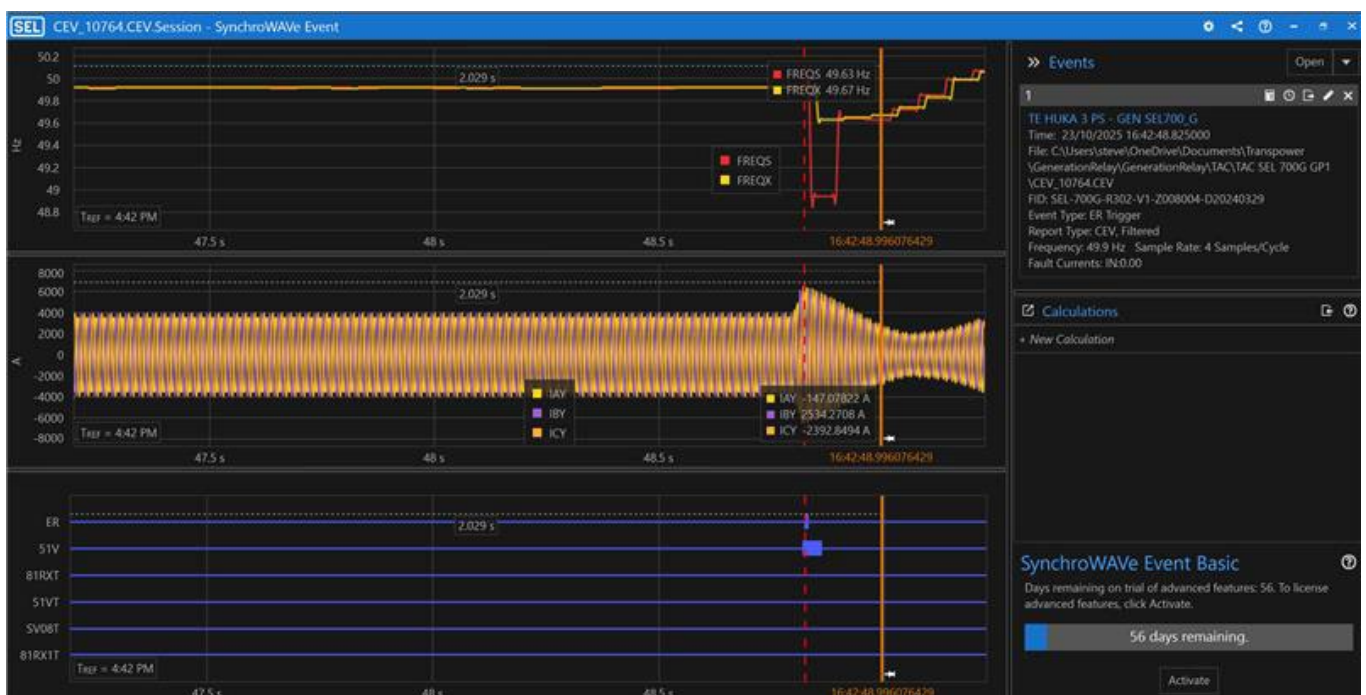


Figure 7 TAC Event Capture ER Flag and 51V Operation Current and Frequency

TAC — first ER event (x axis approximately 47–49 s). The frequency drop is shown with the voltage in the centre panel; the ER flag and 51V are asserted while the 81RXT (RoCoF) element and the 51V trip (51VT) are not. TAC — first ER event (approximately 47–49 s) with the current in the centre panel. 51V is active and the 51V trip (51VT) is not active, ER is active, and the frequency drop coincides with an increase in current — the current-rise / voltage-dip signature that operates the 51V voltage-restrained overcurrent element.

This 51V pick-up is corroborated by the two Te Huka 3 PS protection event logs (Appendix B). Both the SEL-400G and SEL-700G logs record the 51V element asserting at approximately 16:42:48.82 on 23 October 2025; neither log records an assertion of the 81RXT (RoCoF) element.

6.3 Second ER event 81RXT (RoCoF)

Following the 51V event, the relay record contains a second, later ER event, in which the 81RXT (RoCoF) element operated. This second operation is not recorded in either protection event log. The event captures show the 81RXT element asserting during the angular disturbance, with the associated currents and the frequency ramp. It should be noted that the operation of 81RXT was over 450ms after the switching event and was around 200ms after the tripping of TAB. GHD notes that the recorded rate of change of frequency associated with this second event appears slower than would ordinarily be expected to operate a RoCoF element; nevertheless, the 81RXT element was triggered. Whether this reflects the element's setting responding to the change in frequency caused by the loss of TAC, or operation on the underlying angular disturbance, cannot be resolved further from the data provided.

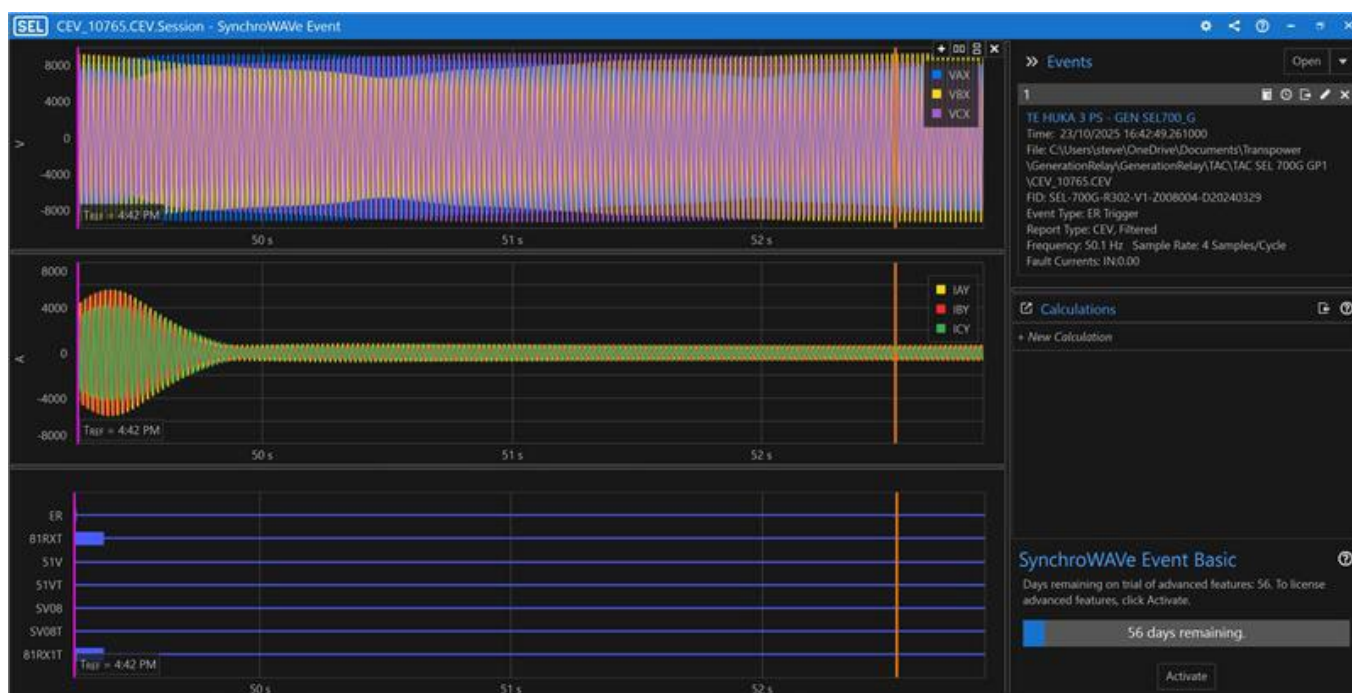


Figure 8 TAC second ER event (x axis approximately 49–53 s).

A further ER flag is raised, this time by operation of the 81RXT (RoCoF) element, with 51V not asserted. This operation is not recorded in the protection event logs.

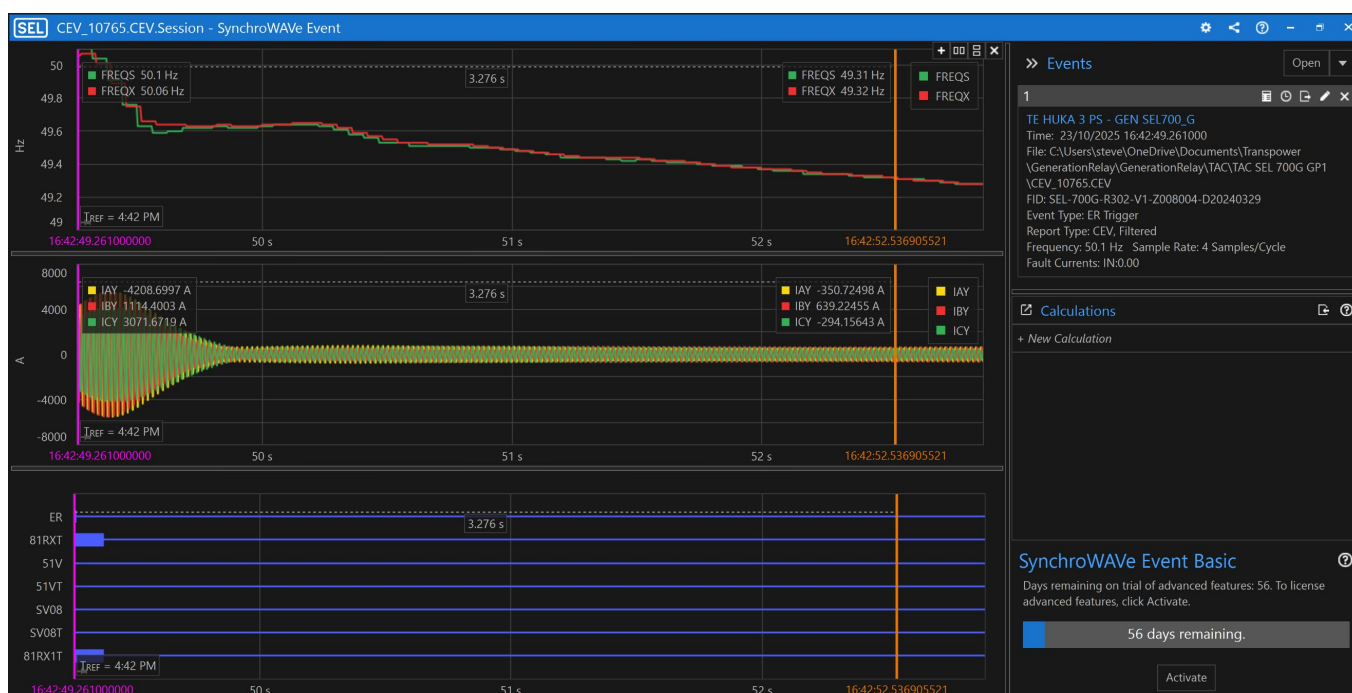


Figure 9 TAC second ER event (x axis approximately 49–53 s).

Second ER event (approximately 49–53 s) with the currents in the centre panel and the frequency ramp shown. The 81RXT (RoCoF) element operates although the frequency rate of change appears slower than would ordinarily operate RoCoF; the element is nevertheless triggered.

6.4 Assessment of the source of the TAC trip

GHD is not able to provide definitive evidence of the source of the TAC trip from the data available, principally because of the missing data identified in Section 6. The following sets out GHD's assessment based on the recorded events:

- Both the 51V and 81RXT elements share the ER report flag, so the ER flag alone does not identify which element issued the trip.
- The 51V element picked up but did not itself trip: the 51V trip (51VT) did not assert. On that basis, the 51V element alone does not account for the trip of the unit.
- The 81RXT (RoCoF) element picked up during the disturbance, coincident with the loss of TAB (Section 4).
- The SER logs of both relays record the 51V pick-up but do not record an 81RXT assertion. The absence of an 81RXT SER message, notwithstanding the pick-up seen in the event capture, is anomalous; it may have a separate cause, and it means the SER logs alone are not definitive as to the tripping element.

Weighing these observations and noting that the 51VT trip did not assert while the 81RXT element picked up coincident with the loss of TAB, GHD's assessment is that the TAC trip is more likely to be associated with the 81RXT (RoCoF) element than with a 51V pickup. GHD emphasises that this is an assessment based on the available records and cannot be stated as definitive, given the missing circuit-breaker data and the short gap in the TAC record (Section 6) and given the anomaly between the SER logs and the event captures. GHD notes that the asset owner is the source of the statement that RoCoF (81RXT) caused the trip; the present assessment does not contradict that statement, but the available data does not allow it to be confirmed with certainty.

6.5 RoCoF commentary

Rate-of-change-of-frequency protection is widely applied for the fast disconnection of generation and for loss-of-mains detection. Because it is derived from the measured rate of change of frequency, it is comparatively stable against transient voltage disturbances (relative to vector-shift methods), but it can be susceptible to pick-up during large angular disturbances. In this event, the two protection logs record only the 51V pick-up; the separate pick-up of the 81RXT (RoCoF) element, evident in the event captures from previous section, was not recorded in the logs.

GHD's general experience of RoCoF relays elsewhere is that rate-of-change-of-frequency relays can pick up following angular disturbances and during faults on the network. There are many international events that can be used to demonstrate such relays operating during system disturbances that do not involve a genuine frequency change. The recommendations commonly put in place to avoid these erroneous operations are to apply a time delay to the protection, so as to avoid inadvertent generator tripping during transient angular disturbances. As with TAB, GHD makes no recommendation to modify settings; the above is provided as an observation of the recorded behaviour.

Sequence of operations and causation (zero-origin analysis)

Adopting the circuit-breaker closure as the common zero (origin) reference, the following relative sequence is observed across the TAB and TAC records:

- At approximately **200 ms** after the breaker closure, the TAB (Tauhara) generator differential element picks up.
- Approximately **50 ms later** (around 250 ms after closure), TAB operates (trips) and the Tauhara generating unit is lost.
- Coincident with the TAB trip, the current recorded at TAC (Te Huka) increases again, and the 81RXT (RoCoF) element picks up.

On the basis of this relative sequence, GHD's working hypothesis on causation is as follows:

- The **TAB trip was caused by the circuit-breaker closure** — specifically the CT saturation and the resulting false differential current described in Section 4.
- The **TAC behaviour may, in turn, have been driven by the TAB trip**: the loss of the Tauhara generation produced a further increase in current and continued frequency fluctuation at Te Huka, coincident with the pick-up of the 81RXT (RoCoF) element. The 51V element at TAC picked up on the initial breaker closure but did not itself trip (Section 5.2).

This causation hypothesis is consistent with the observed sequence but **cannot be established conclusively** from the data provided, for the reasons set out in previous sections in particular the absence of circuit-breaker operation data and a short gap in the TAC record that coincides with the period in which the 81RXT element could have sensed the disturbance.

6.6 Missing Data and limitations

The following data was not available to GHD. Its absence limits the extent to which the source of the TAC trip and the sequence and causation can be established conclusively:

- **Circuit-breaker trigger information**: no information regarding the triggers to the circuit breaker has been provided.
- **Circuit-breaker operation data**: no circuit-breaker information relating to the event (for example breaker status changes or the timing of the closure and any subsequent operations) was provided.

- **Gap in the TAC record:** there is an approximately **40 ms gap** in the TAC data. The first data slot ends at 16:42:49.221 and the second data slot begins at 16:42:49.261. This gap coincides with the period in which the 81RXT (RoCoF) element could have sensed the disturbance; because this data is missing, that pick-up cannot be fully analysed.

GHD would be able to extend the analysis, and to test the assessment in Section 5.4 and the causation hypothesis in Section 5.6 more definitively, if the above data were made available.

7. Discussion

Taken together, the relay records support the following overall picture of the event at the two sites:

- **At TAB**, one CT measured the current as expected and the other did not; this difference between the two CT measurements (CT saturation) produced a false differential current on phase 3, and the operation of the differential element was an effect of that measurement difference rather than a response to a true in-zone fault. No other protection, unrelated to the differential, would have tripped the unit in the absence of the CT issue.
- **At TAC**, the 51V element picked up on the breaker closure but did not itself trip, and the 81RXT (RoCoF) element picked up later, coincident with the TAB trip. Both share the ER flag, and the SER logs record only the 51V pick-up. GHD is not able to confirm definitively which element issued the trip; its assessment (Section 5.4) is that the trip is more likely associated with the 81RXT element, but the available data does not permit certainty.

In both cases the protection responded to the electrical quantities presented at the relay terminals. The distinguishing feature at TAB is that the operate quantity itself was a measurement artefact (a false differential arising from CT divergence) rather than a reflection of a true fault current; and the magnitude of the surge current of the order of twice nominal is below that which would ordinarily be expected to saturate a correctly specified generator-protection CT. The relationship between the TAB trip and the TAC behaviour is a working hypothesis that is limited by the missing data identified in Section 6.

8. Conclusions

1. The under-frequency event of 23 October 2025 followed the energisation of the 220 kV WRK–TAB circuit from Wairakei and the closure of CB662 at Tauhara, which resulted in the tripping of the TAB and TAC generation and a national frequency excursion to approximately 49.20 Hz. At the moment of closure a voltage angle of approximately 23° existed across CB662 and the circuit was closed without check-synchronisation.
2. At TAB, one CT measured the current as expected while the other did not (CT saturation). This difference between the two CT measurements is the primary cause, producing a false differential current on phase 3 (reconstructed as $TRMPSPIL3 = GEN_TRM_IL3 + GEN_SP_IL3$, the relay's own operate quantity). The operation of the 87G differential protection was an effect of that CT measurement difference and not a response to a true internal fault.
3. The REG670 87G differential element operated correctly for the signals it received (pick-up $GENPDIF_STL3$ followed by trip $GENPDIF_TR$, with no intentional delay). The OperDCBiasing setting — the manufacturer's countermeasure for poor CT saturation — was set to Off; on the description of the feature GHD would expect it to have been enabled, unless the design intent was to mitigate saturation through appropriate CT specification (Section 4.6).
4. Absent the CT divergence (saturation), no operate current of sufficient magnitude to cause a differential trip would have been presented to the element during this switching event, and there was no other protection pick-up at TAB, unrelated to the differential, that would have tripped the unit. It was therefore the CT behaviour that caused the TAB unit to trip, and the UFE would not have happened without the false current reading.
5. At TAC, the 51V element picked up on the breaker closure but did not itself trip (the 51V trip, 51VT, did not assert), and the 81RXT (RoCoF) element picked up later during the disturbance. Both elements share the ER report flag ($ER = R_TRIG\ 51V\ OR\ R_TRIG\ 81RXT\ OR\ OUT301$), and the SER logs record only the 51V pick-up.

6. GHD is not able to provide definitive evidence of which element issued the TAC trip. On the available records the 51V trip not asserting, and the 81RXT element picking up coincident with the loss of TAB GHD's assessment is that the trip is more likely associated with the 81RXT (RoCoF) element, but this cannot be confirmed with certainty given the missing data (Section 6) and the anomaly between the SER logs and the event captures.
7. The relay internal timestamps are not a reliable common reference (the two TAC relays differ by approximately three seconds for the same event). Using the circuit-breaker closure as a common zero-origin reference, TAB picks up at approximately 200 ms and trips at approximately 250 ms after closure, and the TAC 81RXT pick-up coincides with the TAB trip consistent with a working hypothesis that the loss of TAB drove the subsequent behaviour at TAC, although this cannot be established conclusively.
8. Certain data required to establish the source of the TAC trip and the causation conclusively was not provided, namely circuit-breaker trigger and operation information, and there is an approximately 40 ms gap in the TAC record (16:42:49.221 to 16:42:49.261) coinciding with the period in which the 81RXT element could have sensed the disturbance.

9. Observations for consideration

These are observations only. In accordance with the agreed scope, GHD does not recommend modified protection settings. The following points are provided for the System Operator's consideration in responding to the Electricity Authority's draft determination:

- The status of the OperDCBiasing function on the TAB REG670 generator differential element (recorded as Off) may warrant review, given its stated purpose as a countermeasure for poor CT saturation; alternatively, if saturation is to be mitigated through CT specification, that specification becomes the primary safeguard and could be confirmed against the duty at this location.
- Where available, the specification of the TAB generator-protection current transformers (class and knee-point voltage) could be reviewed against the through-current and offset duty at this location; GHD would be able to comment further if this information is provided.
- The interpretation of the TAC operation illustrates the importance of resolving shared report flags (such as ER) to element level, and of reconciling event logs against event captures, before attributing a cause; in this case the logs recorded the 51V pick-up but not the subsequent 81RXT (RoCoF) pick-up seen in the captures.
- Consistent with wider international experience, the application of a suitable time delay to rate-of-change-of-frequency protection is commonly used to avoid inadvertent generator tripping during transient angular disturbances.
- The reliability of relay time synchronisation across the site(s) may warrant review, given that the internal timestamps did not provide a common reference for this event; a common, synchronised time source would assist any future sequence-of-events analysis

Appendix A Glossary of terms

Term	Meaning
Picked up / asserted	A protection element has started (its measured quantity has entered the operating region). A pick-up does not, of itself, mean a trip was issued.
Dropped off / de-asserted	A protection element has reset (its measured quantity has left the operating region).
Operated / tripped	A protection element has issued an actual trip.
87G / GENPDIF	Generator differential protection element (percentage-restrained). Operates on the vector sum of the terminal-side and star-point-side CT currents.
51V / 51VT	Voltage-restrained (or voltage-controlled) time-overcurrent protection; 51VT denotes the associated trip. Sensitivity to overcurrent increases as voltage falls, providing detection of faults near the generator that depress the terminal voltage.
81R / 81RXT	Rate-of-change-of-frequency (RoCoF) protection. Used for fast disconnection of generation / loss-of-mains detection; based on the measured rate of change of frequency.
ER	SEL report-trigger flag. Here defined as ER = R_TRIG 51V OR R_TRIG 81RXT OR OUT301 — shared across three sources, so not element-specific on its own.
CT saturation	Condition in which a current transformer core saturates and ceases to faithfully reproduce its primary current, producing measurement error that can appear as a false differential current.
OperDCBiasing	REG670 differential setting providing additional restraint (bias) where poor CT reproduction (saturation) is anticipated. Recorded as Off at TAB.
Zero (origin) reference	Common timing reference adopted for this analysis, defined by the onset of the circuit-breaker closure disturbance in the recorded waveforms, used because the relay internal timestamps were not a reliable common reference.
CB662	The Tauhara 220 kV circuit breaker across which the ~23° voltage angle existed at the moment of energisation.
UFE	Under-frequency event, as defined under the Electricity Industry Participation Code.
WRK / TAB / TAC	Wairakei / Tauhara Geothermal / Te Huka Geothermal, respectively.

Appendix B Te Huka 3 PS Protection Log

GEN SEL400_G

Date: 2025/11/04 Time: 08:51:56.043

TE HUKA 3 PS

Serial Number: 1240237529

FID=SEL-400G-1-R104-V0-Z005002-D20231207

#	DATE	TIME	ELEMENT	STATE
1	2025/10/31	11:34:08.4697	GENVLOS	ASSERTED
2	2025/10/31	11:34:08.4697	59VSS	ASSERTED
3	2025/10/29	07:36:31.0697	GENVLOS	DEASSERTED
4	2025/10/29	07:36:31.0697	59VSS	DEASSERTED
5	2025/10/28	02:00:40.3497	GENVLOS	ASSERTED
6	2025/10/28	02:00:40.3497	59VSS	ASSERTED
7	2025/10/28	02:00:40.3097	GENVLOS	DEASSERTED
8	2025/10/28	02:00:40.3097	59VSS	DEASSERTED
9	2025/10/28	02:00:40.3047	GENVLOS	ASSERTED
10	2025/10/28	02:00:40.3047	59VSS	ASSERTED
11	2025/10/28	02:00:40.2997	GENVLOS	DEASSERTED
12	2025/10/28	02:00:40.2997	59VSS	DEASSERTED
13	2025/10/28	01:33:14.0447	GENVLOS	ASSERTED
14	2025/10/28	01:33:14.0447	59VSS	ASSERTED
15	2025/10/28	01:33:13.9847	GENVLOS	DEASSERTED
16	2025/10/28	01:33:13.9847	59VSS	DEASSERTED
17	2025/10/28	00:14:21.6897	GENVLOS	ASSERTED
18	2025/10/28	00:14:21.6897	59VSS	ASSERTED
19	2025/10/28	00:14:21.6847	GENVLOS	DEASSERTED
20	2025/10/28	00:14:21.6847	59VSS	DEASSERTED
21	2025/10/28	00:14:21.6797	GENVLOS	ASSERTED
22	2025/10/28	00:14:21.6797	59VSS	ASSERTED
23	2025/10/28	00:14:21.6747	GENVLOS	DEASSERTED
24	2025/10/28	00:14:21.6747	59VSS	DEASSERTED
25	2025/10/27	22:50:56.7247	GENVLOS	ASSERTED
26	2025/10/27	22:50:56.7247	59VSS	ASSERTED
27	2025/10/27	22:50:56.6897	GENVLOS	DEASSERTED
28	2025/10/27	22:50:56.6897	59VSS	DEASSERTED
29	2025/10/24	07:03:41.3747	GENVLOS	ASSERTED
30	2025/10/24	07:03:41.3747	59VSS	ASSERTED
31	2025/10/24	07:03:41.3697	GENVLOS	DEASSERTED
32	2025/10/24	07:03:41.3697	59VSS	DEASSERTED
33	2025/10/23	16:43:27.7947	LOPZ	ASSERTED
34	2025/10/23	16:42:56.6347	59VPS	DEASSERTED
35	2025/10/23	16:42:56.6347	SLOWS	DEASSERTED
36	2025/10/23	16:42:56.3997	25VDIFS	DEASSERTED
37	2025/10/23	16:42:56.3997	GENVLOS	ASSERTED
38	2025/10/23	16:42:56.0847	GENVHIS	DEASSERTED
39	2025/10/23	16:42:56.0847	25VDIFS	ASSERTED
40	2025/10/23	16:42:55.2147	59VPS	ASSERTED
41	2025/10/23	16:42:55.2147	SLOWS	ASSERTED81
42	2025/10/23	16:42:55.0447	59VPS	DEASSERTED
43	2025/10/23	16:42:55.0447	SLOWS	DEASSERTED
44	2025/10/23	16:42:55.0347	25VDIFS	DEASSERTED
45	2025/10/23	16:42:55.0347	GENVHIS	ASSERTED

46	2025/10/23	16:42:55.0347	32P02	Deasserted
47	2025/10/23	16:42:55.0247	SFZBKS	DEASSERTED
48	2025/10/23	16:42:55.0247	SLOWS	ASSERTED
49	2025/10/23	16:42:55.0247	32P03	Deasserted
50	2025/10/23	16:42:55.0197	IN201	DEASSERTED
51	2025/10/23	16:42:54.9862	IN302	DEASSERTED
52	2025/10/23	16:42:51.0997	32P02	Asserted
53	2025/10/23	16:42:50.9397	32P02	Deasserted
54	2025/10/23	16:42:50.5197	32P02	Asserted
55	2025/10/23	16:42:50.4697	32P03	Asserted
56	2025/10/23	16:42:50.2747	32P03	Deasserted
57	2025/10/23	16:42:50.2297	32P02	Deasserted
58	2025/10/23	16:42:49.9597	32P02	Asserted
59	2025/10/23	16:42:49.9497	32P03	Asserted
60	2025/10/23	16:42:49.0047	SFBKS	DEASSERTED
61	2025/10/23	16:42:49.0047	FASTS	DEASSERTED
62	2025/10/23	16:42:49.0047	SFZBKS	ASSERTED
63	2025/10/23	16:42:48.9847	SFZBKS	DEASSERTED
64	2025/10/23	16:42:48.9847	SFBKS	ASSERTED
65	2025/10/23	16:42:48.9847	FASTS	ASSERTED
66	2025/10/23	16:42:48.8647	51V	Deasserted
67	2025/10/23	16:42:48.8597	SFBKS	DEASSERTED
68	2025/10/23	16:42:48.8597	FASTS	DEASSERTED
69	2025/10/23	16:42:48.8597	SFZBKS	ASSERTED
70	2025/10/23	16:42:48.8547	SFZBKS	DEASSERTED
71	2025/10/23	16:42:48.8547	SFBKS	ASSERTED
72	2025/10/23	16:42:48.8547	FASTS	ASSERTED
73	2025/10/23	16:42:48.8397	SLOWS	DEASSERTED
74	2025/10/23	16:42:48.8397	SFZBKS	ASSERTED
75	2025/10/23	16:42:48.8247	46Q12	Deasserted
76	2025/10/23	16:42:48.8247	SFZBKS	DEASSERTED
77	2025/10/23	16:42:48.8247	SLOWS	ASSERTED
78	2025/10/23	16:42:48.8197	46Q12	Asserted
79	2025/10/23	16:42:48.8197	51V	Asserted
80	2025/10/20	07:18:49.2547	SLOWS	DEASSERTED
81	2025/10/20	07:18:49.2547	SFZBKS	ASSERTED
82	2025/10/20	07:18:49.2497	SFZBKS	DEASSERTED
83	2025/10/20	07:18:49.2497	SLOWS	ASSERTED
84	2025/10/20	07:18:49.0947	SFBKS	DEASSERTED
85	2025/10/20	07:18:49.0947	FASTS	DEASSERTED
86	2025/10/20	07:18:49.0947	SFZBKS	ASSERTED
87	2025/10/20	07:18:49.0897	SFZBKS	DEASSERTED
88	2025/10/20	07:18:49.0897	SFBKS	ASSERTED
89	2025/10/20	07:18:49.0897	FASTS	ASSERTED
90	2025/10/04	09:37:43.3247	SLOWS	DEASSERTED
91	2025/10/04	09:37:43.3247	SFZBKS	ASSERTED
92	2025/10/04	09:37:43.3197	SFZBKS	DEASSERTED
93	2025/10/04	09:37:43.3197	SLOWS	ASSERTED
94	2025/10/04	09:37:43.2747	SFBKS	DEASSERTED
95	2025/10/04	09:37:43.2747	FASTS	DEASSERTED
96	2025/10/04	09:37:43.2747	SFZBKS	ASSERTED
97	2025/10/04	09:37:43.2697	SFZBKS	DEASSERTED
98	2025/10/04	09:37:43.2697	SFBKS	ASSERTED
99	2025/10/04	09:37:43.2697	FASTS	ASSERTED
100	2025/10/04	09:37:43.1147	SLOWS	DEASSERTED

GEN SEL700_G

Date: 2025/11/04 Time: 08:40:46.015

TE HUKA 3 PS

Time Source: External

Serial No = 0000000000000000

FID = SEL-700G-R302-V1-Z008004-D20240329

CID = 04E2

#	DATE	TIME	ELEMENT	STATE
1	2025/10/31	11:34:08.508	59VSX	Asserted
2	2025/10/29	11:33:14.248	SV08T	Deasserted
3	2025/10/29	11:33:13.245	IN302	Asserted
4	2025/10/29	07:36:31.109	59VSX	Deasserted
5	2025/10/28	02:00:40.407	59VSX	Asserted
6	2025/10/28	02:00:40.337	59VSX	Deasserted
7	2025/10/28	01:33:14.093	59VSX	Asserted
8	2025/10/28	01:33:14.018	59VSX	Deasserted
9	2025/10/23	17:29:34.485	LT27	Deasserted
10	2025/10/23	17:29:34.485	OUT304	Asserted
11	2025/10/23	16:42:58.044	27PPX1	Asserted
12	2025/10/23	16:42:56.730	59VPX	Deasserted
13	2025/10/23	16:42:56.725	59VPX	Asserted
14	2025/10/23	16:42:56.720	59VPX	Deasserted
15	2025/10/23	16:42:55.990	SV08T	Asserted
16	2025/10/23	16:42:55.060	3PWRX2P	Deasserted
17	2025/10/23	16:42:55.021	IN101	Deasserted
18	2025/10/23	16:42:54.987	IN302	Deasserted
19	2025/10/23	16:42:51.123	3PWRX2P	Asserted
20	2025/10/23	16:42:50.951	3PWRX2P	Deasserted
21	2025/10/23	16:42:50.538	3PWRX2P	Asserted
22	2025/10/23	16:42:50.487	3PWRX3P	Deasserted
23	2025/10/23	16:42:50.291	3PWRX3P	Asserted
24	2025/10/23	16:42:50.246	3PWRX2P	Deasserted
25	2025/10/23	16:42:50.055	OUT303	Asserted
26	2025/10/23	16:42:49.979	3PWRX2P	Asserted
27	2025/10/23	16:42:49.964	3PWRX3P	Deasserted
28	2025/10/23	16:42:49.884	RHSM	Asserted
29	2025/10/23	16:42:49.257	LT27	Asserted
30	2025/10/23	16:42:49.257	OUT304	Deasserted
31	2025/10/23	16:42:48.860	51V	Deasserted
32	2025/10/23	16:42:48.820	51V	Asserted
33	2025/08/19	15:28:23.971	46Q1	Deasserted



www.ghd.com

→ **The Power of Commitment**