

North Island AUFLS event Loss of Huntly Power Station

December 13 2011

Presentation for the SRC
February 2012

TRANSPOWER



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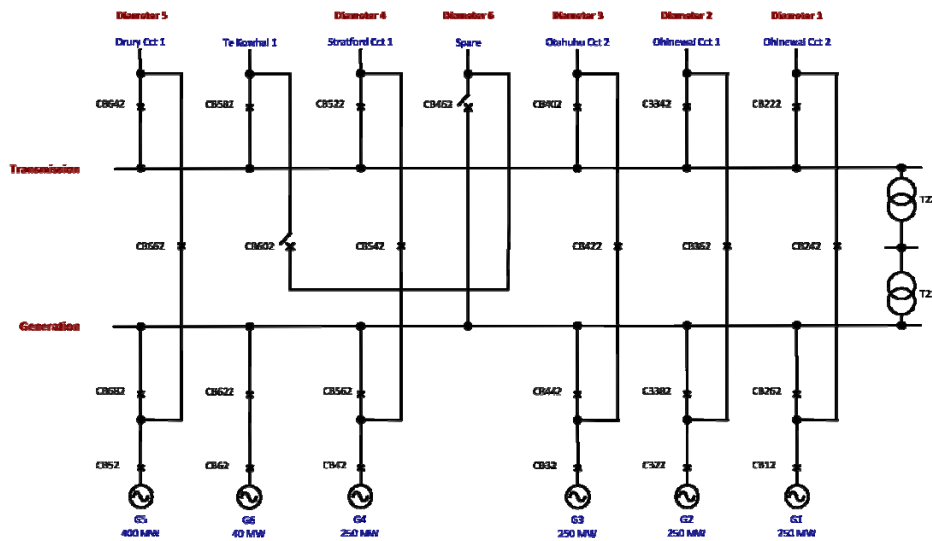
Transpower New Zealand Ltd The National Grid

SRC report

Questions asked

- 1.The cause of the event, including the potential for it to be repeated either at Huntly or other parts of the electricity system (i.e. was the event “one of a kind” or potentially systemic);
- 2.The scale of the event, including the amount of generation disconnected and the resulting impact on the power system (i.e. the timeline of the event, including the change in system frequency over time, when and how interruptible load and reserves were activated, etc.);
- 3.How actual dynamic system performance corresponded with modelled system performance;
- 4.Whether the system performed as expected in a response to an event of this magnitude (we understand that the event was larger than the extended contingent event (ECE) that the system would have been planned to cover);
- 5.The extent of AUFLS activation, including whether the expected level and distribution of load shedding was achieved;
- 6.Whether the process of reconnecting load proceeded in the expected manner;
- 7.How the fault was identified and the measures that were implemented to ensure system security was maintained while this was occurring (including any consideration post-event as to whether this could have been achieved in a more efficient manner); and
- 8.The effectiveness of communication between Transpower and industry participants and the to the wider public.

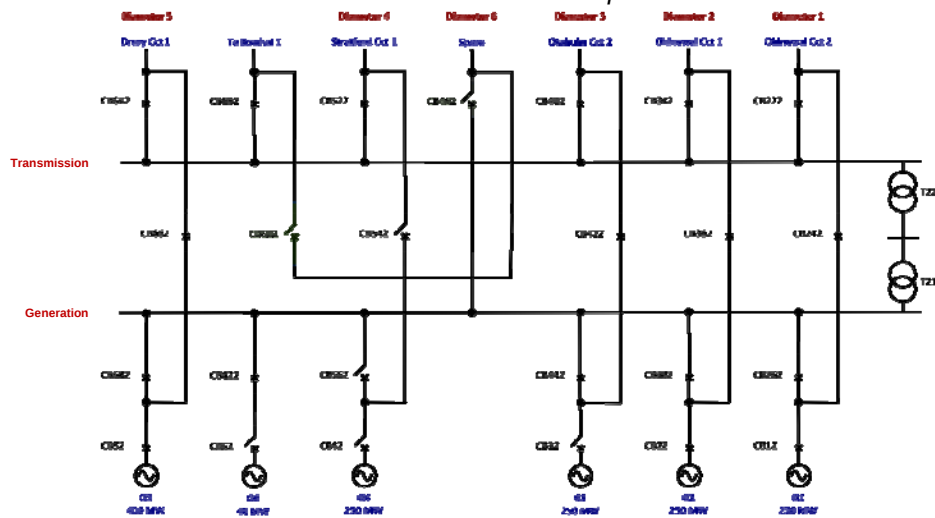
Huntly – normal configuration



CB462 and CB602 are normally open. All other circuit breaker are normally closed when all generating units and transmission lines are in service.

Huntly - operating configuration

13/12/2011 12:11pm



Equipment out of service for maintenance.
Equipment status normally open.
Forcing flag, local status transformer T1 and T2 are not shown near earth switches, disconnector etc.

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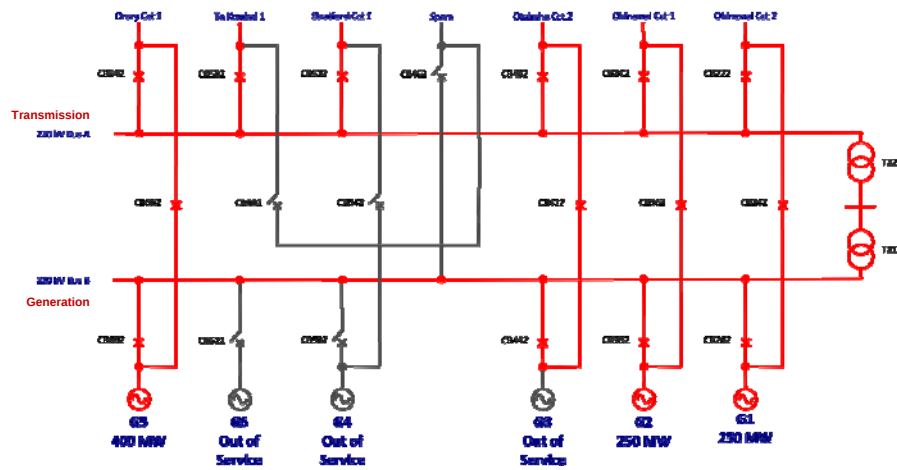
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The Unit 4 diameter was open for Unit 4 maintenance with CB542 and CB562 being open (each diameter comprises two main breakers each connected to a 220kV bus and one half breaker coupling main breakers).

Three generators were in service being Units 1, 2 and 5. Units 3, 4 and 6 were out of service.

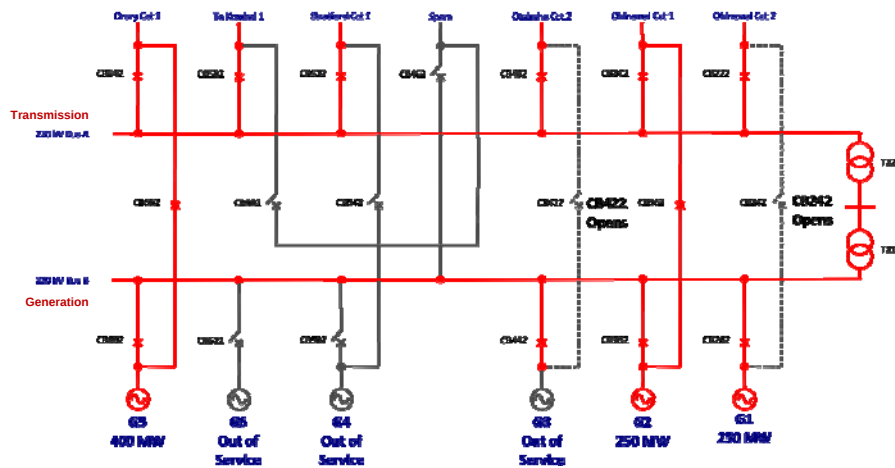
CB462 and CB602 are normally open.

Supply transformers T21 and T22 coupling Bus A and Bus B were both in service.



Transpower trippings (CB242 & 422)

13/12/2011 12:11:39 pm



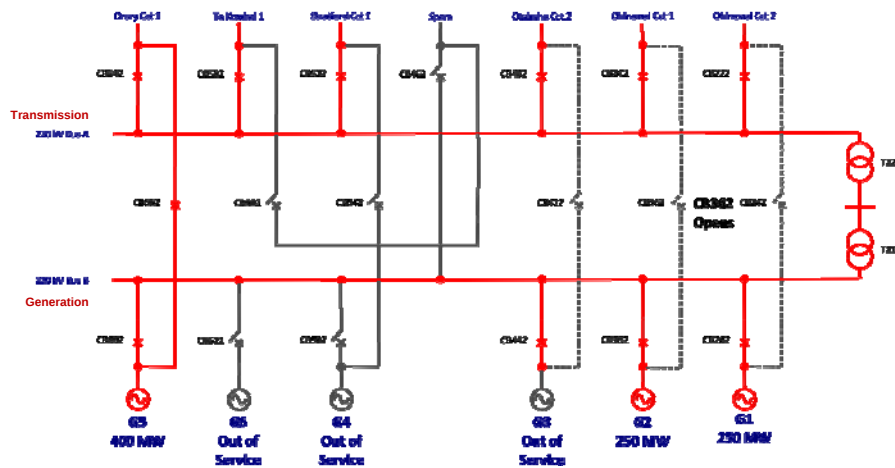
CB422 & CB422 trip

12:11:39.8 pm- Unexpected loss of Diameter 3 (opening CB422)

12:11:39.9 pm - Unexpected loss of Diameter 1 (opening CB242)

Transpower trippings (CB362 trips)

13/12/2011 12:30:44 pm



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CB362 trip

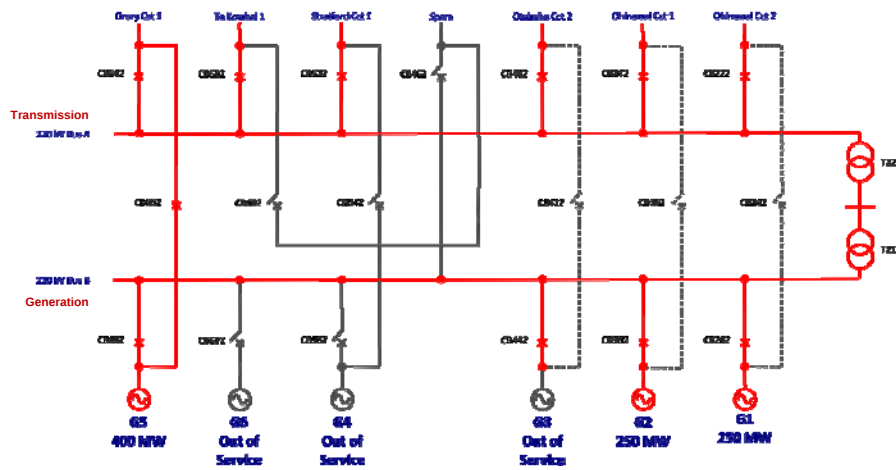
12:30:44.8 pm - Unexpected loss of Diameter 2 (opening CB362)

12:30:47.4 pm - Attempted close on Diameter 1 (CB242) from RCN fails

12:31:25.5 pm - Attempted close on Diameter 3 (CB422) from RCN fails.

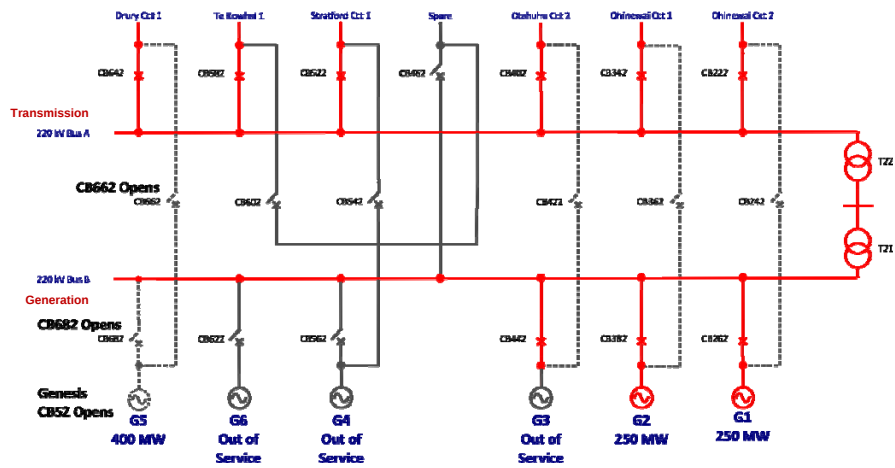
CB closed and opened several times remaining open after about 0.6 seconds.

Configuration immediately prior to generation loss



Generation loss (Unit 5 trip)

12:33:45 pm



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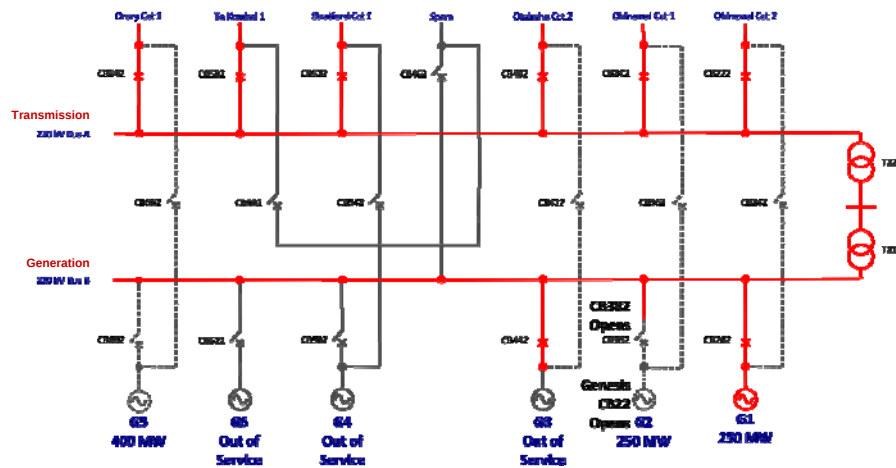
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Unit 5 Trip Event

12:33:44.8 pm - Unexpected loss of Unit 5 and Diameter 5 (opening generator CB52, CB682, CB662)

12:33:48 pm



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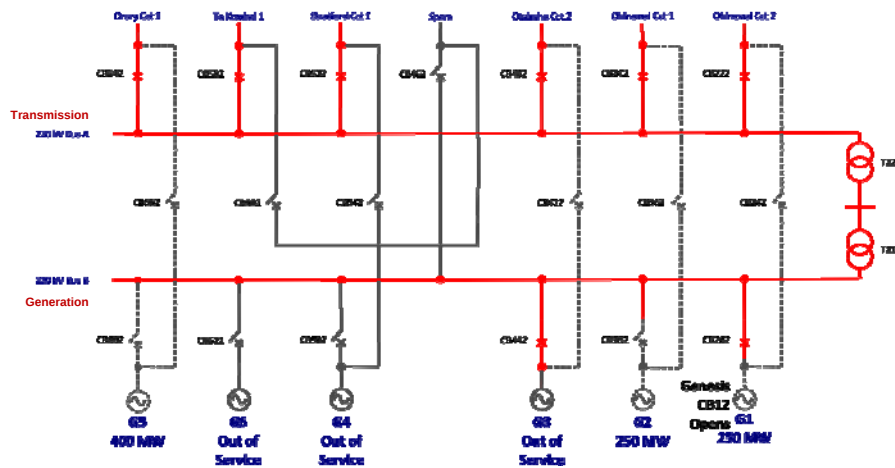
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Unit 2 Trip Event

12:33:47.5 pm - Unit 2 trips from Genesis protection (opening CB382, generator CB22)

Generation loss (Unit 1 Trip)

12:34:08 pm



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Unit 1 Event

12:34:07.5 pm - Unit 1 trips from Genesis protection (opening generator CB12)

Huntly unit 5, 2 and 1 trippings

- With CB422, CB242 and CB362 open, all generating units remained connected to the grid via CB682, CB662 and CB642.
- Transpower assets remaining in service were operating within their capability
- Unit 5 tripping
 - Unit 1 and Unit 2 current (1430 A) combined with that of Unit 5 current (700 A) resulted in the Genesis protection tripping Unit 5 (CB52) on thermal overload.
- Unit 2 and 1 tripping events
 - 0.15 seconds after CB52 tripped, Genesis CB fail protection tripped CB662 and CB682, disconnecting Units 1 and 2 from the grid
 - 2 seconds later Unit 2 tripped
 - 20 seconds later Unit 1 tripped



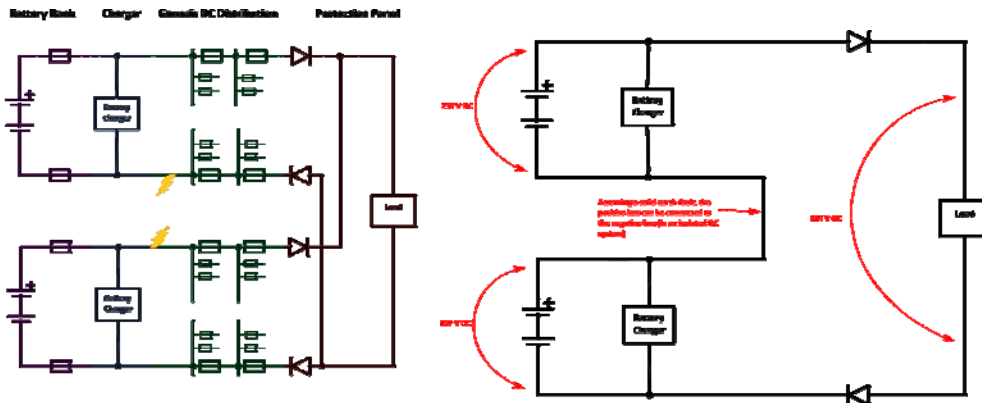
Transpower relays which have the potential to trip CB682 and CB662 are either supplied from a separate 110 V DC supply or not susceptible to the output contact failure associated with the diodes.

It was concluded that the tripping of the CB52, CB662 and CB682 was the result of trip signals from Genesis.

Following Genesis tripping of CB662 and CB682, Units 2 and 1 were unable to supply their pre-event power to the 220kV network (from Bus B to Bus A) due the constraints (throttle) within the only remaining connection between Bus A and Bus B (i.e. via T21 and T22 – 60MVA rating). It is understood that Units 2 and 1 both tripped on overspeed.

Cause of CB242, CB442 & CB362 trips

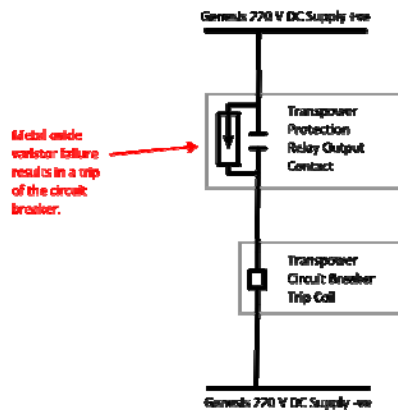
- Trip circuits maloperated due to an over voltage on the CB trip circuits caused by multiple earth faults on the Genesis 220V DC system



The likely over voltage experienced was around twice the Genesis battery charger float voltage of 257 V DC (i.e. 514 V DC). The exact level of the over voltage cannot be determined as it was not directly measured at the point where voltage doubling occurred.

The second earth fault may have occurred during works being undertaken by Genesis' on their emergency lighting system, however, this is difficult to confirm from the limited information available. A similar event on 14/12/11 (i.e. the following day) did occur at the same time as Genesis was undertaken work on the emergency lighting system.

- The over voltage on the 220 VDC trip circuits caused the Transpower protection relay output contact to fail to a low resistance and trip Transpower circuit breakers CB242, CB442 & CB362



The metal oxide varistor (MOV) associated with the output contact is rated for 330 V DC.

When excessive voltage was applied to the metal oxide varistor it became thermally unstable and failed to a short circuit condition (i.e. effectively closing the contact).

The protection relay manufacturer has undertaken tests and has confirmed that for a similar situation the MOV will fail to a short-circuit state.

The over voltage also resulted in damage to transistors internal to the relay.

Actions undertaken to prevent a repeat of the events at Huntly

- The circuitry to Transpower relays which caused the 220V DC over voltage has been modified to ensure this type of fault does not recur.
- An additional diameter at Huntly has been placed into service to increase coupling capability between the transmission system and generation.
- Both Genesis and Transpower have tested equipment which might have been damaged by the over voltage. No additional equipment has been found damaged.
- Transpower understands that Genesis are modifying Unit 5 protection settings



Could steering diode use cause problems elsewhere?

- DC cabling between the battery bank and steering diodes at other Transpower sites is typically short (<50m), indoor and not frequently accessed or modified.
- At Huntly, there are many km of DC cabling which is accessed and modified much more frequently.
- The potential for a similar trip circuit maloperation occurring at sites where Transpower's standard 110V DC supply arrangement is used is significantly lower than that at 220V DC sites.
- 220V DC supplies are only used at three other Transpower sites (Penrose, Mangahao and Wairakei). DC supplies at these sites are under review.
- Additional means for further reducing or totally eliminating the risk of voltage doubling continued to be reviewed.

Similar 220V DC trip circuit maloperation due to DC over voltage requires:

- Simultaneous faults on each battery in the correct locations upstream of the diodes
- Relays which are susceptible to the double voltage
- A 220 V dc supply (this problem does not occur with 110 V DC)

The risk of 110V DC trip circuit maloperation is considered extremely low and has never occurred on a Transpower DC system to the best of Transpower's knowledge. The cabling between the battery bank and steering diodes is typically short, indoor and not frequently accessed or modified.

The risk is sufficiently low such that immediate action isn't considered necessary. Transpower have operated ~50 substations for 30-40 years with steering diodes (i.e. ~6000-odd substation-years of service) without a double earth fault occurring.

The risk is very low in comparison with the Genesis DC system, i.e. there are many of kilometers of cabling increasing exposure with Huntly whereas for Transpower substations the risk area is unchanging, is less than about 50 m and is through circuitry which has been designed very specifically to be robust since it is core to the DC system.

Despite the extremely low risk, Transpower continues to review ways of further reduce risk. One option is the removal of steering diodes in the negative leg for each battery.

Site	Function	Comment
Penrose	CBs 152 & 192 protection	As protection upgrades occur, DC supply is moved to a 110 V DC bank.
Mangahao	33kV CB control bus only	
Wairakei	CBs 122, 132, 152, 172, 182, 192 protection	As protection upgrades occur, DC supply is moved to a 110 V DC bank.

Could a protection co-ordination issue elsewhere cause an AUFLS event?

- Loss of any power station materially larger than 400MW in the North Island or 130 MW in the South Island could cause an AUFLS event
- The event at Huntly was rare and complex
- Transpower sites comply with Electricity Industry Participation Code but we are investigating whether further enhancement is required

The following power stations (listed roughly in order of descending criticality) could have the potential to initiate AUFLS should a latent problem within the generator-grid protection interface exist that could disconnect the entire power station or a significant part of it from the grid (e.g. like Huntly)

- Huntly (1450 MW)
- Manapouri (840 MW) – a single busbar fault would activate AUFLS
- Benmore (540 MW)
- Clyde (432 MW)
- Twizel
- Roxburgh (320 MW)
- Ohau A, B, and C (264, 212, 212 MW)
- Aviemore (220 MW)
- Stratford (585 MW including peakers)
- Tekapo B (160 MW)

Refer to EIPC Part 8 (Common Quality) – Schedule 8.3 (Technical Code A) Section 4 (Requirements for the grid and grid interface).

Transpower are currently reviewing ways to supplement the EIPC requirements. This review commenced in early 2011. The goal is to produce a practical guideline which clarifies and improves the process of co-ordinating protection systems on both sides of the grid interface by clarifying the technical criteria and the review & approval criteria. For example:

- Establishing peer review obligations commensurate with the size of the generation
- Having standard questionnaires which prompt critical review of the designs functionality
- Clarifying the level of co-ordination required between the AO and GO during commissioning and preparation for commissioning