# POWER SYSTEM INCIDENT REPORT

# TRIP OF NO.1 KEILOR TERMINAL STATION 220KV BUSBAR ON 08 OCTOBER 2009

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FINAL

# 1. INTRODUCTION

On the 8th October 2009, the No.3 220kV busbar at Keilor Terminal Station (KTS) was out of service for planned work requiring the B3 220/66 kV transformer to be taken out of service. This left the Keilor 66 kV load supplied through the remaining three 220/66 kV transformers.

At 15:00hrs, the No.1 220kV busbar at KTS tripped which also tripped the B1 220/66kV transformer, reducing the number of transformers connected to the KTS 66kV busbars from three to two. During subsequent switching the loading on one of the remaining transformers increased to the point where its overload protection operated. This resulted in tripping of the transformer and loss of 242 MW of load. Load was gradually restored from 16:17hrs. Restoration of the No.1 KTS 220kV busbar commenced at 17:15hrs.

This report has been prepared under clause 4.8.15 of the National Electricity Rule to assess the adequacy of the provision and response of facilities and services and the appropriateness of actions taken to restore or maintain power system security.

Information for this report has been provided by SP AusNet. Additional information has been obtained from AEMO's Energy Management System and Market Management System.

All references to time in this report refer to Market time (Australian Eastern Standard Time).

# 2. SUMMARY OF EVENTS

Prior to the incident, planned outages were progressing on SP AusNet's network, and the condition of Keilor terminal station was as follows:

The No.3 220kV busbar was out of service for planned work. As a consequence, the B3 220/66kV transformer connecting No.3 busbar to 66kV busbar within the same terminal station was also out of service. The load on the 66kV side of the transformer was consequently being supplied by the B1, B2 and B4 transformers. All 66kV bus section breakers were closed. Figure 1 shows the KTS single line diagram with its 220kV and 66kV connections, including statuses of all relevant circuit breakers (CBs) prior to the incident.

The following events occurred during this incident:

At 15:00:54 hrs, the No.1 220kV busbar at KTS tripped due to the operation of its X busbar protection. This was caused by damaged secondary wiring within the marshalling box of the current transformer (CT) associated with the capacitor bank connected to the No.1 220kV busbar. This resulted in the tripping of all CBs associated with the No1 220kV busbar.

The loss of the B1 transformer due to the tripping of the No. 1 220 kV busbar, reduced the number of transformers supplying the 66kV system from three to two. With all 66 kV bus-tie CBs closed, a network tie was formed across Geelong Terminal Station (GTS), KTS, Sydenham Terminal Station (SYTS) and South Morang Terminal Station (SMTS) via the 66kV busbar system through both the transformers. This caused unequal loading between the B2 and B4 transformers. Figure 2 shows the statuses of relevant CBs immediately following the trip of No.1 220kV busbar and Figure 5 illustrates the loading on B2 and B4 transformers immediately after the tripping.

At 15:09:35 hrs, the B2 transformer with a rating of 185MVA was loaded up to about 222MW. At the same time the loading on the B4 transformer was 99 MW. To avoid automatic load shedding due to the thermal overloading on the B2 transformer, the following tie breakers were opened to split the 66kV system tie:

- No.2 - 3 66kV bustie cb (CB 2B_3B_66 in figures 1 to 4)
- No.1 - 4_EXT bustie cb (CB 1B_4XNB_66 in figures 1 to 4)

These actions did not reduce the B2 transformer loading sufficiently because of the 66 kV sub-transmission loops that were still connected across the Keilor 66 kV buses. Instructions were also issued by the SP AusNet Controllers to Distribution Companies to split these 66kV sub loop ties. These actions were unsuccessful in balancing the loading on the transformers.

Between 15:09 hr and 15:21 hr the loading on the B2 transformer reduced from 222 MW to 197 MW, while the loading on the B4 transformer increased from 99 MW to 133 MW. The loading on the B4 transformer then rapidly increased to 242 MW, while the loading on the B2 transformer reduced to 52 MW due to the opening of the 66kV sub loop ties. The B4 transformer remained at 242 MW for 68 seconds, at which time it tripped on overload protection. This resulted in the loss of 242 MW of load supplied via the No. 4 66kV bus. Figure 3 shows the statuses of relevant CBs immediately following the tripping of B4 transformer. B2 transformer remained on load allowing quick partial load recovery up to the limit of the transformer rating.

At 15:35hrs the market notice 28152 was issued informing the event in Victoria region resulting in a load interruption.

At 16:17:10 hrs, the B3 transformer was returned to service and a 220kV system tie was re-established between GTS and the KTS 500kV busbar via the KTS No.3 220kV busbar (refer Figure 4). This allowed all load to be restored.

At 17:15:07 hrs, the No1 220kV busbar was re-energised and all four transformers were back in service by 18:18:08 hrs.

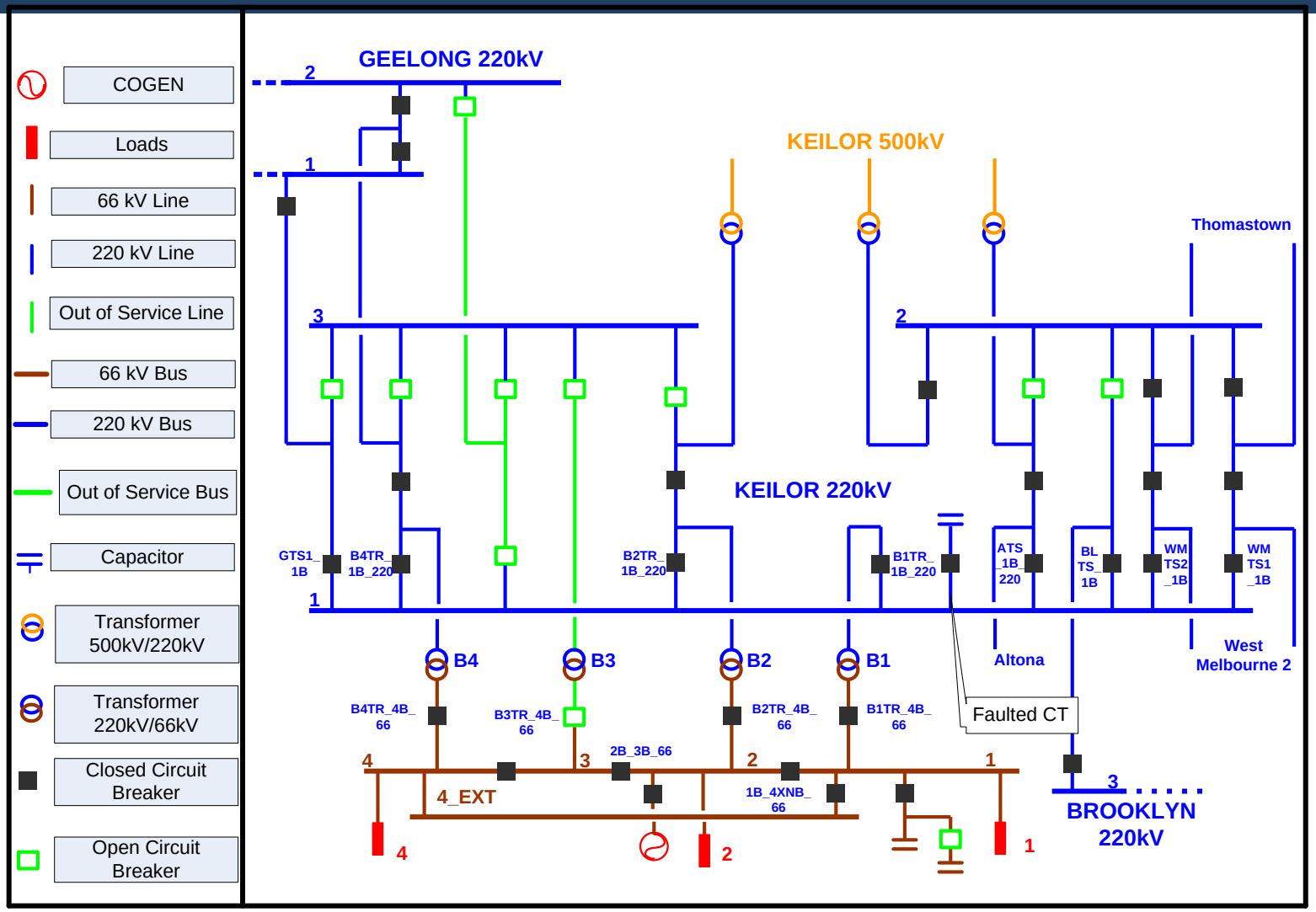


FIGURE 1: PLANNED OUTAGE ON.3 BUSBAR 220KV PRIOR TO OCCURENCE OF EVENT

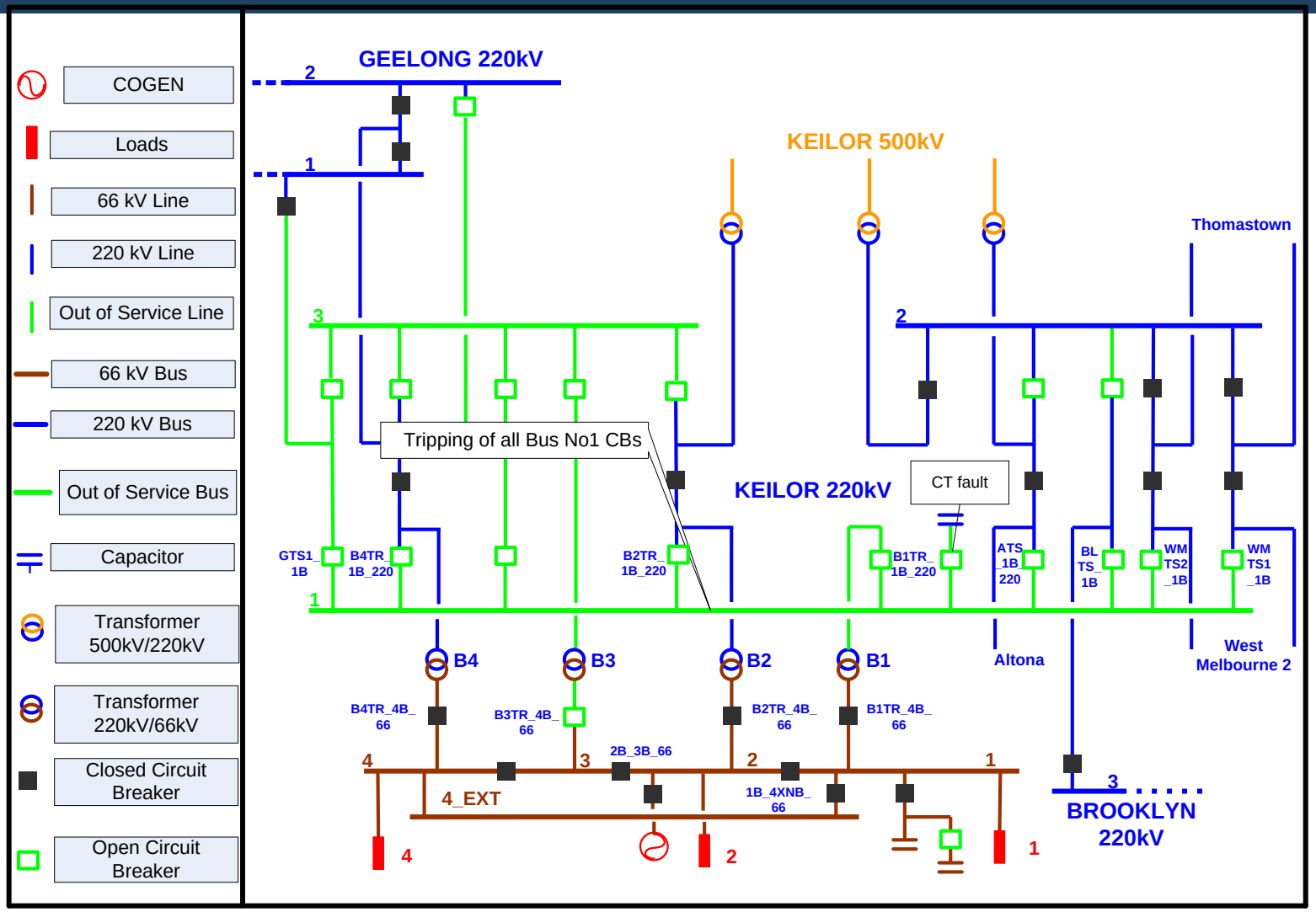


FIGURE 2: TRIPPING OF NO.1 220KV BUSBAR ON KEILOR TERMINAL STATION

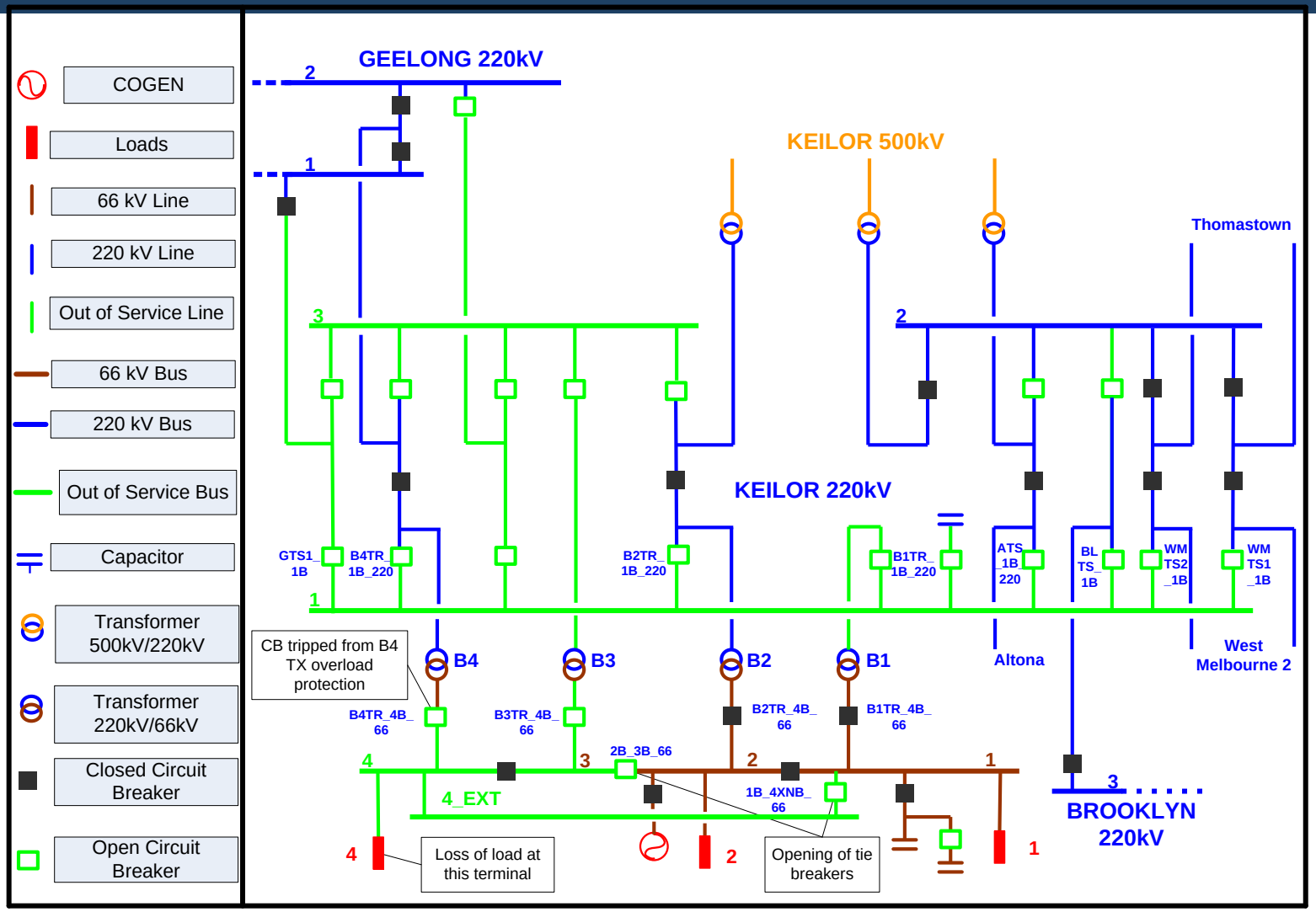


FIGURE 3: CB B4TR_4B_66 TRIPPED FROM B4 TX OVERLOADING

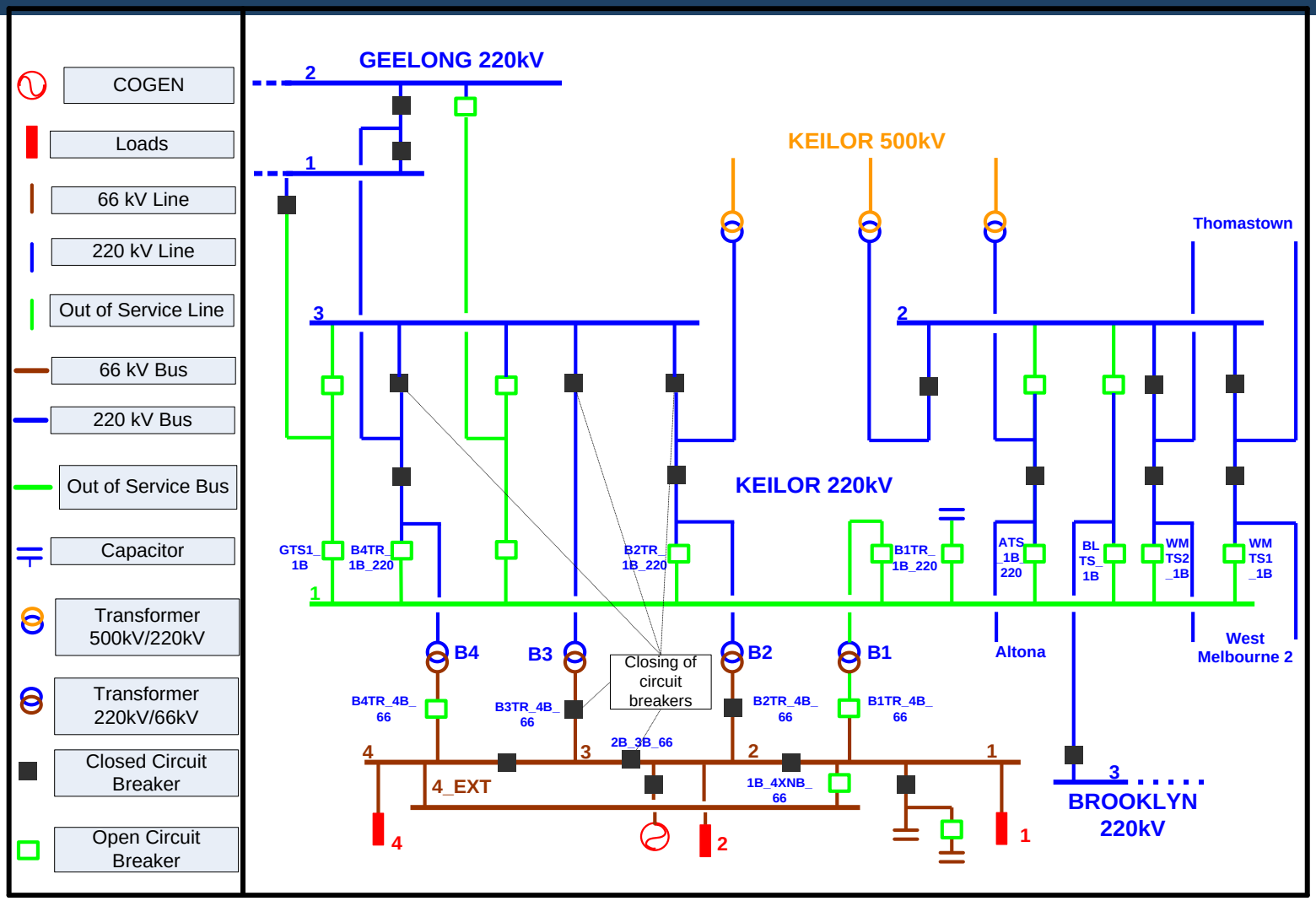


FIGURE 4: RECALLING OF B3 TX AND RESTORATION OF LOAD

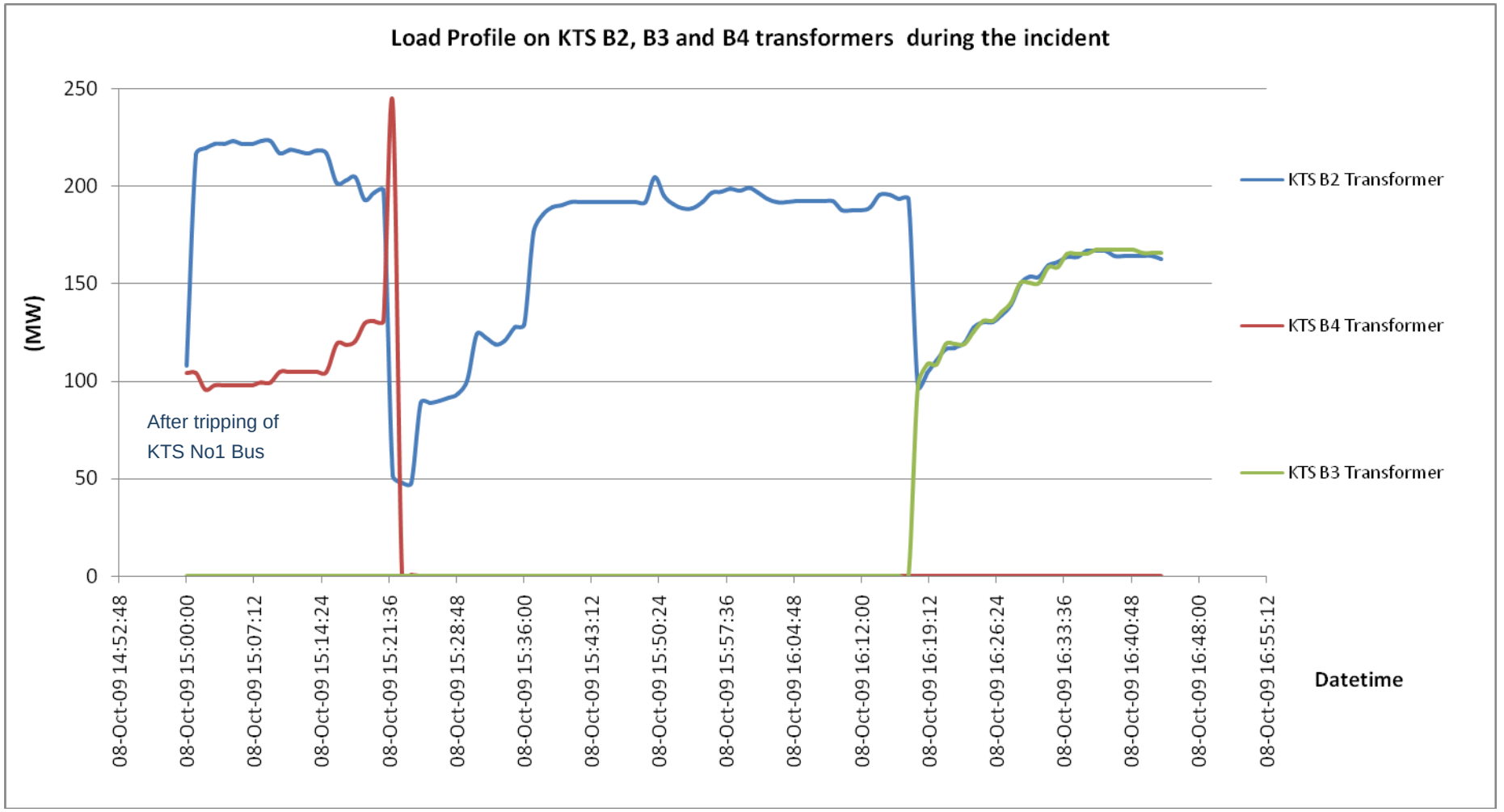


FIGURE 5: LOAD PROFILE OF KTS B2, B3 AND B4 TRANSFORMERS

# 3. ANALYSIS OF EVENTS

Investigation carried out by SP AusNet revealed that arcing had resulted in short circuiting of a CT secondary wiring connection; this was associated with the capacitor bank connected to the No.1 220kV busbar at KTS. The short circuit caused the X protection of the No.1 220kV busbar to operate and trip the busbar.

After the tripping of No.1 220kV busbar at KTS, the 66kV load was supplied by two transformers (B2 and B4) with a combined rating of 370MVA. At this time the combined load on the Keilor 66 kV buses was approximately 320 MW, well below the combined rating of the transformers. However the load was not evenly shared between the B2 and B4 transformers with 222 MW of load on the B2 transformer, compared to its rating of 185 MVA. At the same time the B4 transformer was loaded to 99 MW. Figure 5 shows the loading on the B2 and B4 transformers during this event. The uneven loading occurred because the Keilor 66 kV bustie circuit breakers were all closed, with the transformers effectively forming a network tie between GTS, KTS, SYTS and SMTS.

The Keilor 66 kV bustie circuit breakers 2B_3B_66 and 1B_4XNB_66 were consequently opened at 15:09 hrs, separating the 66kV busbars to remove the parallel between the two transformers. This reduced the load on the B2 transformer to 197 MW, while the B4 transformer loading increased to 133 MW.

However, there were still ties across the Keilor 66 kV buses due to the 66 kV sub-transmission loops. There was a gradual rearrangement of 66kV load after the bus split through the opening of these 66 kV loops, with load on the B2 transformer reducing to 52 MW. During the same period loading on the B4 transformer increased to approximately 242 MW. This resulted in the B4 transformer tripping on overload protection with the consequent loss of 242 MW of load.

It is believed the tripping of the B4 transformer occurred because opening the Keilor 66 kV buses and sub-loop ties resulted in considerable load imbalance between:

- the Keilor No. 1 and 2 buses being supplied by the B2 transformer (242 MW), and
- the Keilor No. 3 and 4 buses being supplied by the B4 transformer (52 MW).

It would have been difficult for the SP AusNet operator to determine this load imbalance until the 66 kV sub-loop ties were opened. The B2 transformer also tripped very quickly after these ties were opened, preventing any operator action to re-balance the loads.

A possible approach to avoid this in future would be to open the 66 kV sub-loop ties before opening the Keilor 66 kV bustie cbs. This would allow the operator to observe the radial load being supplied from each of the Keilor 66 kV buses prior to opening the Keilor bustie cbs. By judicious opening of the 66 kV sub-loop ties and bustie cbs a better sharing of the loading on the B2 and B4 transformers could be achieved.

Load was progressively restored after 16:17hrs, when the B3 transformer was returned to service. The capacitor bank on No.1 220kV busbar at KTS could not be energised until the faulty CT was replaced on 9th October 2009.

## 4. POWER SYSTEM SECURITY

There were no power system security violations during this event. The power system frequency remained within the normal operating frequency band.

## 5. CONCLUSIONS

The trip of the KTS No.1 220kV busbar and B1 transformer at a time when a planned outage was progressing resulted in the eventual trip of the B4 transformer on overload protection, interrupting approximately 242MW of load supplied from KTS. The B4 transformer trip resulted from uneven load sharing between the B2 and B4 transformer following the opening of the Keilor 66 kV bustie cbs and the 66 kV sub-loop connections. The interrupted load was progressively restored commencing from 16:17hrs. AEMO and SP AusNet operation staffs were able to manage this power system incident efficiently.

## 6. RECOMMENDATION

In future, balancing the transformer flows will not be manually performed, as SP AusNet will instead rely on an automated overload protection system to trip load following such an event. Thereafter SP AusNet will explore all possible means in an effective manner to restore load in the shortest possible time.