REPORT ON POWER DISRUPTION ON NORTH-SOUTH AND EAST-WEST LINES (NSEWL) AND CIRCLE LINE (CCL) ON 14 OCTOBER 2020 ("INCIDENT")

1. At 6.58pm on 14 October 2020, a 22kV power outage occurred, which affected train services on the North-South Line (NSL) between Woodlands (WDL) and Jurong East (JUR) stations and on the East-West Line (EWL) between Queenstown (QUE) and Gul Circle (GCL) stations. As a result, 12 trains were stalled on the viaduct sections in-between stations (see Figure 1). In-train lighting and air-conditioning were also affected. The backup battery on the affected trains automatically kicked in to provide emergency lighting as well as mechanical ventilation.

2. To maintain train services on the unaffected sections of the NSEWL, trains were turned around at the following stations:

a) WDL on the NSL towards Orchard station;
b) GCL towards Tuas Link (TLK) station on the EWL; and
c) QUE towards Pasir Ris station on the EWL.

3. Single-line train shuttle services were implemented between Marsiling (MSL) and WDL stations, and between Dover (DVR) and QUE stations.

4. At 7.34pm, a second 22kV power outage occurred, which affected train services on the CCL between Serangoon (CSER) and HarbourFront (CHBF) stations. Three trains were stalled in the tunnels with commuters on board (See Figure 1). Trains were turned around at CSER and Tai Seng stations towards Stadium station to continue service on the unaffected sectors of CCL.

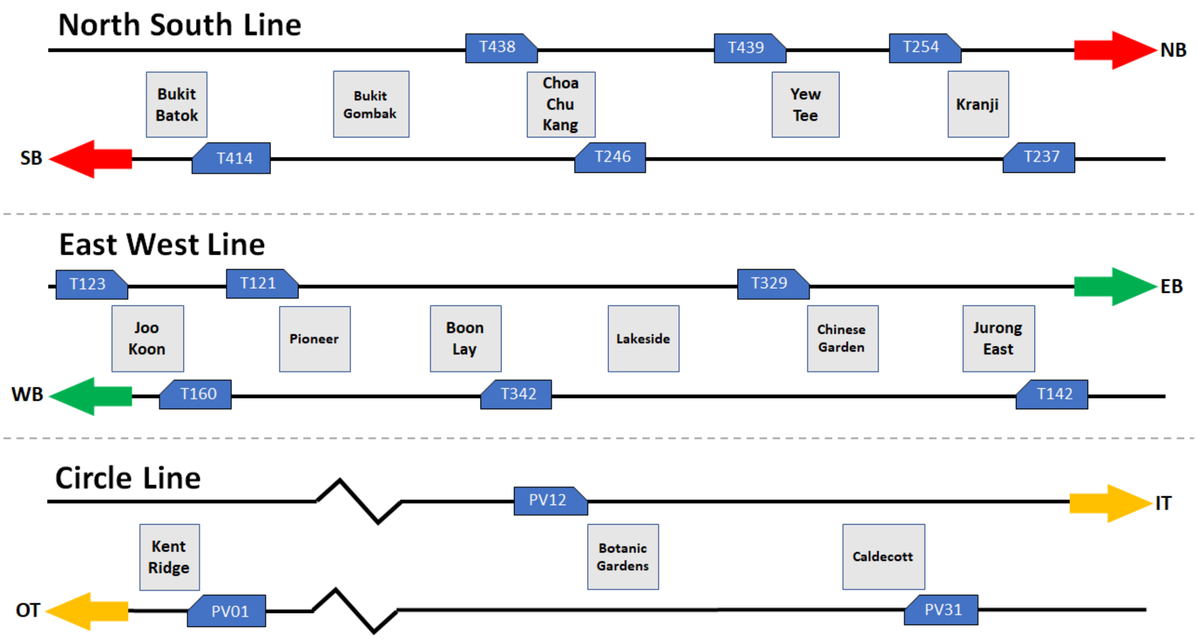


Figure 1: Location of Stalled Trains on NSEWL and CCL (Not to Scale)

Safety of Staff and Commuters During Detrainment

5. When it was assessed that the 22kV power supply for the NSEWL and CCL could not be restored quickly, SMRT initiated the detrainment of the commuters on the stalled trains at the two lines at 7.38pm and 7.46pm, respectively. To protect both SMRT staff and commuters, electrical protection devices were installed to guard against accidental turning on of traction power. SMRT staff walked along the tracks to reach the stalled trains to check on the well-being of the commuters on board and assisted and guided commuters to the nearest station. The commencement of train-to-track detrainment of the commuters from the 12 stalled trains started on the NSEWL at 7.53pm, and for the three stalled trains on the CCL at 7.59pm. Commuters from the three CCL trains which had stalled close to the stations arrived safely at the nearest station platforms by 8.17pm. Commuters from the 11 NSEWL trains also arrived safely at their nearest station platforms by 8.42pm.

Power Restoration for CCL

6. The 22kV power supply was restored for CCL at 8.00pm. As train-to-track detrainment of commuters from the three stalled trains had already commenced, restoring traction power to the detrainment sectors was held back for safety reasons. Train service along CCL was progressively resumed from 8.43pm upon completion of safety checks. These safety checks can only be carried out after the commuters had arrived safely at the nearest station platforms.

Power Restoration for NSEWL

7. Meanwhile, the 22kV power supply was restored for NSEWL once the faulty cables were isolated. As train-to-track detrainment had commenced, traction power to the detrainment sectors was not restored.

8. Due to inclement weather and lightning risk, the detrainment of the last NSEWL train on the viaduct near Bukit Batok (BBT) station was halted temporarily at 8.44pm for safety reasons. About 78 commuters remained on-board until traction power was restored at that BBT sector, and the train was then brought to BBT for the commuters to alight directly onto the platform at 9.43pm. Traction power for NSEWL was restored at 9.54pm, and train service progressively resumed along NSEWL thereafter.

9. The incident lasted 216 minutes (3 hours 36 minutes) from 6.58pm to 10.34pm on NSEWL affecting about 110,000 commuters, and 69 minutes (1 hour 9 minutes) from 7.34pm to 8.43pm on CCL affecting about 13,000 commuters. Of these, about 6,500 commuters were on the stalled NSEWL trains and 275 of them on the CCL trains.

10. Regular public announcements on service disruption were made to all stations and trains throughout the network. Information related to the incidents were also provided to commuters via the various signages in the stations, SMRT Connect App and Twitter messages. There was feedback that more updates on the progress of the arrangement leading to the train-to-track detrainment can be made available for better awareness and preparedness.

11. Free boarding of regular bus services was provided immediately at the affected MRT stations, with an additional 120 bridging buses mobilised to ply along the affected stretches. There were periods of crowd congestion at the bus points of the affected stations initially and later at the stations where trains turned around.

DESIGN OF POWER SUPPLY SYSTEM

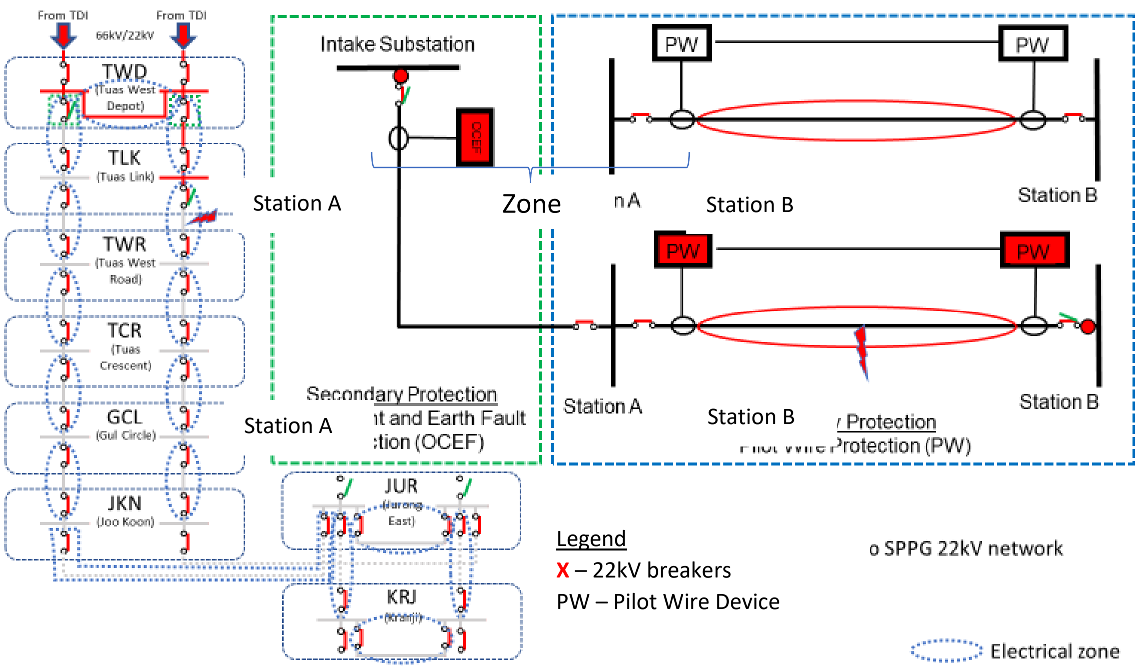


Figure 2: Typical 22kV Protection Scheme

12. The Rapid Transit System (RTS) 22kV network is designed to operate in a ring configuration as in Singapore Power Grid's (SPPG) 22kV network design. Figure 2 shows the

typical protection scheme for the RTS 22kV network. An electrical zone comprises a set of 22kV cables between stations which incorporates its own primary protection through the use of Pilot Wire (PW) protection devices. The primary protection essentially checks that the current flowing into the zone is equal to the current flowing out of the zone. In the event of an abnormal current flow (i.e. a fault), the primary protection will detect it and trigger the operation of the 22kV breakers, thereby effectively isolating the fault within the zone. With the fault isolated, the 22kV network ring configuration design will allow train service to continue.

13. The electrical zone between the two stations comprises 3-phase 22kV cables laid out physically on two layers of brackets (See Figure 3). Collectively, these two sets of cables are designed to carry the full current required for train operations.

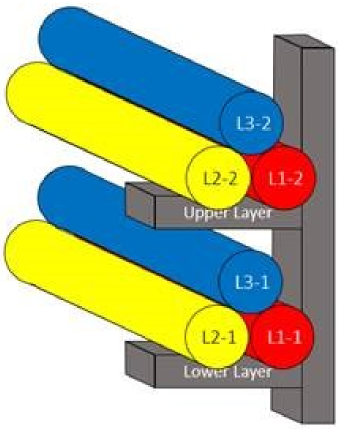


Figure 3: 3-Phase 22kV Cables Laid Out Physically on Two Layers

14. In the event the primary protection fails to operate, the RTS 22kV network has a secondary protection scheme designed to trigger the electrical isolation of a larger sector (i.e. several electrical zones) to ensure personnel safety and equipment protection.

15. Power to the RTS 22kV network is supplied from the 66kV network. Several 66kV electrical intake sub-stations are located strategically across the RTS 22kV network to provide alternative power supply in the event of a 66kV intake failure. When needed, the affected power sector can be switched to draw power from an alternative electrical intake sub-station. This is implemented through a set of breakers known as the "Division of Power Point (DPP)", strategically located on the RTS 22kV network.

CAUSE OF POWER FAILURE

16. A set of faulty 22kV cables between TLK and Tuas West Road (TWR) stations activated the primary protection, which is designed to trip open and "lock-out[1]" the 22kV breakers at TLK (breaker HL304) and TWR (breaker HL303). (See Figure 4). However, the 22kV breaker at TWR (breaker HL303) failed. This activated the secondary protection which tripped open and "locked-out" a 22kV breaker at Tuas West Depot (TWD) (breaker HL302).

[1] A lock-out requires an on-site manual reset and cannot be done remotely from the Operations Control Centre.

This cut off the 22kV power supply from the Tuas Depot Intake (TDI) substation affecting the NSEWL from TWR to JUR and JUR to KRJ.

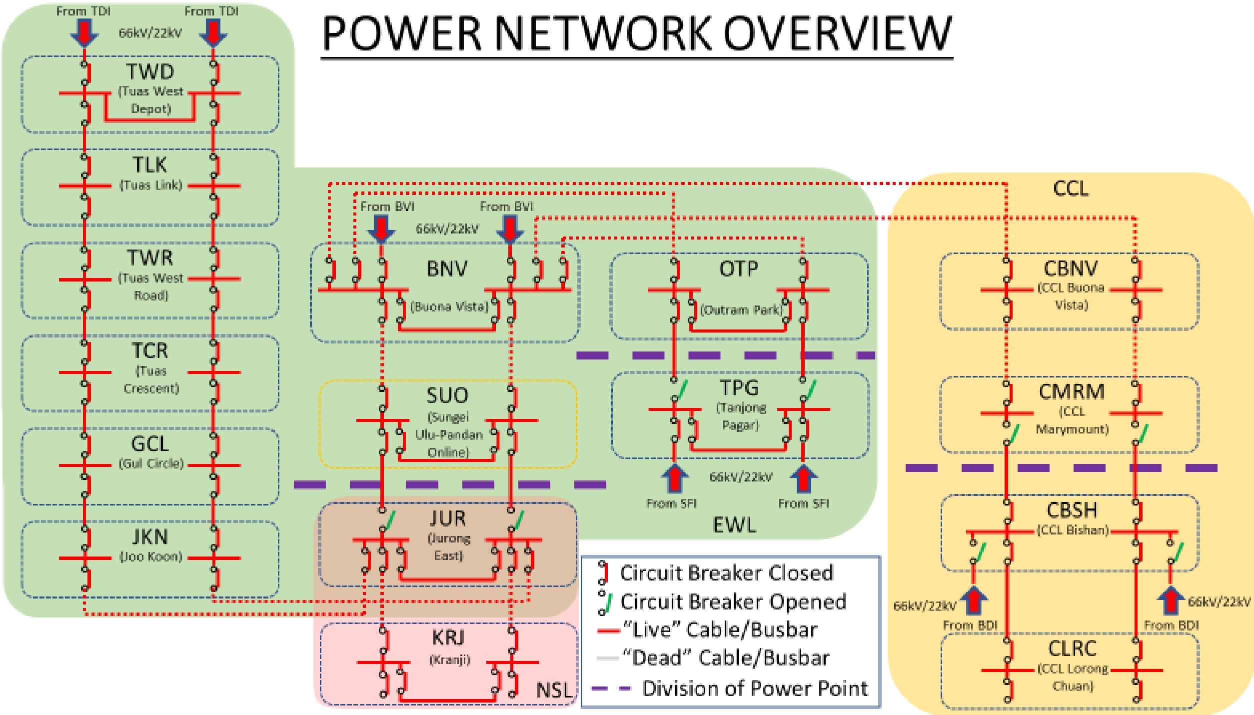
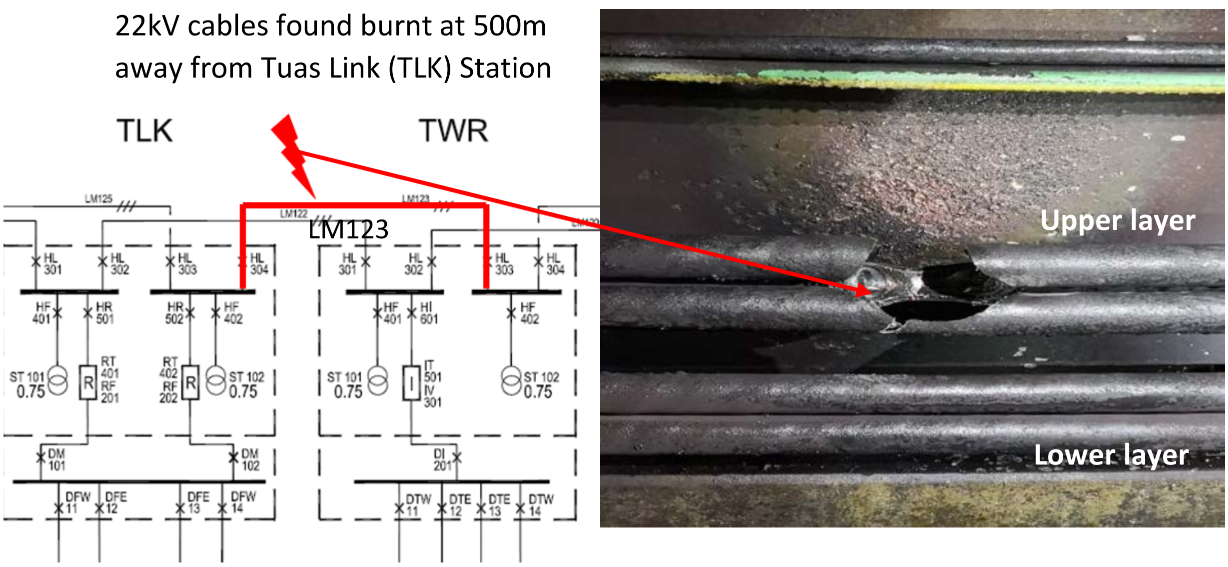
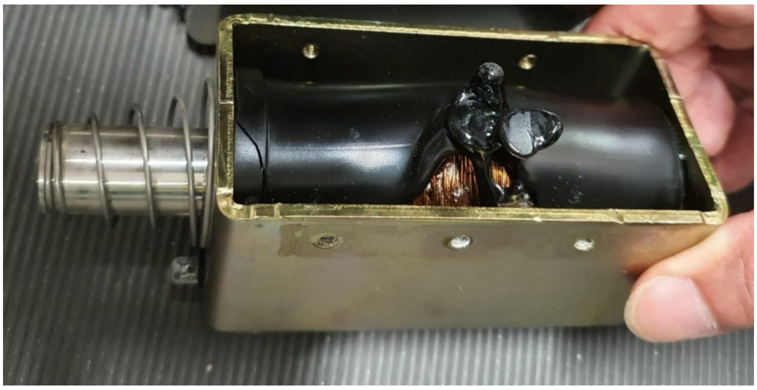


Figure 4: Schematic Power Diagram of Affected Areas on 14 Oct

17. Site investigations conducted during engineering hours found that the 22kV cables on the upper layer were burnt through (refer to Picture 1). Measurements carried out indicated that there were short circuits between the three 22kV cables on the upper layer that led to high fault current burning through the cables at the fault location. This occurred at about 500m from TLK. A trip coil in the 22kV breaker at TWR (breaker HL303) was also found to have melted (refer to Picture 2). As a result, the TWR 22 kV breaker (breaker HL303) failed to operate and to isolate the faulty cables.



Picture 1: Burnt 22kV Cables



Picture 2: Melted 22kV Breaker Trip Coil

POWER RECOVERY PROCESS

18. Based on the design of the RTS 22kV network, Figures 5A and 5B illustrate the power recovery options for the restoration of the power to NSEWL.

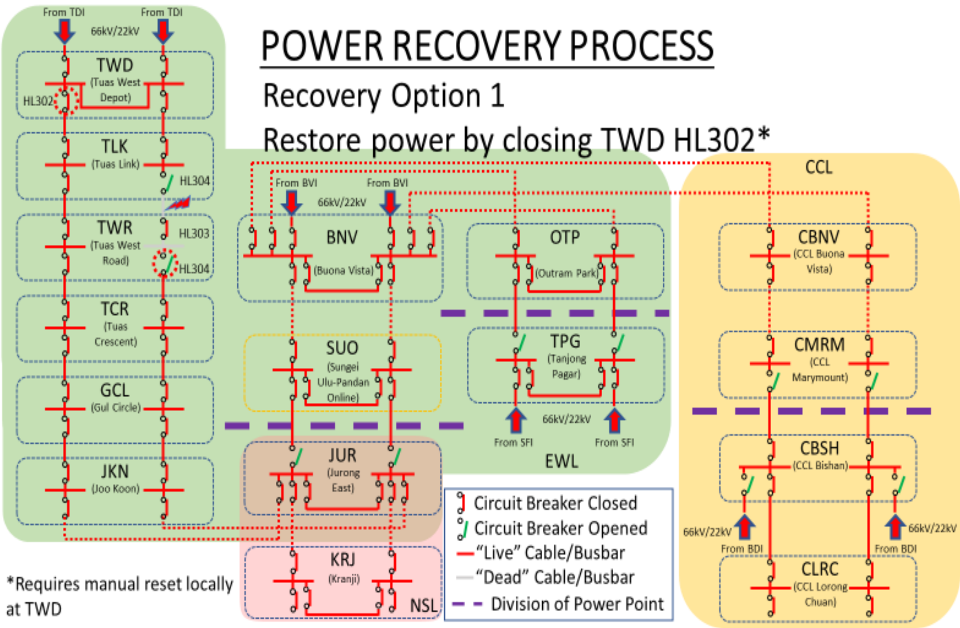
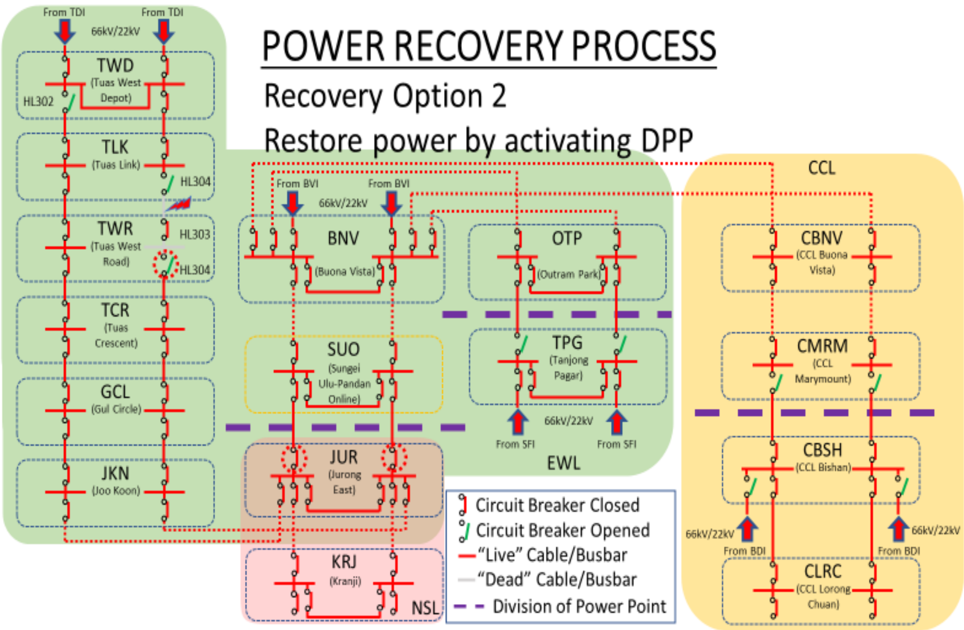


Figure 5A: Power Recovery Option 1

Recovery Option 1

- Once the cable fault location is identified, recovery could be initiated by remotely opening TWR (breaker HL304) from the OCC to isolate the faulty cables.
- The lock-out of the TWD (breaker HL302) requires on-site manual closure to restore 22kV power supply to all affected stations.
- The on-site manual closure requires SMRT to dispatch a team to TWD from the maintenance base (e.g. at JUR).



Recovery Option 2

- Once the cable fault location is identified, recovery could be initiated by remotely opening TWR (breaker HL304) to isolate the faulty cables.
- With the TWD (breaker HL302) still open, the power supply from the alternative intake could then be triggered (from OCC) through the remote activation of the DPP at JUR (i.e. JUR (breaker HL303) and JUR (breaker HL306)).

Figure 5B: Power Recovery Option 2

19. Based on the investigation findings, SMRT initially tried to reset the breaker at TWD (breaker HL302) in line with Recovery Option 1 to restore power from TDI. However, this did not work as the cable fault between TLK and TWR was not isolated. SMRT then decided to activate the DPP operation (Recovery Option 2) to draw power from the alternate intake sub-station located at Buona Vista (BVI). This action caused a voltage dip at BVI.

20. The protection devices at BVI were activated in response to a voltage dip. As BVI also serves the CCL, this caused the CCL power outage. If the faulty cables had been isolated, the CCL outage could have been avoided and power restored to the affected TWE stations.

21. SMRT managed to restore 22kV power supply to the affected section of the CCL by 8.00pm by drawing power from the Bishan Depot Intake (BDI). Meanwhile, SMRT isolated the electrical zone with the faulty cable at Tuas West Road station, and restored power to the NSEWL.

IMMEDIATE RECOVERY MEASURES TAKEN

22. Rectification works on the faulty cables between TLK and TWR were carried out and completed over two nights (16 and 17 October 2020). The trip coil for the 22kV breaker at TWR (breaker HL303) was immediately replaced and tested during the engineering hours of the incident night.

23. As a precautionary measure, SMRT combed through all the Tuas West Extension (TWE) stations to ensure all the trip coils were functional. Two additional trip coils were found at TWD that exhibited inconsistent performance that could result in a similar failure. Alstom Transport (S) Pte Ltd (Alstom) is the main contractor for TWE's power system. Alstom is carrying out further forensic examination on the faulty trip coils of the 22kV breaker at TWR (breaker HL303).

CABLE FAULTS ON TUAS EXTENSION

24. The Tuas West Extension commenced operations in May 2017. No cable fault was experienced in 2017, two cable faults occurred in 2018, and none in 2019. After the first two instances in 2018, the main power system contractor Alstom had implemented close monitoring for the 22kV cables, including condition monitoring for the affected electrical zones. In January 2020 and June 2020, two further cable faults occurred (Picture 3), Alstom then expanded condition monitoring system for all the 22kV cables along the entire TWE. In all of these four instances of cable faults (located at different stretch of TWE), train services were not affected as the primary protection operated to isolate the faulty cables. After the June 2020 cable fault, Alstom agreed to replace all the upper layer 22kV cables with higher specification cables and provided an extended warranty of 20 years for the lower layer cables, with the commitment that these would also be replaced if the monitoring showed deterioration. This 18-month replacement work was scheduled to start in October 2020.

Jul 2018 (GUL – JKN) | Oct 2018 (TWR - TCR) | Jan 2020 (TWR – TCR) | Jun 2020 (GUL – JKN)

Picture 3: 22kV Cable Faults in 2018 and 2020

25. Following the 14 Oct 2020 incident, Alstom has acceded to LTA's further request to extend the cable replacement to include the lower layer, while they carry out fault investigation with their cable supplier into the cause of the 22kV cable failure. Approximately 150km of 22kV cables will be replaced. As replacement for the lower layer of cables will take time to arrive, LTA will schedule Early Closures/Late Openings on weekends or Full Sunday Closures for limited periods in 2021 to facilitate the cable physical replacement works.

22kV BREAKER TRIP COIL FAILURE

26. Prior to the 14 Oct 2020 incident, this failure mode of the 22kV breaker trip coil had not been encountered at TWE. Alstom has sent the faulty 22kV breaker trip coils at TWR (breaker HL303) and TWD for forensic examinations.

27. While the cable replacement is in progress, to provide assurance, Alstom will be replacing all TWE 22kV breaker trip coils[2]. LTA will implement weekend Early Closures from November 2020 to accelerate the trip coil replacement works and completed by end 2020.

28. Following this incident, SMRT will increase the frequency of checks from every 12 months to every six months to ensure good function health of trip coils and 22kV breakers.

[2] There is a total of 113 22kV breakers with trip coils in TWE.

SUMMARY

29. The incident was the result of the concurrent occurrence of a cable fault and failure of the primary protection to isolate the fault due to a faulty 22kV breaker trip coil at TWR (breaker HL303). This activated the secondary protection at the 22kV breaker at TWD (breaker HL302) which then disrupted the 22kV power supply on the NSEWL from TWR to JUR and JUR to KRJ.

30. An attempt to restore 22kV power supply to the NSEWL from the BVI substation failed because it was done without first isolating the cable fault between TLK and TWR. This extended the 22kV power supply disruption to the affected stretch on the CCL. When it was assessed that the 22kV power supply for the NSEWL and CCL could not be restored quickly, detrainment was executed as per Standard Operating Procedures (SOP).

31. Alstom has agreed to replace all TWE 22kV cables by end-2021. While the cable replacement is in progress, to provide assurance, Alstom will replace all TWE 22kV breaker trip coils by end-2020.

32. SMRT will review their power recovery SOP. In the interim period, whilst the cables are being replaced, SMRT will increase their monitoring of the functional health of the trip coils and conduct more frequent functional tests of their 22kV breakers.

33. SMRT will continue to improve its communication with the commuters in the event of stalled trains, and arrange for the Train Captains or OCC to provide commuters in the stalled trains with more information on the progress status leading up to the detrainment.