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中華電力有限公司
CLP Power Hong Kong Limited

26 August 2022

Investigation Report on CLP Cable Bridge Fire Incident on 21 June 2022

CLP Power Hong Kong Limited (CLP Power) today (26 August) made public the investigation report on the cable bridge fire incident in Yuen Long which occurred on 21 June 2022. According to the comprehensive investigation and analysis, it is highly possible that a fluorescent light installed below the cross beam within a section approximately four metres from the junction between the steel bridge and the concrete chamber at Kwong Yip Street caught fire and ignited the nearest pilot cable below, with the fire spreading to the adjacent pilot and power cables.

CLP Power is committed to providing customers with a highly reliable power supply. This cable bridge fire incident was extremely rare and affected the power supply to Yuen Long, Tin Shui Wai and part of Tuen Mun concurrently. CLP Power is deeply concerned about the incident and immediately set up an investigation panel comprising experts in power, civil, and fire engineering to find out what triggered the fire and make recommendations.

In the past weeks, CLP Power has been cooperating with relevant Government departments in their investigations, including having a joint inspection on 26 June with them to collect evidence and following up on the incident in accordance with the Electricity Ordinance. A preliminary report and a further report were submitted to the Government 3 days and 14 days after the incident respectively. The Investigation Panel submitted a final report to the Electrical and Mechanical Services Department on 22 August 2022, and the Government agrees in principle with the cause of fire and improvement proposals in the report.

CLP Power Managing Director Mr T K Chiang said, "CLP Power attaches great importance to all the recommendations put forward in the report. They will be followed through earnestly and thoroughly to prevent a recurrence of similar incidents in future and ensure a safe and reliable electricity supply. We would also like to thank relevant Government departments and community leaders for their assistance and valuable advice, as well as technical teams and contractors for their tremendous efforts."

"We appreciate the serious inconvenience caused to many citizens during the evening peak hours on a hot summer night and the disappointment it meant for our customers. We would like to sincerely apologise to the affected citizens and customers. We believe that there are important lessons we can learn for the future."

<u>The Incident</u>

At around 7:10pm on 21 June 2022, a CLP Power cable bridge spanning the nullah between Wang Lok Street and Kwong Yip Street in Yuen Long caught fire, affecting power supply to around 175,000 customers in Yuen Long, Tin Shui Wai and part of Tuen Mun. After tremendous efforts by our engineering staff in re-arranging emergency supply, CLP Power restored the power supply to some 90% of the affected customers around 7 hours after the incident, and the remaining 20,000 customers were notified that their supply was restored at around 8:00am on the next morning after the incident.

After the cable bridge caught fire, all cables inside the bridge were damaged. The engineering teams worked around the clock and made every effort to carry out new cable laying work. The 3 sets of 132kV high-voltage replacement cables were laid and energised within a week, fully restoring the power supply reliability of the grid in the affected districts. The damaged bridge was dismantled and removed.

<u>Cause of the Fire</u>

The intense fire which caused the bridge to collapse and seriously damaged the equipment inside the bridge made it very challenging to find out the actual cause of the fire.

According to laboratory test results and analyses conducted by the investigation panel, it has been confirmed that the fire was not caused by foul play. Neither power loading, the electrical protection system, hot weather nor high-voltage cables was a cause.

The fire expert considered that this fire incident was extremely rare. It is highly possible that a fluorescent light installed below the cross beam within a section approximately four metres from the junction between the steel bridge and the concrete chamber at Kwong Yip Street caught fire and ignited the nearest pilot cable below, with the fire spreading to the adjacent pilot and power cables. The fire then continued to spread from the Kwong Yip Street end to the Wang Lok Street end.

Power Grid Design and Power Restoration Challenge

According to the planning and design of the power grid, there are 3 sources supplying power to Yuen Long and Tin Shui Wai. They include the main source in the cable bridge and two other backup sources. As one of the backup sources had earlier been damaged, CLP Power had to make full use of the remaining backup source to supply power to affected customers.

The supply restoration process was full of challenges. Since the fire also damaged the communication cables inside the cable bridge, this affected the ability of System Control Centre to monitor the real-time status of the power systems in the affected area, making it difficult to immediately arrange other backup supplies through remote control. CLP Power urgently deployed 150 technical staff to different locations in the affected area to conduct load assessment and manual switching to facilitate the step-by-step re-arrangement of power supply to ensure that the backup supply was safe and reliable. In the process, priority was given to restoring essential services, including hospitals and railways.

Design of the Cable Bridge

The cable bridge located at Wang Lok Street in Yuen Long was commissioned in 1992. Its design complied with the relevant statutory requirements. It was constructed to support the development of Yuen Long and increase in electricity demand. Regular inspections and maintenance have been conducted after its commission. All the power and communication cables in the bridge operated normally before the fire broke out.

Risk Reduction Measures

To alleviate public concerns, CLP Power inspected the condition and equipment of 4 other cable bridges immediately and has completed a series of additional risk reduction measures to enhance the fire protection measures in these cable bridges. These measures include painting the cables with an appropriate fire-retardant coating, installation of heat detection systems and a wet-type fire suppression system, and replacing all fluorescent lights in the cable bridges.

The final report has recommended improvement measures in five areas, including management of low voltage installations, further enhancement of fire safety and security measures, emergency preparedness and communication, data communication enhancements within the power system and facility management. CLP Power will diligently follow through the recommendations made by the Panel.

1) **Management of low voltage installations**: Review the lifespan and maintenance of low voltage installations in common cable route infrastructure and establish an appropriate refurbishment / replacement programme.

2) **Further enhancement of fire safety and security measures**: Review the risk and reliability of the current high-voltage transmission circuits running through common cable route infrastructure, as well as the effectiveness and feasibility of the measures concerning security, fire protection and cable diversion. A fire hazard hunt on CLP operational facilities using a risk / probability matrix is also recommended.

3) **Emergency preparedness and communication**: Review emergency preparedness of key facilities coupled with joint exercises with the emergency services departments, and review the supply restoration process and stakeholders' communication for major supply interruptions.

4) **Data communication enhancements within the power system**: Increase redundancy in communication cables along different routes to enhance the reliability of our remote-control capability.

5) **Facility management**: Good housekeeping with a focus on ensuring that excess materials used on site are stored properly.

<u>Appreciation Vouchers</u>

To show care and express gratitude for the affected customers' understanding, CLP Power will allocate HK$20 million to offer each affected residential customer Appreciation Vouchers worth HK$100 that can be used at the around 600 participating merchants in the three districts. The initiative also aims to boost economic activities in Yuen Long, Tin Shui Wai and Tuen Mun, bringing benefits to local businesses. The vouchers will be dispatched from mid-September.

The detailed findings of the investigation are set out in the annex.

<u>About CLP Power Hong Kong Limited</u>

CLP Power Hong Kong Limited ("CLP Power") is the Hong Kong utility subsidiary wholly owned by CLP Holdings Limited, a company listed on the Hong Kong Stock Exchange and one of the largest investor-owned power businesses in Asia. CLP Power operates a vertically integrated electricity supply business in Hong Kong, and provides a highly reliable supply of electricity and excellent customer services to more than six million people in its supply area.

- Ends -

Annex

CLP Cable Bridge Fire Incident

on 21st June 2022

INCIDENT INVESTIGATION PANEL REPORT

Submitted by:

Mr. Paul Poon
Vice Chancellor – CLP Power Academy

Investigation Panel Chairman

Date: 22nd August 2022

This report has been translated into Chinese. The Chinese version is for reference only. If there is any conflict or inconsistency between the English version and the Chinese version, the English version shall prevail.

Executive Summary

Background

On 21st June 2022, a CLP cable bridge located near The Spectra, Wang Lok Street in Yuen Long caught fire. The bridge, which includes an A and a B cable compartment, spans a drainage nullah that is between Wang Lok Street and Kwong Yip Street. The observed evidence suggests that fire was most intense at the Kwong Yip Street end in Compartment A (see Attachment 1).

The bridge concerned was designed by a reputable engineering consultant using international standards and in accordance with local building codes (see Attachment 4), and the design was submitted for approval by relevant Government departments and an Occupation Permit (NT 58/92) was issued. The bridge was commissioned in 1992.

The bridge consists of two concrete Chambers, one at each end of the bridge, which support a shallow arch steel structure that spans across the nullah.

On the day of the incident there were no known operational or fault incidents in the concerned area, and all the cables were operating well below their design load limit. No person was injured and no property other than the bridge and cables/equipment inside was damaged.

During the joint site inspection on 26th June 2022, and subsequent discussions with the Police, Fire Services Department (FSD), the Government Laboratory and Electrical and Mechanical Services Department (EMSD), it was agreed that there were no obvious signs that the fire resulted from foul play.

Smoke was first seen coming from the Kwong Yip Street end of the bridge at around 18:30 hours. Shortly after 19:00 hours, the fire had spread along the length of the bridge.

Three 132kV high-voltage circuits and eight 11kV high-voltage circuits, as well as a number of communication cables installed in the cable bridge were damaged as a result of the fire and the loss of these cables affected the power supply to around 175,000 customers in Yuen Long, Tin Shui Wai and part of Tuen Mun. The damaged communication cables also caused the loss of remote control and monitoring functions by CLP's Control Centre.

The cable bridge collapsed during the fire. The fire was brought under control by FSD at around 20:30 hours.

Possible causes and development of the fire

Based on the available evidence, and supported by the views of the independent fire engineering consultant appointed by CLP, Dr. Young Wong of Ove Arup & Partners Hong Kong Ltd., the following conclusions have been reached:

1. As noted above, there are no obvious signs that the fire resulted from foul play.

2. On the day of the incident there were no known operational or fault incidents in the concerned area, and all the cables were operating well below their design load limit. (Circuit loading data at 19:10 hours prior to tripping for all 132kV and 11kV cables indicate maximum loading was at 45% or less. It therefore is considered to be highly unlikely that the fire started due to overload.)

3. The electrical protection operated as designed and automatically isolated the damaged 132kV and 11kV circuits from the CLP's system within milliseconds, and therefore, protection system operation is not considered to be a contributing factor to the incident.

4. Whilst the weather on the day of the incident was hot, weather (environmental factors) is not considered to be a contributing factor to the incident and customer demand was observed to be within normal limits and adequately met by supply.

5. Three fault points were identified after the fire (two on one 132kV cable and the other one on an 11kV cable), but the available evidence suggests that these were caused by the fire, rather than being causes of the fire. It is also unlikely that heat required for igniting a fire was generated by induced circulating current flowing through a high-resistance path, because there are multiple paths for any induced current to flow in a steel bridge. Further, the overall earthing resistance of the bridge was believed to be low.

6. The available evidence points at the fire starting in Compartment A near Kwong Yip Street, and that:

    a) From public videos and photo footage and statements received, smoke was first seen coming from the Kwong Yip Street end of the bridge. Flame was seen emitting from both Compartments A and B of the cable bridge adjacent to Kwong Yip Street at an early stage of the fire;

    b) Fire damage was more severe in Compartment A, including total collapse of the cable racks in Compartment A, but not Compartment B;

    c) Fire pattern indicating very high temperature burn was observed in Chamber A (approximately 4 metres long) and covering approximately four metres section of the cable bridge in Compartment A from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end;

    d) Results from petrographic examination of the concrete core samples taken at Chamber A at Kwong Yip Street end, carried out by an independent laboratory, further support the conclusion that there was an intense fire within Chamber A at Kwong Yip Street end, with temperatures having reached 900°C in the Chamber. In the approximately four metres section of the cable bridge in Compartment A from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end, the top part of the bridge showed a large degree of oxidation caused by severe burn. It is noted that the higher the temperature and the longer the time of exposure to a fire, the more pronounced the effects of oxidation;

    e) CLP system records of cables tripping indicates the sequence of cable alarms and defective signals of the pilot/ fibre-optic (FO) cables, 11kV and 132kV cables. The first signal was a common alarm received from a pilot cable in Compartment A (time zero, 19:10:27), followed by defective signals from Compartment B around 2.5 minutes later;

f) Results of the computational fluid dynamics (CFD) simulation conducted by CLP's independent fire engineering consultant indicates that the fire was developed at Compartment A near Kwong Yip Street spreading to the rest of the bridge. We also observed that the spreading from Compartment A to Compartment B was more rapid and easy, compared to the opposite direction; and

g) Testing on the concrete wall of the sump pit in Chamber A at Kwong Yip Street shows that the water level before the incident was about 1.5 metres high. This water level meant that there was a limited void for any accumulation of inflammable gas to initiate the fire within Chamber A. Further, there was no evidence found of any source of inflammable gas into the pit or of the presence of inflammable gas at the time of incident, and the bridge had good natural ventilation, including to the sump pit area above the water level.

7. Based on the information available, it is estimated that the fire origin was within Compartment A, in the area from the entrance door to Chamber A to approximately four metres along the cable bridge from the junction between the bridge and concrete chamber at Kwong Yip Street end. This is the area shaded in red in the diagrams in Attachment 4.

8. Given the likely area of fire origin, the following two possible ignition sources have been examined inside Chamber A at Kwong Yip Street end:

a) A burnt out electrical item, which has been established to be a submersible sump pump, was identified on the grating at the deck level within Chamber A. However, it is impossible to find evidence to say conclusively whether this burnt out pump was or was not connected to power prior to the fire incident, and other testing did not support this item being an ignition source, and the cause of this scenario was considered highly unlikely; and

b) Low voltage (LV) fixed installations within Chamber A at Kwong Yip Street end, including LV sump pump control panel and the fluorescent light[1] within Chamber A. Assessment by CLP's independent fire engineering consultant using an LV switch board indicates that it is unlikely that there would have been a direct fire spread by radiation from the LV sump pump control panel to the cable. Further, it is observed by CLP that the metal casing of the LV sump pump control panel was in a closed position and seemed to be intact, and the LV sump pump control panel was not located directly above the sump pit, meaning that direct ignition from the LV sump pump control panel to the cables in the sump pit is highly unlikely. The CLP independent fire engineering consultant is of the opinion that it is also highly unlikely that the fluorescent light installed in Chamber A was an ignition source based on the observation that the fluorescent light was not directly over the nearest cable and with a distance more than two metres.

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[1] Fluorescent light includes associated fittings, circuits, and termination.

9. In addition, given the likely area of fire origin, the following two further possible ignition sources have been examined within the approximately four metres section of the cable bridge in Compartment A from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end:

    a) As regards cable fault points, no 132kV or 11kV cable fault points were identified within this approximately four metres section. The two 132kV cable fault points identified above (paragraph 5) were located around seven metres from the junction between Chamber A and the steel bridge at Kwong Yip Street end, and in any event for the reasons discussed in paragraph 4.8 of the main body of this report are considered to have been caused by the fire, rather than being causes of the fire; and

    b) Another possible ignition source in the area is the fluorescent lights attached to each of the cross beams at ceiling level in both Compartments of the bridge. These fluorescent lights were installed below the cross beams of the bridge approximately 350mm – 400mm above the nearest pilot cable right underneath them. These fluorescent lights at times would have been operating under high surrounding temperature, since the bridge was commissioned in 1992, and they had ballasts (essentially transformers which do not require any maintenance other than replacement upon failure) . The LV distribution board was examined after the incident, and the miniature circuit breakers (MCBs) controlling the lighting circuits were found to be in between the "Tripped" and "Off" positions indicating that the power supply to the fluorescent lights was most probably "On" before the incident. The LV distribution board was located within Chamber A at the Wang Lok Street end, and a light switch was located immediately inside the door entrance to each Chamber.

10. It may be possible that a fluorescent light in the area might have overheated and caught fire at the outset of the incident which could have resulted in the typically polyethylene casing and/or the polycarbonate diffuser catching fire and subsequently falling, either in a molten form or in pieces, directly on to the sheaths of the nearest pilot cable and the adjacent Cross-Linked Polyethylene (XLPE) cables, or reaching sufficient radiant heat to ignite the cable sheaths. An experiment conducted by an independent laboratory on 12th August 2022 on a similar fluorescent light fitting, in which the light fitting was ignited using a flame torch, confirmed that such phenomenon was a feasible hypothesis. Fluorescent lights igniting a fire is a rare occurrence, but enquiries suggest that overheating can be caused by factors such as deterioration of parts.

11. The independent fire engineering consultant has concluded that the fluorescent lights within approximately four metres section from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end could be a possible ignition source. This in turn had the potential to ignite the nearest pilot cable which in turn could then spread the fire to the adjacent pilot and power cables in the likely area of fire origin.

12. Based on the above, the most likely ignition source was a fluorescent light located in the four metres section of the cable bridge in Compartment A as measured from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end.

13. Once a small fire had developed as discussed above, what was needed to sustain the fire would be a combination of fuel and oxygen. As regards fuel, there was significant fire load available along the whole length of the bridge, consisting primarily of the sheaths of the nine 132kV XLPE cables, five 11kV XLPE cables and four 11kV paper-insulated cables which could be sufficient to sustain the subject fire. There was a higher fire load density in Compartment A compared to Compartment B. As regards oxygen, the natural ventilation within the bridge provided ample oxygen to propagate and grow the fire.

14. The above theory of the fire development is consistent with the public videos and photo footage, the fire modelling result from independent fire engineering consultant and the sequence of events recorded.

Supply interruption

Three 132kV and eight 11kV high-voltage cable circuits installed in the cable bridge were damaged as a result of the fire, the loss of these cable circuits affected the power supply to around 175,000 customers in Yuen Long, Tin Shui Wai and part of Tuen Mun.

Supply restoration

Supply restoration work began immediately after the incident and priority was given to essential services including hospitals and railways. About 90% of the affected customers were restored within 7 hours mainly through the two sets of 132kV cable circuits in normally-open (NO) arrangement and installed along a different route, while supply to the remaining customers was progressively restored by 11kV backup supplies. At 06:31 hours on 22nd June 2022, the 11kV supply was fully restored, and after conducting load assessment, at 08:00 hours on 22nd June 2022, the remaining customers were notified that their supply had been restored.

The 11kV supply restoration process was challenging because the supervisory and remote control system – through which restoration of supply can be normally arranged quickly and remotely - was not functioning due to the damage of associated communication cables by the fire, and as a result, operational switching and load assessment had to be carried out manually at site throughout the night.

As noted above, the fire had caused the loss of the supervisory and remote control system. CLP therefore had to make this initial assessment of the possible duration of the supply interruption without the usual system information. To maintain essential services, CLP provided electricity supply for elevators, lighting in common areas and water pumps for residents in housing estates affected by the incident.

CLP Power engineering teams carried out urgent repair work onsite by laying temporary replacement cables. The first 132kV and eight 11kV replacement circuits were successfully energised on 24th June 2022. The second 132kV circuit was energised on 27th June 2022, and the energisation of the remaining 132kV circuit was completed on 28th June 2022, fully restoring the supply capability of the power grid in the affected region. These temporary cables have been protected by a temporary encasement with compacted backfill and strong cover plates.

Recommendations and Additional Risk Reduction Measures

In respect of the incident that occurred, the following recommendations and additional risk reduction measures are made, and are grouped as follows:

a) The cable bridge damaged in the incident;
b) The other four cable bridges; and
c) Common cable route infrastructure.

<u>The cable bridge damaged in the incident</u>

- The cable bridge damaged in the incident has been decommissioned. The steel bridge structure has been removed, and the concrete chambers at both ends will be demolished (in progress).
- Temporary cables have been laid and energised to restore the integrity of the system.
- Replace the temporary cables with a permanent set of cables installed using a trenchless method as an option. Subject to the necessary route identification and permitting, this is expected to be completed in 1-2 years.

<u>The other four cable bridges</u>

Significant power failure involving any of the four other cable bridges is considered to be remote, and noting that three of the cable bridges do not have fluorescent lights, and fluorescent lights on the remaining bridge are located over the centre walkway, more than one metre away from the cables. Nevertheless, to alleviate concerns that might be raised by nearby residents, the following additional risk reduction measures either have been completed or are recommended in respect of these bridges:

- The cables inside the cable bridges have been painted with an appropriate fire-retardant coating (2 hours rating) to provide protection against external fire sources and/or stopping fire spreading from adjacent cables/other sources.
- Suitable heat detection systems have been installed along the interior compartment of the cable bridges with an alarm signal linked to CLP’s 24-hours manned Security Control Centre and System Control Centre.
- A wet-type fire suppression system has been fitted along the length of the four cable bridges.
- All fluorescent lights have been replaced.
- A risk assessment including the cable installation and segregation methodologies, fire hazards within the cable bridges, and the influence to power supply in case of equipment damage, is recommended to be carried out.

<u>Common cable route infrastructure</u>

- Lifespan and maintenance of light fittings and other low voltage building services installations, and associated circuits, will be reviewed with equipment suppliers and industry sources, and an appropriate refurbishment/replacement program established consistent with industry best practices.
- Risk assessments and reliability reviews, including fire hazards and the influence to power supply in case of equipment damage, will be conducted on the current 132kV and 400kV

circuits that are run on/through common infrastructure (e.g. cable bridges, cable tunnels or other single corridor structures)

- The effectiveness and feasibility of adopting the following enhancement measures will be reviewed by reference to industry best practices. Implementation plan will be formulated according to risk assessment result of each infrastructure.
  - Installation of fire detection system, e.g. heat detection system
  - Installation of firefighting system, e.g. wet-type fire suppression system
  - Application of fire-retardant coating to power cables
  - Burying power cables in soil to reduce fire risk
  - Segregation of power cable circuits with fire-resistant materials
  - Enhancement of electrical protection for low voltage building services installations by new technologies
  - Enhancement of security system, e.g. CCTV, intruder alarm, E-padlock systems
  - Enhancement of resilience design against foul play, e.g. additional security barrier
  - Diversion of cable circuit to other cable route

Additional General Recommendations

Emergency Preparedness and Communications

- A review of the emergency preparedness of key facilities and for general call out is recommended to be carried out, including internal drills. Where appropriate, some joint exercises with the emergency services departments should be considered.
- A review of the supply restoration process and stakeholders' communication for major supply interruptions with the simultaneous loss of remote monitoring and control functions from the CLP Control Centre is recommended and its effectiveness could be verified by drills.
- Enhance the operational control with redundancy in communication cables along different routes. Before such redundancy is implemented, explore the secure use of commercial telecom network during emergency.

General

- A campaign of good housekeeping with a focus on ensuring that excess materials used on site will not be accumulated or stored in non-designated areas.
- A fire hazard hunt on CLP operational facilities using a risk/probability matrix, focusing on high consequence low probability events, including the close proximity of low voltage fixed installations to pilot cables and XLPE power cables.

Contents

Executive Summary

1. Introduction

1.1 On 21st June 2022, a CLP cable bridge located near The Spectra, Wang Lok Street in Yuen Long caught fire, affecting power supply to around 175,000 customers in Yuen Long, Tin Shui Wai and part of Tuen Mun.

1.2 Since the installation of the cable bridge, the area around the bridge has been urbanized and built up over time. This urbanization has meant that the amount of electricity consumed locally and transported through the cables within the bridge has increased. The change in usage of the land in the area over time has included the development of the nullah, which was widened from the original Shan Pui River as shown in Attachment 1.

1.3 This increase in electricity consumption has meant that additional cables have been added in the bridge over time. Cable technology has also changed with the older 132kV oil-filled cables being decommissioned and replaced by the newer Cross-Linked Polyethylene (XLPE) cables. The replaced oil-filled cables were kept in-situ, initially as spares, but were disconnected at the two ends and drained of oil. The types of cables within the cable bridge at the time of the incident and their operational status is shown in Attachment 2. As the loading has increased, additional cables have been added in advance to ensure that there is adequate supply and to avoid any potential overloading of the power cables. Two sets of 132kV cable circuits have been arranged in normally-open (NO) arrangement serving as backup supply contingency installed along a different route (through a different cable bridge across the nullah). A further 132kV backup feeder was installed from Black Point to Tin Shui Wai 'A' to enhance the supply security in the concerned network.

 

Internal View of the Cable Bridge from Wang Lok Street

1.4 As part of the design of the bridge, one sump pit is constructed at the bottom of the chamber at each compartment and at each end of the bridge where power cables, pilot cables and fibre-optic (FO) cables entered into the pits before climbing up onto the bridge deck. Each sump pit has an installed pump to automatically discharge this seepage water as collected inside the pit.

2. The Investigation Panel

2.1 CLP is greatly concerned about the incident and therefore quickly set up a dedicated specialist Investigation Panel to investigate and report on the cause of the incident, and to make recommendations to assist in preventing the recurrence of any similar incident. In addition as an electricity supplier, CLP must comply with the statutory requirements under the Electricity Ordinance to notify and report to the Director of Electrical and Mechanical Services (EMSD) regarding any electrical accident.

2.2 Terms of Reference were set for the Investigation Panel to investigate and prepare a report on the CLP Cable Bridge Fire Incident. The report shall:

a) Set out the facts relating to the incident;
b) Identify, insofar as is possible, the cause or causes of the incident;
c) Set out what remedial action has been taken; and
d) Make recommendations to prevent or minimize the risk of the recurrence of a similar or related incident.

2.3 The Panel was constituted on 24th June 2022.

2.4 The Investigation Panel has five members:

○ Mr. Paul Poon (Chair)	Vice Chancellor - CLP Power Academy
○ Mr. Paul Chan (Member)	Civil & Structural Consultant
○ Ms. Elaine Chong (Member)	General Counsel – Hong Kong
○ Mr. David Crighton (Member)	Senior Director of CLP Holdings Limited
○ Mr. Poon Yut Ming (Member)	Safety & Fire Consultant

This Panel is supported by Dr. Young Wong, Director, Ove Arup & Partners Hong Kong Limited as an independent fire engineering consultant to assist the Panel with this investigation.

3. The Incident

3.1 No one was injured during the Incident and no property other than the cable bridge itself was damaged by the fire.

3.2 On 21st June 2022, a CLP cable bridge located near The Spectra, Wang Lok Street in Yuen Long caught fire, affecting power supply to around 175,000 customers in Yuen Long, Tin Shui Wai and part of Tuen Mun.

3.3 Smoke was first seen coming from the Kwong Yip Street end of the bridge at around 18:30 hours. (This having been reported by a member of the public to the Police during a post-incident enquiry, and then passed on by the Police to CLP after the event. CLP was first informed of this by the Police during the site inspection on 26th June 2022.)

3.4 Shortly after 19:00 hours the fire had spread along the length of the bridge and was reported as being clearly visible through the louvres along the length of the bridge.

3.5 At 19:05 hours, CLP emergency team was instructed to attend the scene after a call was received from a member of the public.

3.6 At 19:13 hours the circuit breakers controlling various 11kV cables routed through the cable bridge tripped. Shortly after this, circuit breakers controlling the 132kV circuits also routed through the same cable bridge tripped at 19:15 hours.

3.7 At 19:15 hours, FSD informed CLP Security about the fire and FSD arrived at the scene at 19:17 hours. (FSD subsequently informed CLP that FSD received public's report on fire at 19:12 hours.)

3.8 FSD applied water in an attempt to douse the fire. Directly tackling the fire was not easy as the bridge is enclosed along its length by a set of louvred panels. With CLP's help, FSD were able to access the ends of the bridge through 3 of the 4 access doors at the two chambers (i.e. except for the door of Compartment A in the chamber close to Kwong Yip Street end) located at the two ends of the bridge. However, given the length of the bridge and the fact that it was entirely enclosed by steel cladding, it was not easy to extinguish the fire from the top or sides.

3.9 The fire eventually led to burning of all the cables inside and the collapse of the bridge at around 19:50 hours, due to overheating leading to the yielding of the steel work at the mid span of the bridge and power supply to around 175,000 customers was interrupted in Yuen Long, Tin Shui Wai and part of Tuen Mun.

3.10 The fire was brought under control at around 20:30 hours and completely extinguished at 23:44 hours.

3.11 The site was closed for a couple of days so that the whole bridge structure could be temporarily supported to make it safe for access.

3.12 The fire incident also damaged communication cables, leading to problems in monitoring and controlling the system from CLP's System Control Centre. This meant that manual local switching and load checking by site staff was required to restore supplies throughout the night.

3.13 Supply restoration to the affected customers started at 19:20 hours and priority was given to essential services including hospitals and railways. About 90% of the affected customers were restored within 7 hours mainly through the two sets of 132kV cable circuits in normally-open (NO) arrangement and installed along a different route. At around mid-night, CLP made a prudent assessment, which was that it could take approximately two days to restore supply for the remaining 20,000 customers not already reconnected. In fact, supply to the remaining customers was progressively restored by 11kV backup supplies. At 06:31 hours on 22nd June 2022, the 11kV supply was fully restored, and after conducting load assessment, at 08:00 hours on 22nd June 2022, the remaining customers were notified that their supply had been restored.

3.14 The 11kV supply restoration process was challenging because the supervisory and remote control system – through which restoration of supply can be normally arranged quickly and remotely - was not functioning due to the damage of associated communication cables by the fire, and as a result, operational switching and load assessment had to be carried out manually at site throughout the night. For the details of the restoration and customer numbers affected, please refer to paragraph 3.15 below and Attachment 3.

3.15 The restoration timeline is summarized as follows:-

Time of restoration	**Restored customers (,000)**	**Restored Percentage**	**Remaining Affected customers (,000)**	**Remaining affected Percentage**
Supply interruption	0	0%	175	100%
2 hours after incident	85	49%	90	51%
3 hours after incident	108	62%	67	38%
6 hours after incident	141	81%	34	19%
7 hours after incident	155	89%	20	11%
13 hours after incident	175	100%	0	0%

3.16 Subsequent to the completion of supply restoration to customers, to ensure supply reliability under further contingencies, temporary 132kV, 11kV and communication cables with suitable mechanical protection were installed along the pavement of a nearby road crossing the nullah as replacement cables to by-pass the burnt cables on the bridge.

3.17 At the time of the cable bridge incident, the 132kV feeder from Black Point to Tin Shui Wai ‘A’ circuit was under repair and therefore unable to provide backup to the 132kV system (the TSA substation). The unplanned outage on the Black Point to Tin Shui Wai ‘A’ circuit had arisen from a power cable and associated communication cable damage, due to excavation work on the mainland side. This circuit is now restored.

4. Possible Causes and Development of the Fire

4.1 During the joint site inspection on 26th June 2022, and subsequent discussions with the Police, FSD, the Government Laboratory and EMSD, it was agreed that there were no obvious signs that the fire resulted from foul play.

4.2 The cable bridge concerned was designed by a reputable engineering consultant using international standards[2] and in accordance with local building codes (see Attachment 4), and the design was submitted for approval by the relevant Government department and Occupation Permit (NT58/92) obtained in 1992. The bridge was constructed in structural steelwork which provided multiple parallel metal paths for any stray current to flow to earth.

4.3 CLP’s maintenance record indicates that during the scheduled annual routine inspection of the cable bridge on 7th October 2020, including functional check of the fluorescent light[3]s, no abnormality was found. An inspection record on 12th November 2021 also shows that the bridge and equipment therein were normal. All the four other cable bridges are inspected annually. Based on available information, several other visits were made to the bridge by cable maintenance staff and meter readers between January 2022 and June 2022, and no abnormity was reported.

4.4 Based on the available evidence, and supported by the views of the independent fire engineering consultant appointed by CLP, Dr Young Wong of Ove Arup & Partners Hong Kong Ltd, the following conclusions have been reached.

4.5 On the day of the incident there were no known operational or fault incidents in the concerned area, and all the cables were operating well below their design load limit. (Circuit loading data at 19:10 hours, prior to tripping, for all 132kV and 11kV cables indicate maximum loading at 45% or less. It therefore is considered to be highly unlikely that the fire started due to overload.)

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[2] The relevant standards and codes in 1990 were the following: Design: BS5950 and code of practice on the structural use of steel in Hong Kong; Materials: BS4360.

[3] Fluorescent light includes associated fittings, circuits, and termination.

4.6 The electrical protection operated as designed and automatically isolated the damaged 132kV and 11kV circuits from the CLP's system within milliseconds, and therefore, protection system operation is not considered to be a contributing factor to the incident.

4.7 Whilst the weather on the day of the incident was hot at around 30 degrees C, weather (environmental factors) is not considered to be a contributing factor to the incident and customer demand was observed to be within normal limits and adequately met by supply.

4.8 Three fault points were identified after the fire during the inspection on 26th June in the 132kV cables and the 11kV cables, but the available evidence suggests that these were caused by the fire, rather than being causes of the fire. The available evidence includes the following:

a) The three fault points were located away from what is believed to be the starting point of the fire in Compartment A near Kwong Yip Street as noted below, and the computational fluid dynamic (CFD) fire simulation compiled by the independent fire engineering consultant indicates that the fire spreading from Compartment A to Compartment B is more rapid and easy compared to the opposite direction.

b) The 132kV cable circuit tripped five minutes after its pilot cable became defective, whereas if the fire had started in the 132kV cable, it would have tripped first.

c) Microscopic and metallographic examination by an independent laboratory confirms that there was no sign of arcing at the two 132kV cable circuit fault points.

d) Microscopic and metallographic examinations by an independent laboratory of the one 11kV cable fault point has shown evidence of possible short circuit. Despite the evidence of short circuit found on this 11kV cable fault point, it was not possible to establish such cable defect as the cause of fire. Further, it must be noted that the one 11kV cable fault point was located in Compartment B, not in Compartment A.

4.9 It is unlikely that heat sufficient to ignite a fire was generated by induced circulating current flowing through a high-resistance path, because there are multiple paths for any induced current to flow in a steel bridge. Further, the overall earthing resistance of the bridge was believed to be low.

4.10 The available evidence points at the fire starting in Compartment A near Kwong Yip Street and that:

a) From public video and photo footage and statements received, smoke was first seen coming from the Kwong Yip Street end of the bridge. Flame was seen emitting from both Compartments A and B of the cable bridge adjacent to Kwong Yip Street at an early stage of the fire;

b) Fire damage was more severe in Compartment A, including total collapse of the cable racks in Compartment A, but not Compartment B;

c) Fire pattern indicating very high temperature burn was observed in Chamber A (approximately 4 metres long) and four metres section of the cable bridge in Compartment A from the junction between the steel bridge and concrete chamber at

Kwong Yip Street end. For easy reference, the area is shaded red in the diagrams in Attachment 4;

d) Results from petrographic examination of the concrete core samples taken at Chamber A at Kwong Yip Street end, carried out by an independent laboratory, further support the conclusion that there was an intense fire within Chamber A at Kwong Yip Street end, with temperatures having reached 900°C in the Chamber. In the approximately four metres section of the cable bridge from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end, the top part of the bridge showed a large degree of oxidation caused by severe burn. It is noted that the higher the temperature and the longer the time of exposure to a fire, the more pronounced are the effects of oxidation;

e) CLP system records of cables tripping indicates the sequence of cable alarms and defective signals of the pilot/FO cables, 11kV and 132kV cables. The first signal was a common alarm received from a pilot cable in Compartment A (time zero, 19:10:27), followed by defective signals from Compartment B around 2.5 minutes later;

f) Results of the computational fluid dynamics (CFD) simulation conducted by CLP's independent fire engineering consultant indicates that the fire developed at Compartment A near Kwong Yip Street spreading to the rest of the bridge. We also observed that the fire spreading from Compartment A to Compartment B was more rapid and easy, compared to the opposite direction;

g) Testing on the concrete wall of the sump pit in Chamber A at Kwong Yip Street shows that the water level before the incident was about 1.5 metres high. This water level meant that there was a limited void for any accumulation of inflammable gas to initiate the fire within Chamber A. Further, there was no evidence found of any source of inflammable gas into the pit or of the presence of inflammable gas at the time of incident, and the bridge had good natural ventilation, including to the sump pit area above the water level.

4.11 Based on the information available, as stated in paragraph 4.10 (c) above, it is estimated that the fire origin was within Compartment A, in the area from the entrance door to Chamber A to approximately four metres along the cable bridge from the junction between the bridge and concrete chamber at Kwong Yip Street end. This is the area shaded in red in the diagrams in Attachment 4.

4.12 Given that the likely fire start location was established inside Compartment A near Kwong Yip Street, the following two possible ignition sources within Chamber A Kwong Yip Street and near the entrance have been identified:

a) A burnt out electrical item, which has been established to be a submersible sump pump, was identified on the grating at the deck level within Chamber A. However, it is impossible to find evidence to say conclusively whether this burnt out pump was or was not connected to power prior to the fire incident, and other testing did not support this item being an ignition source, and the cause of this scenario was considered highly unlikely; and

b) Low voltage (LV) fixed installations within Chamber A at Kwong Yip Street end, including LV sump pump control panel and the fluorescent light within Chamber A. Assessment by CLP's independent fire engineering consultant using an LV switch board indicates that it is unlikely that there would have been a direct fire spread by radiation from the LV sump pump control panel to the cable. Further, it is observed by CLP that the metal casing of the LV sump pump control panel was in a closed position and seemed to be intact, and the LV sump pump control panel was not located directly above the sump pit, meaning that direct ignition from the LV sump pump control panel to the cables in the sump pit is highly unlikely. The CLP independent fire engineering consultant is of the opinion that it is also highly unlikely that the fluorescent light installed in Chamber A was an ignition source based on the observation that the fluorescent light was not directly over the nearest cable and with a distance more than two metres.

4.13 Given the likely area of fire origin, the following two possible ignition sources have been examined within the approximately four metres section of the cable bridge in Compartment A from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end:

a) No 132kV fault points could be identified within the likely area of fire origin. The two 132kV cable fault points identified above (paragraph 4.8) were located approximately seven metres from the junction between Chamber A and the steel bridge at Kwong Yip Street end, and also as noted above, microscopic and metallographic examination by an independent laboratory confirms that there was no sign of arcing at these two 132kV cable fault points; and

b) Another possible ignition source in the area is the fluorescent lights attached to each of the cross beams at ceiling level in both Compartments of the bridge. These fluorescent lights were installed below the cross beams of the bridge approximately 350mm – 400mm above the nearest pilot cable right underneath them. These fluorescent lights at times would have been operating under high surrounding temperature, since the bridge was commissioned in 1992, and they had ballasts (essentially transformers which do not require maintenance other than replacement upon failure). The LV distribution board was examined after the incident, and the miniature circuit breakers (MCBs) controlling the lighting circuits were found to be in between the "Tripped" and "Off" positions indicating that the power supply to the fluorescent lights was most probably "On" before the incident. The LV distribution board was located within Chamber A at the Wang Lok Street end, and a light switch was located immediately inside the door entrance to each Chamber.

4.14 It may be possible that a fluorescent light in the area might have overheated and caught fire at the outset of the incident resulting in the typically polyethylene casing and/or the polycarbonate diffuser catching fire and subsequently falling, either in a molten form or in pieces, directly on to the sheaths of the nearest pilot cable and the adjacent XLPE cables, or reaching sufficient radiant heat to ignite the cable sheaths. An experiment conducted by an independent laboratory on 12th August 2022 on a similar fluorescent light fitting, in which the light fitting was ignited using a flame torch, confirmed that such phenomenon was a feasible hypothesis. Fluorescent lights igniting a fire is a rare occurrence, but enquiries suggest that overheating can be caused by factors such as deterioration of parts.

4.15 The independent fire engineering consultant has concluded that the fluorescent lights within approximately four metres from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end could be a possible ignition source. This in turn had the potential to ignite the nearest pilot cable which in turn could then spread the fire to the adjacent pilot and power cables in the likely area of fire origin.

4.16 Based on the above, the most likely ignition source was a fluorescent light located in the four metres section of the cable bridge in Compartment A as measured from the junction between the steel bridge and the concrete chamber at Kwong Yip Street end.

4.17 Once a small fire had developed as discussed above, what was needed to sustain the fire would be a combination of fuel and oxygen. As regards fuel, there was significant fire load available along the whole length of the bridge, consisting primarily of the sheaths of the nine 132kV XLPE cables, five 11kV XLPE cables and four 11kV paper-insulated cables which could be sufficient to sustain the subject fire. There was a higher fire load density in Compartment A compared to Compartment B. As regards oxygen, the natural ventilation within the bridge provided ample oxygen to propagate and grow the fire.

4.18 The above theory of the fire development is consistent with the public videos and photo footage, the fire modelling result from independent fire consultant and the sequence of events recorded.

4.19 Further to the conclusions set out above, the following additional background should be noted:

a) The majority of the main steelwork remained intact, and the majority of the roof and side sheeting, purlins, railings and open metal floor panels did not sustain severe fire damage. Durasteel panels at the centre spine along the length of the bridge were observed to be intact. Cable racks in Compartment A were seen to suffer the most severe fire damage with the majority of cables with sheath cover and the insulation completely consumed by the fire up to the cable entry point at the sump pit, whereas the sheaths of the cables in the other three chamber compartments were in good condition; and

b) The concrete enclosures at the end of the two compartments except Chamber A at Kwong Yip Street end were charred with black soot to different degrees. A buff colour was observed on the concrete surface on Chamber A and spalling was seen on the ceiling edge in the Chamber abutting the steel bridge on the Kwong Yip Street end. Surface paint on the steel stairway, railings and platform inside Chamber A was not seen as opposed to the observation of remaining blue paint on similar steel ancillary structures in the other three chambers.

5. Other Observations

5.1 Housekeeping

- Several drums of cable sealing and cable jointing compound and tarpaulin bags of expanded polystyrene beads were found to be stored in Wang Lok Street end of the cable bridge. These were not consumed in the fire.

5.2 No fire detection or fire protection system installed but fire-retardant coating was applied to the bottom part of some of the cables.

5.3 Cable segregation

- The cable distribution (132kV, 11kV, pilot cables and fibre-optic cables) between Compartment A and Compartment B within the cable bridge could have been better segregated.
- The cable bridge carried a number of key circuits, the failure of the bridge meant that multiple key circuits were impacted, and this affected the redundancy/resilience of the system.

5.4 Communication channels for power system

- Pilot and signal cables, routed along the cable bridge together with the main power cables, were damaged during the fire. This meant that field signals back to the CLP Control Centre and some of the remote-control capabilities were lost, hampering the power restoration efforts.

6 Recommendations and Additional Risk Reduction Measures

6.1 In respect of the incident, the following recommendations and additional risk reduction measures are made, and are grouped as follows:

a) The existing cable bridge damaged in this incident;
b) The four other cable bridges; and
c) Common cable route infrastructure.

6.2 The cable bridge damaged in the incident

- The cable bridge damaged in the incident has been decommissioned. The steel bridge structure has been removed, and the concrete chambers at both ends will be demolished (in progress).
- Temporary cables have been laid and energised in a protected environment to restore the integrity of the system.
- Replace the temporary cables with a permanent set of cables installed using a trenchless method as an option. Subject to the necessary route identification and permitting, this is expected to be completed in 1-2 years.

6.3 The other four cable bridges

Significant power failure involving any of the four other cable bridges is considered to be remote, and noting that three of the cable bridges do not have fluorescent lights, and fluorescent lights on the remaining bridge are located over the centre walkway, more than one metre away from the cables. Nevertheless, to alleviate concerns that might be raised by nearby residents, the following additional risk reduction measures either have been completed or are recommended in respect of these bridges:

- The cables inside the cable bridges have been painted with an appropriate fire-retardant coating (2 hours rating) to provide protection against external fire sources and/or stopping fire spreading from adjacent cables/other sources.
- Suitable heat detection systems have been installed along the interior compartment of the cable bridges with an alarm signal linked to CLP's 24-hours manned Security Control Centre and System Control Centre.
- A wet-type fire suppression system has been fitted along the length of the four cable bridges.
- All fluorescent lights have been replaced.
- A risk assessment including the cable installation and segregation methodologies, fire hazards within the cable bridges, and the influence to power supply in case of equipment damage, is recommended to be carried out. (To be completed by end November 2022.)

6.4 Common cable route infrastructure

- Lifespan and maintenance of light fittings and other low voltage building services installations, and associated circuits, will be reviewed with equipment suppliers and industry sources, and an appropriate refurbishment/replacement program established consistent with industry best practices by the end of 2022.
- Risk assessments and reliability reviews, including fire hazards and the influence to power supply in case of equipment damage, will be conducted on the current 132kV and 400kV circuits that are run on/through common infrastructure (e.g. cable bridges, cable tunnels or other single corridor structures) , and this is expected to be completed by end November 2022.
- The effectiveness and feasibility of adopting the following enhancement measures will be reviewed by reference to industry best practices. Implementation plan will be formulated according to risk assessment result of each infrastructure in year 2023.
    - Installation of fire detection system, e.g. heat detection system
    - Installation of firefighting system, e.g. wet-type fire suppression system
    - Application of fire-retardant coating to power cables
    - Burying power cables in soil to reduce fire risk
    - Segregation of power cable circuits with fire-resistant materials
    - Enhancement of electrical protection for low voltage building services installations by new technologies
    - Enhancement of security system, e.g. CCTV, intruder alarm, E-padlock systems
    - Enhancement of resilience design against foul play, e.g. additional security barrier
    - Diversion of cable circuit to other cable route

7 Additional General Recommendations

7.1 Emergency Preparedness and Communications

- A review of the emergency preparedness of key facilities and for general call out is recommended to be carried out, including internal drills. Where appropriate some joint exercises with the emergency services departments should be considered.
- A review of the supply restoration process and stakeholders' communication for major supply interruptions with the simultaneous loss of remote monitoring and control functions from the CLP Control Centre is recommended and its effectiveness could be verified by drills.
- Enhance the operational control with redundancy in communication cables along different routes. Before such redundancy is implemented, explore the secure use of commercial telecom network during emergency.

These are expected to be completed by the end of year 2022.

7.2 General

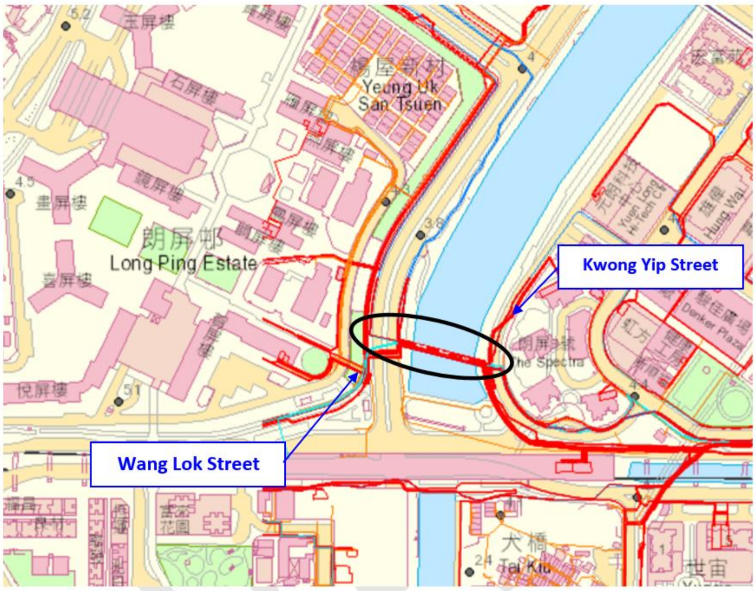
- A campaign of good housekeeping with a focus on ensuring that excess materials used on site will not be accumulated or stored in non-designated areas.
- A fire hazard hunt on CLP operational facilities using a risk/probability matrix, focusing on high consequence low probability events, including the close proximity of low voltage fixed installations to pilot cables and XLPE power cables.

These are expected to be completed by the end of year 2022.

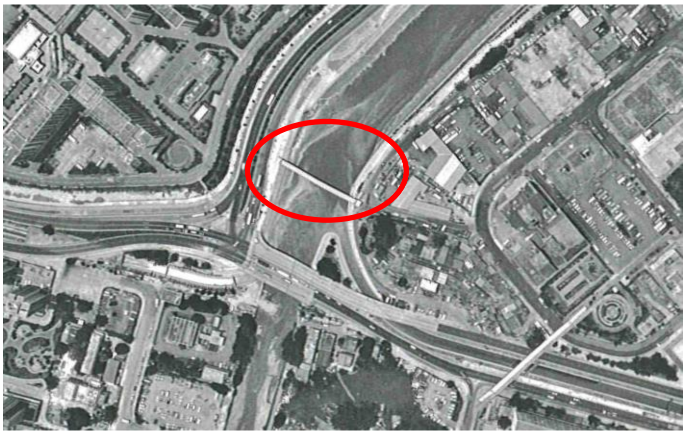
8 Attachments

Attachment	
1	Map of the Incident Location, Aerial Photograph and Bridge Layout
2	Cable Bridge Installation Layout
3	Supply Restoration Progress
4	Bridge Construction

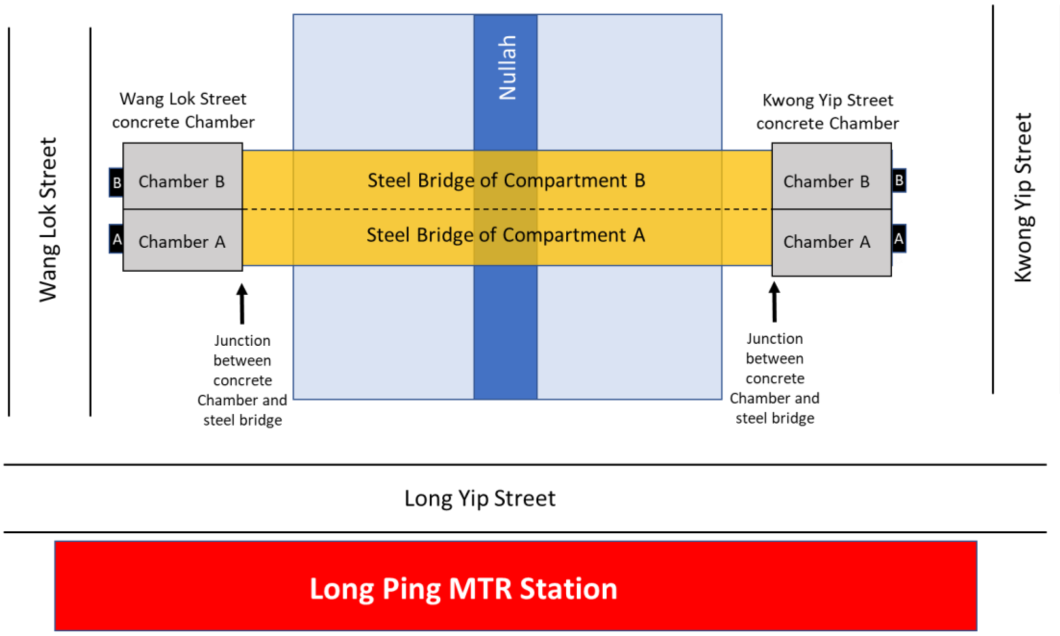
Attachment 1 : Map of the Incident Location, Aerial Photograph and Bridge Layout



Location of Cable bridge at Wang Lok Street and Kwong Yip Street



Area after the completion of the bridge (1993)



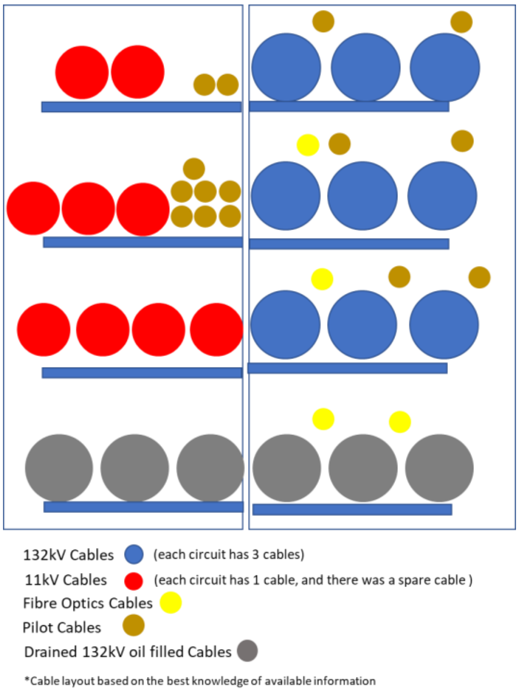
Remarks:

- Compartment A includes concrete Chamber A at Kwong Yip Street end, concrete Chamber A at Wang Lok Street end and the cable bridge Compartment between the 2 Chambers
- Compartment B includes concrete Chamber B at Kwong Yip Street end, concrete Chamber B at Wang Lok Street end and the cable bridge Compartment between the 2 Chambers

Bridge Layout

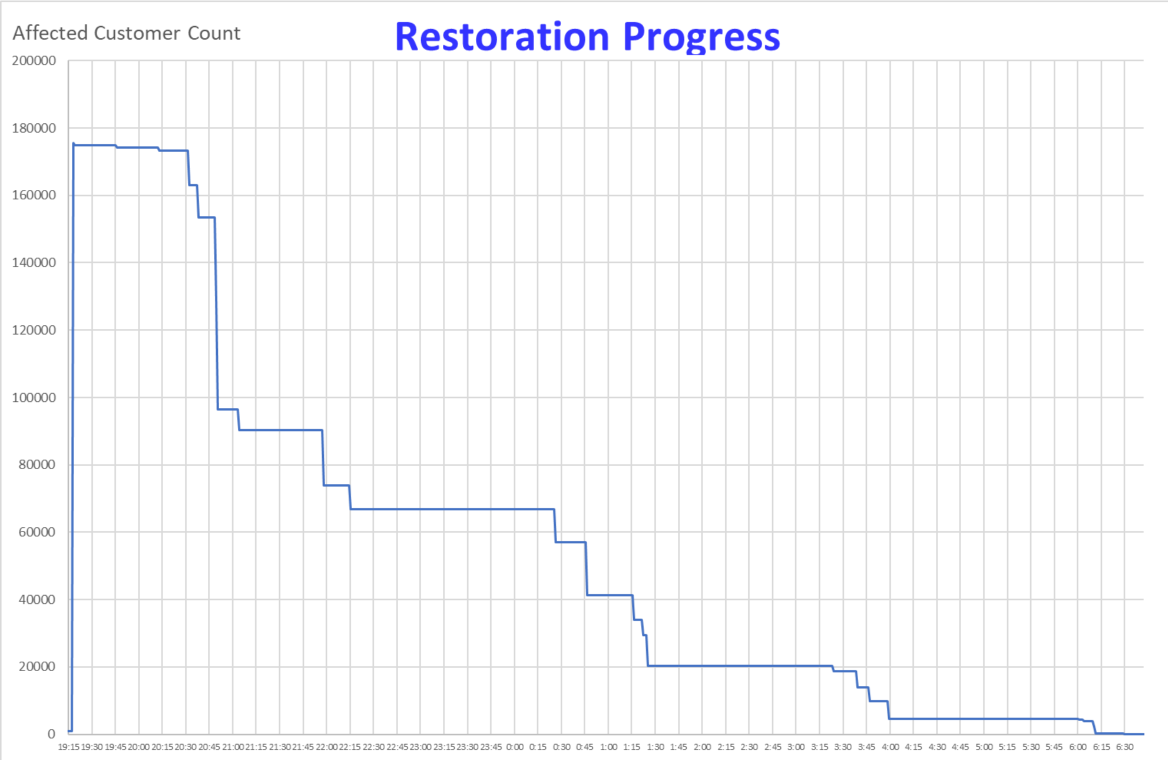
Attachment 2 : Cable Bridge Installation Layout

View of Compartment B of the cable bridge, from inside the bridge and looking towards Kwong Yip Street entrance, showing the installation of the 11kV and the disused 132kV now drained oil filled cables (lower layer).



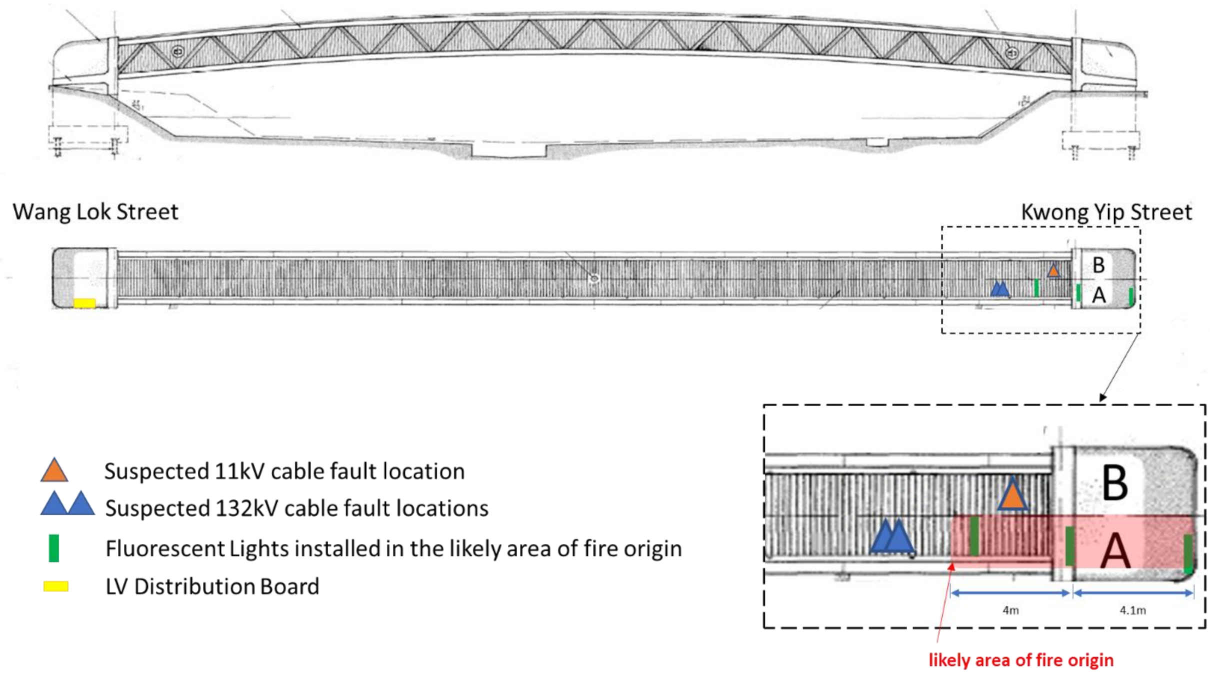
View of Compartment A of the cable bridge, from inside the bridge and looking towards Kwong Yip Street entrance, showing the cable racks on 132kV cables.

Attachment 3 : Supply Restoration Progress

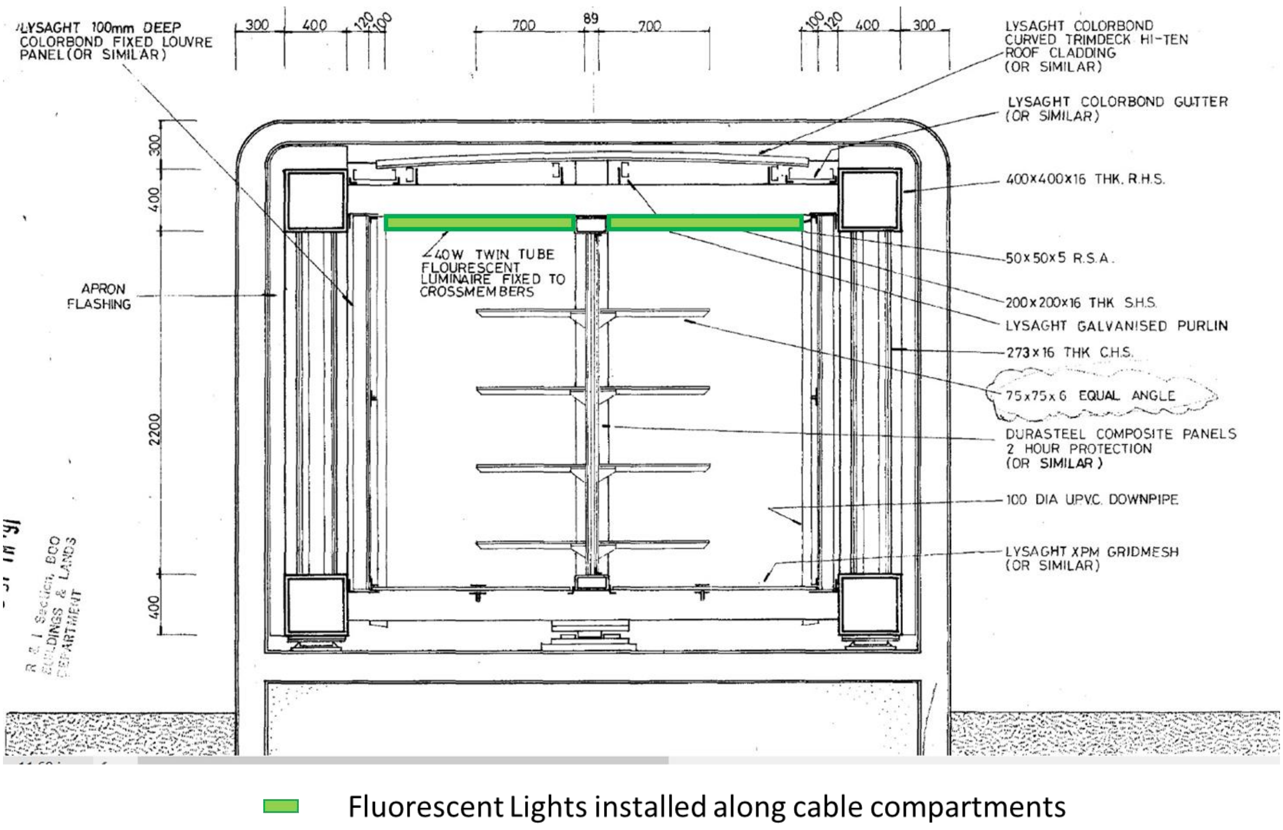


Time of restoration	Restored Customers (,000)	Restored Percentage	Remaining Affected Customers (,000)	Remaining Affected Percentage
Supply interruption	0	0%	175	100%
2 hours after incident	85	49%	90	51%
3 hours after incident	108	62%	67	38%
6 hours after incident	141	81%	34	19%
7 hours after incident	155	89%	20	11%
13 hours after incident	175	100%	0	0%

Attachment 4 : Bridge Construction



Elevation and Plan of cable bridge



Cable bridge cross section view

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