For discussion on
27 May 2024

Legislative Council
Panel on Environmental Affairs

Electrical Incidents of CLP Power Hong Kong Limited in 2024

Purpose

The Government has received the investigation reports on the five electrical incidents in 2024 from CLP Power Hong Kong Limited ("CLP") to the Director of Electrical and Mechanical Services ("the Director"). The concerned electrical incidents are:

(I) Electrical incident at Nga Ying Chau Street Substation, Tsing Yi on 1 January[1];
(II) Electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January;
(III) Guide wire sagging incident at Au Tau, Yuen Long on 19 March;
(IV) Transmission system voltage dip incident on 30 March; and
(V) Transmission system voltage dip incident on 6 April.

2. The Government submitted to the Panel on 26 February the information paper on the gist of the reports, the causes of incidents and the improvement measures of the above-mentioned incidents (I) and (II) (see **Annex I**). This paper aims to report to the Panel the latest progress of the follow-up actions on these two incidents, as well as the gist of the reports, follow-up actions on and improvement measures for the remaining three incidents (*i.e.* the above-mentioned incidents (III), (IV) and (V)).

[1] causing a voltage dip

Background

3. In accordance with the Electricity Ordinance (Cap. 406) ("the Ordinance"), the Government monitors the operation of the power companies to ensure the safe and reliable supply of electricity in Hong Kong. The Ordinance stipulates the powers and obligations of electricity suppliers, including, in the case of an electrical accident, giving the Director a report of the cause and the remedial action has been, or will be done, to prevent a recurrence of the accident.

4. The Government is very concerned about CLP's five electrical incidents occurred one after another in the first four months of 2024. The incidents affected the daily life and aroused the concerns of the public on the reliability of electricity supply. Subsequent to each of the incidents, the Electrical and Mechanical Services Department ("EMSD") immediately sent staff to the site to conduct investigation, followed up with CLP on the development of the incidents and urged CLP to promptly complete the repair work, as well as requested CLP to identify the causes of the incidents as soon as possible and submit investigation reports within four weeks[2] after the respective incidents.

5. EMSD received on 27 January, 20 January, 15 April, 26 April and 3 May, respectively, the reports submitted by CLP concerning (I) the electrical incident at Nga Ying Chau Street Substation, Tsing Yi on 1 January, (II) the electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January, (III) the guide wire sagging incident at Au Tau, Yuen Long on 19 March, (IV) the transmission system voltage dip incident on 30 March, and (V) the transmission system voltage dip incident on 6 April. The reports gave an account of the details and causes of the incidents, as well as the improvement measures. Copies of the reports on incidents (I) and (II) are attached to the information paper submitted by the Government to the Panel on 26 February (see **Annex I**), while copies of the reports on the three other incidents (*i.e.* incidents (III), (IV) and (V)) are at **Annexes II, III and IV** respectively.

[2] Apart from the electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January on which CLP was requested to submit investigation report within two weeks, CLP was required to submit investigation reports within four weeks of the four other electrical incidents.

Causes of the Incidents and Improvement Measures

Incident (I): Electrical incident at Nga Ying Chau Street Substation, Tsing Yi on 1 January and incident (II): Electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January

6. According to CLP's report on incident (I), there was material flaw inside the outdoor 132kV cable sealing end located at the Nga Ying Chau Street 132kV Substation, which led to the degradation of the insulation over the time of use. Eventually, a short circuit fault occurred at the cable sealing end and caused it to smoke. The incident resulted in a short voltage dip without interruption in the power supply during the period. According to CLP's report on incident (II), the premature aging of the 11kV underground cable joint in CLP's substation located in On Mei House, Cheung On Estate led to deterioration of hydrophobic capability. As a result, moisture entered the joint and corroded the internal components. This eventually caused the insulation to breakdown, which resulted in partial power supply interruption for 388 customers in On Mei House.

7. On the improvement measures for and follow-up actions on incidents (I) and (II), at the request of EMSD, CLP completed the inspection on the power supply system in Tsing Yi district in January, and the inspection on same type of cable joints and cable sealing ends in other districts in February. The concerned equipment has been confirmed to be under normal operation condition. EMSD conducted spot-checks on the inspection work and found no abnormality. EMSD will continue to closely monitor CLP's implementation of the various improvement measures, including reviewing the maintenance regime of the territory-wide transmission and distribution system, examining and enhancing the procurement management, formulating the condition assessment plan on insulation soundness, and exploring innovation and technology solutions for online condition monitoring for both cable joints and cable sealing ends of the same types. EMSD requested CLP to complete above-mentioned improvement measures in phases within 2024 and report its progress to EMSD on a regular basis.

Incident (III): Guide wire sagging incident at Au Tau, Yuen Long on 19 March

8. According to CLP's report on incident (III) (**Annex II**), CLP's contractor was carrying out restringing works on a de-energized 400kV overhead line circuit at around 12:21 pm on that day. During the works, a guide wire which did not carry electricity sagged to the level of the vehicular bridge, eventually interfering the nearby 11kV electricity supply system resulting in power interruption of 68 customers. The incident caused no injury. CLP's investigation findings show that the incident was related to CLP's contractor's failure to implement the material fall prevention system in accordance with the method statement and poor coordination among the contractor's working personnel on site during the works.

9. Taking into account the views of an independent third-party expert, EMSD confirmed in principle the causes of the incident as stated in the report on incident (III). To prevent recurrence of similar incidents, CLP pledged to step up its monitoring of the concerned contractor to ensure its effective implementation of site safety measures and improvement to the site coordination work; CLP would also introduce new technologies and digital applications to enhance site management. The Government considers that incident (III) was entirely caused by human error. While the concerned works was carried out by CLP's contractor, CLP failed to properly monitor the contractor. CLP, as the project proponent, should bear the ultimate responsibility. Having examined the report, EMSD is of the view that that CLP failed to effectively monitor the contractor and site safety management. EMSD instructed CLP to formulate an effective mechanism to ensure that all safety measures are implemented by the contractors in high-risk works in all outsourced contracts, and arrange CLP staff to provide adequate on-site monitoring in high-risk works in all outsourced contracts, and adopt smart site safety related technologies to enhance site safety and quality of work. To this end, EMSD also issued a warning letter to CLP to admonish and request CLP to strictly put in place the proper safety measures when carrying out high-risk works to prevent endangering public safety.

Incident (IV): Transmission system voltage dip incident on 30 March

10. According to CLP's report on incident (IV) (**Annex III**), a 400kV overhead line circuit connecting Yuen Long and Lai Chi Kok was affected by hill fire at Shap Pat Heung, Yuen Long, leading to a fault at the concerned circuit at around 12:28 pm on that day. The incident resulted in a short voltage dip without interruption in power supply during the period. Upon investigation, CLP believed that the incident was caused by the hill fire occurring in Shap Pat Heung, Yuen Long on that day. To prevent recurrence of the incident, CLP would continue to take precautionary measures to minimise the chance of voltage dips caused by and impact of hill fire. The measures include enhancing vegetation patrol and equipment condition assessment by small unmanned aircrafts during hill fire seasons, enhancing communication with the Fire Services Department on hill fire cases and voltage dip incidents, as well as raising public awareness on voltage dips through community liaison activities. Taking into account the views of an independent third-party expert, EMSD confirmed in principle the causes of the incident and the improvement proposals as stated in the report on incident (IV).

Incident (V): Transmission system voltage dip incident on 6 April

11. According to CLP's report on incident (V) (**Annex IV**), a fault occurred at the electricity supply facilities in Black Point Power Station at around 1:29 pm on that day. The incident resulted in a short voltage dip without interruption in power supply during the period. Upon investigation, CLP believed that the incident was caused by lightning strike on that day. To prevent recurrence of the incident, CLP would enhance the resilience of the relevant generation and transmission equipment against lightning strikes, including a comprehensive testing and review of the lightning protection system and the associated earthing system. EMSD is currently examining the report on incident (V) in detail in consultation with an independent third-party expert, and evaluating whether the identified cause is well founded and the improvement measures are appropriate. If needed, EMSD will request CLP to make clarifications or provide further information.

12. In light of the series of incidents of CLP occurred one after another recently, in addition to stepping up the inspections of the concerned substations and power supply equipment, EMSD has requested CLP to critically review the asset management system of its power supply system, including the requirement for maintenance regime of generation, transmission and distribution equipment, resilience provisions for power supply system against external interference, and management of outsourced works contracts, with a view to enhancing its power supply reliability and electrical safety performance.

Way forward

13. EMSD will closely monitor CLP's implementation of the various improvement measures suggested in the reports and the additional measures recommended by EMSD upon reviewing the reports to prevent recurrence of similar incidents. Meanwhile, to minimise the impact on the daily life of the public due to voltage dip incidents, EMSD, upon notification of the incidents, will request the registered lift contractors to send staff to affected areas to help release the passengers trapped in the lifts and reset the operation of the lifts.

14. In view of recent frequent voltage dip incidents of CLP resulting in a certain number of lift entrapment cases, and taking into account views from various sectors of the community considering that CLP should bear responsibilities for voltage dip incidents, the Environment and Ecology Bureau met with CLP and proposed that a penalty scheme be established for significant voltage dip incidents and included in the existing penalty mechanism of the Scheme of Control Agreement with CLP. CLP is still considering the proposal.

Environment and Ecology Bureau
Electrical and Mechanical Services Department
May 2024

For information

Legislative Council
Panel on Environmental Affairs

Electrical Incidents of CLP Power Hong Kong Limited in Tsing Yi in January 2024

Purpose

The Government received on 20 and 27 January 2024 respectively the investigation reports submitted by CLP Power Hong Kong Limited ("CLP") to the Director of Electrical and Mechanical Services ("the Director") concerning the electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January and the electrical incident at Nga Ying Chau Street Substation, Tsing Yi on 1 January. This paper aims to report to the Panel on the major points of the reports and summarise the follow-up actions and improvement measures in response to the two incidents.

Background

2. In accordance with the Electricity Ordinance (Cap. 406) ("the Ordinance"), the Government monitors the operation of the power companies to ensure the safe and reliable supply of electricity in Hong Kong. The Ordinance stipulates the powers and obligations of electricity suppliers, including, in the case of an electrical accident, giving the Director a report of the cause and the remedial action has been, or will be done, to prevent a recurrence of the accident.

3. The Government is very concerned about CLP's two electrical incidents, which were not caused by external factors such as adverse weather, happened in Tsing Yi within a short period of time. The incidents affected the daily life and aroused concern of the public. Subsequent to the two incidents, the Electrical and Mechanical Services Department

("EMSD") immediately sent staff to the site to conduct investigation, followed up with CLP on the development of the incidents and urged CLP to promptly complete the repair work, as well as requested CLP to identify the causes of the incidents as soon as possible and submit investigation reports within four weeks and two weeks after the corresponding incidents respectively.

4. Subsequently, EMSD had a special meeting with CLP on 8 January and requested CLP to immediately strengthen inspections on the power supply system in Tsing Yi district within January and to arrange inspections of concerned components, *i.e.* cable joints and cable sealing ends of the same types, in other districts. EMSD also urged CLP to comprehensively review the maintenance regime of the territory-wide transmission and distribution system to ensure the reliability of power supply and prevent recurrence of similar incidents.

5. EMSD received on 20 and 27 January respectively the reports submitted by CLP concerning the electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January and the electrical incident at Nga Ying Chau Street Substation, Tsing Yi on 1 January. The reports give an account of the details and causes of the incidents, as well as the improvement measures. Copies of the two reports are at **Annexes I and II** respectively.

Cause of Incident

6. For the electrical incident at Nga Ying Chau Street Substation, Tsing Yi on 1 January, according to CLP's report (**Annex II**), a fault occurred at the outdoor 132kV cable sealing end located at the Nga Ying Chau Street 132kV Substation at around 3:13 pm, causing damage to the cable sealing end and leading to smoke. The associated automatic electrical protection system immediately isolated the faulty part. The incident resulted in short voltage dip but no interruption in the power supply uring the period. Upon investigation, CLP believed that there was material flaw inside the concerned cable sealing end, leading to the degradation of the insulation over the time of use. Eventually, a short circuit fault occurred at the cable sealing end.

7. As regards the electrical incident in On Mei House, Cheung On Estate, Tsing Yi on 7 January, according to CLP's report (**Annex I**), a fault occurred at a 11kV underground cable joint in CLP's substation located in On Mei House, Cheung On Estate at around 9:38 am, leading to partial power interruption in On Mei House, affecting 388 customers. Subsequently CLP restored the power supply to all customers at 11:04 am. Upon investigation, CLP believed that the incident involved the premature aging of the concerned cable joint material, leading to deterioration of hydrophobic capability of the cable joint. As a result, moisture entered the cable joint and corroded the internal components. This eventually caused breakdown of the insulation, which resulted in the incident.

8. After an in-depth investigation and review by CLP and an independent third-party electrical engineering expert hired by CLP, the two incidents were confirmed to have occurred at power supply systems with two different voltage levels, and were independent events.

Improvement Measures

9. At the request of EMSD, CLP completed the inspection on the power supply system in Tsing Yi district within January, including the inspection of power supply equipment in four 132kV substations and 370 numbers of 11kV substations, as well as testing of the same types of 11kV cable joints and 132kV cable sealing ends in Tsing Yi district. The equipment has been confirmed to be under normal operation conditions. EMSD conducted spot-checks on the inspection work and found no abnormality. In addition, EMSD has been following up with CLP on their inspection work on the same types of cable joints and cable sealing ends in other districts to be completed by February and will also conduct the spot check.

10. As suggested in its reports, in order to further enhance the maintenance work, CLP will formulate condition assessment plan on insulation soundness for the same type of cable joints and explore innovation and technology solution for online condition monitoring for the same type of cable sealing ends. Having considered the reports, EMSD considered that CLP should formulate condition assessment plan on

insulation soundness and explore innovation and technology solution for online condition monitoring for both cable joints and cable sealing ends of the same types. EMSD will also step up inspections of the concerned substations and power supply equipment to monitor and ensure their power supply reliability and electrical safety performance.

11. Furthermore, CLP suggested in the reports that at EMSD's request, it had engaged an independent expert consultant to review the maintenance regime of the territory-wide transmission and distribution system to ensure the safe and reliable supply of electricity in Hong Kong. Having considered the reports, given that two incidents are both related to the equipment materials, EMSD has requested CLP to review and enhance its procurement management, in particular on the procurement of important components of the power system, with a view to ensuring the compliance with international standards and related technical requirements of power supply equipment.

Conclusion

12. Having considered the relevant justifications and investigation results in the two reports, EMSD confirmed in principle the causes of the incidents and improvement proposals. EMSD will closely monitor CLP's implementation of the various improvement measures suggested in the reports and the additional measures recommended by EMSD upon reviewing the reports (see paragraphs 10 and 11 above).

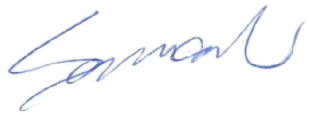
Environment and Ecology Bureau
Electrical and Mechanical Services Department
February 2024

Annex I

Power Supply Interruption Incident at On Mei House, Tsing Yi On 7 January 2024

INCIDENT INVESTIGATION REPORT

Submitted by:



Mr. Sam Law
Director - Asset Management

Date: 20th January 2024

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

On 7 January 2024, a CLP 11kV transformer feeder circuit providing power supply to a customer substation, On Mei House 'B' substation inside On Mei House of Cheung On Estate, Tsing Yi experienced a fault at 09:38 hours, interrupting power supply to 388 customers in On Mei House.

On Mei House, housing a total of 808 customers is supplied by two customer substations. The interruption to On Mei House 'B' substation affected 388 customers, i.e. 48% of customers in On Mei House. Upon investigation by CLP emergency response team, it was discovered that an 11kV trifurcating transition cable joint[1] (the "tri-joint") inside On Mei House 'B' substation was faulty. The faulty tri-joint was immediately isolated for repair and CLP, in parallel, coordinated with the estate management office of Cheung On Estate to arrange switching at customer side for immediate power restoration to affected customers from another CLP's in-service supply source. Power supply was fully restored at 11:04 hours that morning. The tri-joint concerned was also replaced for re-energisation in the evening of the same day.

The concerned tri-joint was commissioned in 2000, thus had been in service for about 23 years. Investigation suggests premature aging of the joint material that led to deterioration of hydrophobic (water proofing) capability bringing out gradual breakdown of the insulation in the tri-joint.

The tri-joint concerned inside On Mei House 'B' substation was designed according to IEC-60502 Standard. The Original Equipment Manufacturer (OEM) of the tri-joint has supplied CLP with similar types of joints since 1998. At present, there are 26 sets of tri-joints used in similar transformer feeder circuits in CLP's network. CLP's records reveal that there was only one fault incident associated with the concerned type of tri-joint before, this was the second incident of tri-joint fault in 25 years.

Nevertheless, to alleviate the concern of residents in Tsing Yi area, CLP has taken immediate additional measures which include conducting partial discharge testing on the other transformer feeder circuits with the same type of tri-joint, as well as inspecting all 370 customer substations in Tsing Yi area with partial discharge and infra-red measurements on power equipment. All such measures were completed on 18 January 2024. No abnormality was found.

[1] Trifurcating transition cable joint is designed for jointing a three-core cable to three single-core cable

CLP will also continue to undertake partial discharge testing on the rest of similar transformer feeder circuits with the same type of tri-joints in other districts to formulate an asset condition assessment plan. These testing are expected to be completed by February 2024.

As a longer term measure, CLP is committed to undertaking a comprehensive review for the maintenance regime of the power supply system. Further, to enhance communication with customers affected by power interruption, apart from strengthening liaison with property management companies to improve coordination of incident response actions, CLP will leverage our close contact with community leaders including District Officers, District Councillors, rural committee members, etc. to ensure timely information dissemination.

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1. Introduction

On 7 January 2024 at 09:38 hours, a power supply interruption incident occurred at On Mei House 'B' substation inside On Mei House, Cheung On Estate in Tsing Yi area. The CLP real-time operation system indicated a suspected fault on a CLP 11kV transformer feeder circuit supplying On Mei House 'B' substation, one of the two customers substations in On Mei House. The Automatic Protection System was activated to isolate the fault. The incident resulted in power supply interruption to 388 customers.

On Mei House, housing a total of 808 customers is supplied by two customer substations. The interruption to On Mei House 'B' substation affected 388 customers, i.e. 48% of customers in On Mei House. Upon site investigation by CLP emergency response team, it was discovered that an 11kV trifurcating transition cable joint (the "tri-joint") inside the On Mei House 'B' substation was faulty. The faulty tri-joint was immediately isolated for repair and CLP, in parallel, coordinated with the estate management office of Cheung On Estate to arrange switching at customer side for immediate power restoration to affected customers from another CLP's in-service supply source. Power supply was fully restored at 11:04 hours that morning. The tri-joint concerned was also replaced for re-energisation at 19:17 hours on the same day.

Subsequent to the tri-joint fault incident, CLP took immediate action to commence repair work and fault investigation, at the same time stepped up preventive measures in Tsing Yi area in order to prevent further power interruption to customers.

2. The Equipment Fault Incident and Restoration Arrangement

The equipment at fault was an 11kV tri-joint connecting 150 sq.mm Aluminium Paper Insulated Lead Covered (PILC) three-core cable to 95 sq.mm Copper High-Density Cross-linked Polyethylene (XLPE) single-core cables. It was commissioned in 2000.

There was no personal injury in the incident and no property damage other than the tri-joint concerned.

A total of 388 customers, among the 808 customers residing in On Mei House experienced interruption of power supply. There was an 11kV voltage dip that lasted for about 0.22 second.

The following is the sequence of events on 7 January 2024:

- At 09:38 hours, an alarm indicated a suspected fault on an 11kV transformer feeder circuit supplying the customer substation "On Mei House 'B' substation" in Cheung On Estate, Tsing Yi. CLP emergency response team was called to attend site.
- At 09:58 hours, CLP emergency response team arrived at the site and started to inspect the substation. An 11kV tri-joint installed inside a cable trench of On Mei House 'B' substation was found faulty. The faulty 11kV cable circuit was then isolated and earthed.
- Shortly afterwards, CLP coordinated with the estate management office of Cheung On Estate to arrange a registered electrical worker to perform switching on customer side low voltage switchboard for power restoration to affected customers.
- At 11:04 hours, upon arrival of the registered electrical worker from the estate management office, switching was done on the customer side low voltage switchboard. Power supply was fully restored from another CLP's in-service supply source.
- At 19:17 hours, the faulty tri-joint was replaced, and the transformer circuit was re-energised.
- At 10:10 hours on 8 January 2024, the registered electrical worker from the estate management office restored the change-over at the customer's low voltage switchboard, supply arrangement then resumed normal.

3. The Investigation

3.1 Design and Maintenance Record

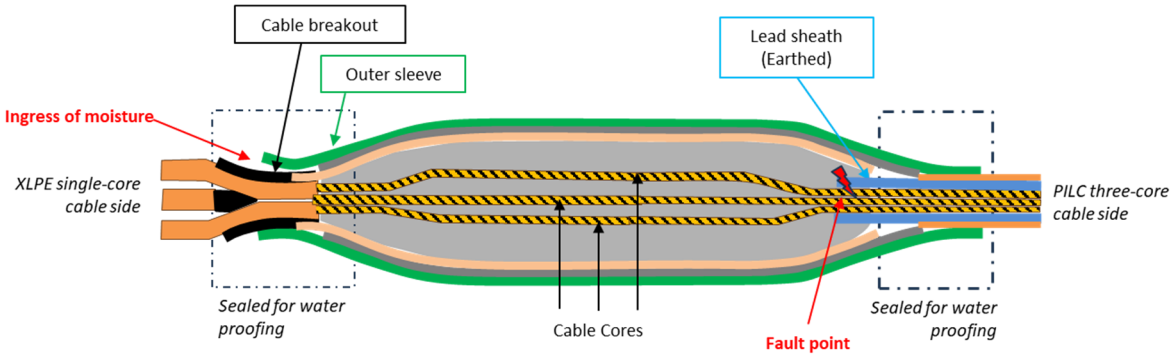
1. The faulty tri-joint connected a 150 sq.mm Aluminium PILC three-cores cable from On Mei House 'A' substation to a 95 sq.mm Copper XLPE single-core cables for termination to a transformer inside the On Mei House 'B' substation.
2. The faulty tri-joint was commissioned in 2000 thus had been in service for about 23 years. It was installed inside a cable trench covered by chequer plates in On Mei House 'B' substation.
3. The OEM of the tri-joint concerned has supplied CLP with similar types of tri-joints since 1998. Currently, there are 26 sets of 11kV tri-joints from the same OEM used in similar transformer feeder circuits in CLP's network.
4. The tri-joint was designed in accordance with IEC-60502 standard "Power cables with extruded insulation and their accessories for rated voltages from 1 kV up to 30 kV".
5. The OEM had no requirement for any specific maintenance for this type of tri-joint. Further, with reference to the prevailing practices in the power industry, there is no specific maintenance requirement on cable joints. Inspection of the customer substation takes place at a two-year interval. The last inspection was conducted in July 2022, and no abnormality was observed.
6. According to records, there was only one fault incident associated with the concerned type of tri-joint happened in 2015 since the tri-joints were introduced to CLP system in 1998. Therefore, this was the second incident of tri-joint fault in 25 years.

3.2 Investigation Findings

Further to site inspection, a detailed investigation into the faulty tri-joint by dissection at CLP workshop was conducted on 8 January 2024.

Investigation revealed that the water proofing capability of the tri-joint was impaired. The outer sleeve and the cable breakout which were supposed to tightly adhere to each other for water proofing was found peeled off at the XLPE cable side, leaving a gap that allowed ingress of moisture.

Moisture was present inside the joint evidenced by sign of corrosion on the metallic part inside the tri-joint body. Deterioration in insulation was observed, in particular at the earthed lead sheath of the PILC cable that formed a weak point where insulation breakdown developed over time, and a fault eventually occurred at the tri-joint.



4. Root Cause Analysis

Based on the investigation findings, it appears that there was premature aging of the joint material that led to deterioration of the sealing at the outer sleeve as such the hydrophobic (water proofing) capability of the tri-joint was impaired.

In the typical design of land cable joints including tri-joints, the hydrophobic capability is achieved by having a tight sealing between the outer sleeve and the cable breakout of the joint to withstand normal water pressure.

However, with the impaired hydrophobic capability, moisture entered the joint through the sealing gaps which then seeped into the inner part of the tri-joint, and all inner components including the lead sheath were directly exposed to corrosion effect caused by the moisture. The insulation integrity deteriorated over time thus leading to the insulation breakdown.

Exclusion of Other Possible Causes

Other common failure causes to cable joints were also analysed to support the investigation conclusion:

1. **Overload**: According to loading records in the past 5 years (up to the date of power interruption), the loading on the circuit remained below 40 amperes which was well below the rated current carrying capacity of the cable (240 amperes). The circuit operated in normal condition and early aging due to overloading could be ruled out.
2. **Third-party Interference**: No indentation or signs of external interference was observed on the tri-joint. It is reasonable to eliminate the possibility of third-party damage to the tri-joint leading to the failure.
3. **Workmanship**: Detailed investigation of the faulty tri-joint revealed no sign of defective workmanship. The fault point located inside the lead sheath at PILC cable side, which was not bent nor in any position giving rise to extra stress. On checking against the jointing instruction and the effort anticipated for disassembling a proper joint, there was no deviation that indicated improper

assembly, loosen connections, inadequate sealing, or other workmanship defects.

5. Status of Installation in System

The incident involved an 11kV tri-joint connecting 150 sq.mm Aluminium PILC three-core cable to 95 sq.mm Copper XLPE single-core cables. The 11kV tri-joint was commissioned in 2000. Similar types of tri-joints have been supplied by the same OEM since 1998, and the design of the tri-joint follows international standard. At present, there are 26 sets of tri-joints supplied by the same OEM used in similar transformer feeder circuits in CLP's network.

CLP's records revealed there was only one fault incident associated with the concerned type of tri-joint before this incident. This was the second failure in 25 years for tri-joints installed in such a configuration.

The current CLP maintenance regime has no maintenance requirement for 11kV tri-joints, which align with all cable joint OEM recommendations and prevailing practices in the power industry.

The International Council on Large Electric Systems (CIGRE[2]) suggests that the PILC cable system is typically expected to have 50-60 years of service life under normal operating conditions. It also revealed that corrective maintenance (i.e. by repairing or replacing the failed equipment) is the commonly adopted maintenance strategy for Medium Voltage (MV), i.e. 1kV - 36kV, cable system.

Despite the fact that no specific maintenance practice was recommended for MV cable system, CLP conducts a substation inspection every two years. The substation inspection includes checking on the environment conditions of the substation, visual inspection of exposed cables as well as partial discharge testing on the MV switchgear and cable terminations to identify abnormality, if any. Such maintenance practice is on par with industrial standard, although limitations still exist to unearth hidden issue in the system.

[2] CIGRE (The International Council on Large Electric Systems) established in 1921, is a global nonprofit organization that focuses on high voltage electricity, with thousands of professionals from over 90 countries and 1250 member organizations, including leading experts in the field.

6. Follow Up Action

Recommendation for Risk Reduction Measures

To step up efforts to allay the concerns of customers, CLP has taken immediate additional measures to patrol and inspect customer substations in Tsing Yi area with a view to reducing the risk of power supply interruption to customers in the area.

Measures for Enhancing Supply Security in Tsing Yi Area

i. Inspect all 370 customer substations in Tsing Yi area, including infra-red measurements on low voltage distribution board and partial discharge testing on 11kV switchgear

   Completed on 17 January 2024. No abnormality was found.

ii. Conduct partial discharge testing on the other transformer feeder circuit with the same type of tri-joints in Tsing Yi area

   Completed on 18 January 2024. No abnormality was found.

iii. Elevate cable route patrol on construction sites in Tsing Yi area to prevent third-party damage to underground cables.

Measures for Monitoring the Tri-joints

iv. Continue partial discharge testing on the rest of similar transformer feeder circuits with the same type of tri-joints in other districts for condition assessment.

   24 sets in other districts to be completed by February 2024.

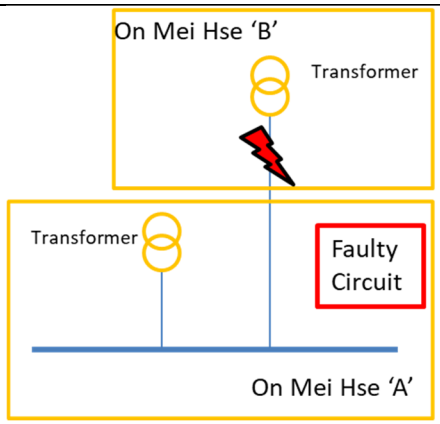
v. Formulate further condition assessment plan for all same type of tri-joints with the same supply configuration, taking opportunity of equipment shutdown with coordination of customers.

Long-Term Plan

vi. A comprehensive review of the maintenance regime of the power supply system.

vii. To enhance communication with customers affected by power interruption, apart from strengthening liaison with property management companies to improve coordination of incident response actions, CLP will leverage our close contact with community leaders including District Officers, District Councillors, rural committee members, etc. to ensure timely information dissemination.

7. Attachments

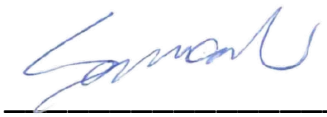
1.	 11kV Network diagram of the faulty circuit
2	 Environment of On Mei House 'B' Substation

Annex II

Nga Ying Chau Street Substation Voltage Dip Incident On 1 January 2024

INCIDENT INVESTIGATION REPORT

Submitted by:



Mr. Sam Law
Director - Asset Management

Date: 27th January 2024

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

On 1 January 2024, a voltage dip incident occurred which involved a power system component fault inside a CLP 132kV substation located at Nga Ying Chau Street in Tsing Yi area. Power supply remained uninterrupted during the incident.

At 15:13 hours, the CLP real-time operation system detected a system abnormality associated with a 132kV cable connecting a Ring Main Unit (RMU) and a transformer inside the substation and the circuit was automatically isolated by CLP's protection system. Site investigation by CLP emergency response team discovered that an outdoor cable sealing end (CSE) connecting to the RMU at L3 phase was faulty. The fault caused a voltage dip (L3 phase voltage dropped to 25% for about 0.08 second), but with the N-1 design of the 132kV supply network, power supply was maintained through auto-switching to CLP's alternative supply path, as such no supply interruption occurred.

Witnesses reported seeing white smoke from the substation and hearing a loud sound at the scene. The white smoke had dissipated before the CLP emergency response team arrived at 15:40 hours, and Fire Services Department (FSD) and Hong Kong Police Force (HKPF) were already at the scene. There was no sign of fire at the scene.

Further investigation into the faulty CSE revealed no sign of corrosion on metallic parts. Fragments of broken insulator collected from the scene were inspected, among them, insulation material breakdown was identified inside the CSE. Signs of electric discharge were also found in close vicinity.

The investigation suggests material flaw to be the cause of failure in the CSE, degrading the insulation material over time until electric discharge occurred, which resulted in an electrical fault at the CSE. The origin of the material flaw could not be confirmed as the insulator has been totally sealed without re-opening since commissioning.

The white smoke reported at the scene is likely due to dissipation of silicone oil, the insulation oil inside the CSE, under high pressure, as there was no sign of fire or any melted fragment found at the scene.

The concerned CSE has been operating in system for about 26 years. CLP has performed regular maintenance on RMU and substation inspection which covered the concerned CSE, no abnormality was reported from the last substation inspection done in November 2023.

The CSE concerned inside the 132kV substation at Nga Ying Chau Street was designed according to IEC-60859 Standard. This model of CSE has been introduced to CLP's network since 1991, a total of 74 sets are in use in system and no failure case associated with the concerned model of CSE had been reported so far. As such, the CSE fault incident on 1 January 2024 was considered a standalone case.

Subsequent to the equipment fault incident, CLP has taken immediate steps to inspect all four 132kV substations in Tsing Yi area and conducted partial discharge testing on all CSEs in those four

substations which revealed no abnormality. Further checking on remaining CSEs of the same model in other districts were also done to confirm healthy conditions.

CLP will continue to conduct partial discharge testing on all CSEs of the same model to assess the insulation condition. Such testing is expected to be completed by February 2024.

As a longer-term measure, CLP will undertake a comprehensive review of the maintenance regime of the power supply system and explore innovation and technology solution for online condition monitoring.

Table of Contents

1. Introduction

On 1 January 2024 at 15:13 hours, a voltage dip incident occurred which involved a power system component fault inside a CLP 132kV substation located at Nga Ying Chau Street (NGA) in Tsing Yi area. The CLP real-time operation system detected a fault on the 132kV cable circuit connecting a ring main unit (RMU) and a transformer inside the substation and the circuit was automatically isolated from the supply network immediately by CLP's protection system. There was no power interruption as the supply was maintained through auto-switching to CLP's alternative supply path. However, a voltage dip occurred, with L3 phase voltage dropped to 25% for about 0.08 second.

Witnesses reported seeing white smoke from the substation and hearing a loud sound at the scene. The white smoke had dissipated before CLP emergency response team arrived at around 15:40 hours, Fire Services Department (FSD), and Hong Kong Police Force (HKPF) were already at the scene. There was no sign of fire at scene.

Upon preliminary investigation, CLP emergency response team reported that an outdoor cable sealing end (CSE) at the L3 phase of the NGA RMU No. 1 connecting a transformer was broken, the faulty component was referred "132kV RMU L3 Phase CSE".

CLP took immediate action to commence repair work and fault investigation, at the same time enhanced preventive actions by inspecting all 132kV substations and conducting partial discharge testing on RMU CSEs in Tsing Yi in order to ensure power supply security in the area and prevent similar fault case.

2. The Incident

The power system component at fault was a 132kV cable sealing end (CSE) for connecting a 500 sq.mm single core Copper Cross-linked Polyethylene (XLPE) cable to the 132kV RMU in NGA substation. The CSE was commissioned in 1998.

There was no personal injury incurred in the incident and no property damage other than the concerned CSE.

The following is the sequence of events on 1 January 2024:

- At 15:13 hours, the RMU circuit tripped with alarm received by CLP System Control Centre. CLP emergency response team was called to attend site.
- At 15:20 hours, FSD informed CLP Security about a reported sound from NGA substation and the message was relayed to CLP System Control Centre.
- At 15:29 hours, CLP notified EMSD about the incident according to established reporting mechanism.
- At 15:40 hours, CLP emergency response team arrived NGA substation and started site investigation with FSD and HKPF. There was no sign of fire at scene.
- Preliminary site investigation revealed presence of oil track spread inside RMU No.1 bay, the CSE at L3 phase was found broken.

3. Restoration Arrangement

The CLP automatic protection system isolated the faulty circuit upon detection of the fault. However, the fault at 132kV level induced a voltage dip, a L3 phase voltage drop to 25% level for about 0.08 second was recorded. There were reported people trapped in lifts and false activation of fire alarm in the Kwai Tsing area.

With the N-1 design of the 132kV supply network, power supply was maintained through auto-switching to CLP's alternative supply path, as such no supply interruption occurred.

Upon examination and testing at site, the concerned RMU remained intact, the faulty CSE will be replaced with a new one which is planned for completion by 31 January 2024, without need for any power shutdown to customers.

4. The Investigation

4.1 Design and Maintenance Record

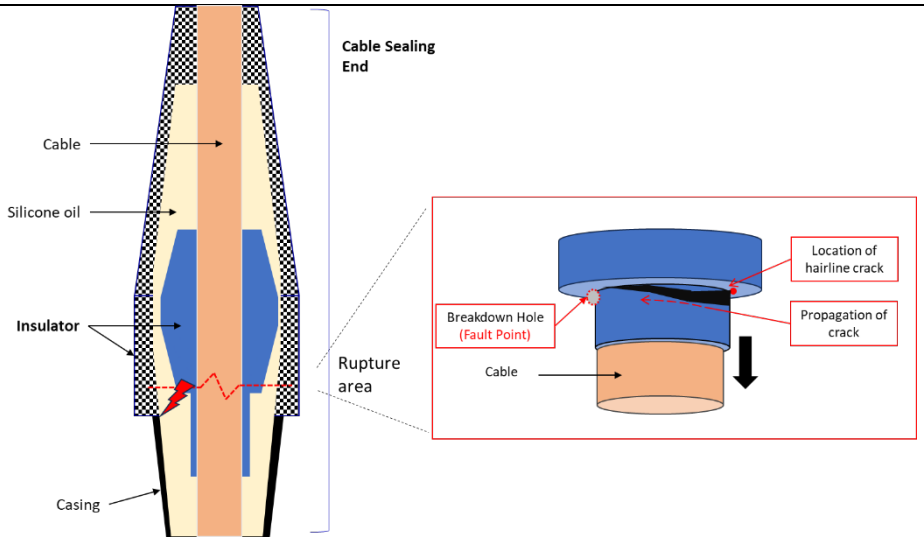
1. The faulty CSE was a 132kV CSE for connecting a 500 sq.mm single-core Copper XLPE cable to the 132kV RMU. The concerned CSE was commissioned in 1998, thus has been in service for about 26 years. The designed capacity of the CSE is 150MVA, and records indicated no overload in the circuit.
2. The insulation oil adopted in the CSE was silicone oil for filling voids within the insulator.
3. Same model of 132kV CSE was supplied under same supply contract in late 1990's. At present, a total of 74 sets of same model CSE are in use in CLP's network.
4. The CSE was designed in accordance with IEC-60859 standard "Cable connections for gas-insulated metal-enclosed switchgear for rated voltages of 72,5 kV and above - Fluid-filled and extruded insulation cables - Fluid-filled and dry type cable-terminations".
5. The Original Equipment Manufacturer (OEM) had no requirement for any specific maintenance on the CSE. The CLP maintenance regime on CSE includes periodic inspection during RMU regular maintenance at six-year intervals and substation inspection at six-month intervals. The last NGA substation inspection was done in November 2023 which revealed no abnormality.
6. There was no failure record for same model of CSE prior to the incident.

4.2 Investigation Findings

Upon site investigation on 1 January 2024, only the L3 phase CSE of the RMU was damaged while all other components were checked in good condition. Fragments of the insulator were found in the vicinity of the CSE and traces of insulating oil were spread on the wall of the RMU bay at a level aligned with the installation height of the damaged part of the CSE.

A detailed investigation into the faulty CSE by dissection at CLP workshop was conducted on 8 January and 9 January 2024. Insulation oil within the broken insulator was leaked out. The insulator ruptured with its lower part detached.

A hairline crack was found on the lower part of the insulator which propagated horizontally to a breakdown hole, sign of electric discharge was identified on the cable immediately beneath the breakdown hole which was inferred the fault point. The other two phases, i.e. L1 phase and L2 phase CSE connected to the same RMU were also dissected, no similar crack nor other abnormality found.



132kV RMU L3 Phase CSE

5. Root Cause Analysis

The investigation suggests a material flaw inside the CSE to be the root cause of the fault.

The origination of the hairline crack could not be confirmed. Such crack was not expected during installation, and the CSE had not been reopened since commissioning, it is uncertain when it was formed. CLP's prevailing installation procedures ensure inspection and commissioning tests are done to confirm installation quality, it is reasonable to infer that the hairline crack was developed after the time of commissioning. Investigation into the two other L1 and L2 phases CSE found no similar hairline crack, which confirmed not a type defect but a standalone case.

The CSE is consistently subject to thermal cycling and mechanical stress during operation. Such temperature variations and mechanical stress cause movement and extra stress could exert on any weak point like the hairline crack found on the insulator. Over time, the small crack developed into a more severe one, which degraded the insulation material and eventually resulted in electric discharge that failed the CSE.

Other Relevant Findings

5.1 The White Smoke

As reported, white smoke emitted from Nga Ying Chau Street Substation during the incident, which dissipated within a short time. There was no sign of fire, or any melted

fragments found at the scene, as such, possibility of white smoke as a result of combustion could be ruled out.

Silicon oil was present inside the CSE, which was adopted to fill voids within the CSE for insulation and moisture protection purpose. It is commonly adopted in the industry as an insulation medium which is not a hazardous substance.

At the time of fault, it was possible that high pressure had been developed within the CSE which ruptured the insulator. Small cracks developed around the insulator like nozzles, through which silicon oil spilled out in the form of mist and carried away by air, which appeared like white smoke.

5.2 Oil Sampling of the CSE

Silicon oil in two other L1 and L2 phases CSEs were sampled for laboratory tests which included dissolved gas analysis (DGA), and analysis of water content, breakdown voltage, acidity and color at CLP oil laboratory.

The test results of the oil samples from both L1 phase and L2 phases CSE were satisfactory.

5.3 Exclusion of Other Possible Causes

Other common failure causes to power equipment were also analyzed to support the investigation conclusion:

1. **Overload:** According to loading records in the past 5 years (up to the date of the incident), the loading on the circuit remained below 35MVA, i.e. well below the design capacity of 150MVA. The failure of the CSE due to overload could be ruled out.
2. **Third-Party Interference:** The faulty CSE is physically enclosed, no indentation mark or sign of third-party interference was observed during dissection. Failure due to third-party interference could be ruled out. Maintenance record indicated the CSE had not been opened nor exposed.
3. **Environmental Factor**: The faulty CSE was not located in an outdoor area with adverse environmental conditions, no sign of corrosion or oxidation was identified. Therefore, it is reasonable to eliminate the environmental factors as a cause of failure.
4. **Workmanship**: Detailed investigation of the faulty CSE revealed no sign of workmanship issues. On checking against the installation instruction, there was no deviation from the expected assembly, no loosen connections, no inadequate sealing, or other workmanship defects upon dissection of the CSE.
5. **Moisture Ingress**: There was no sign of moisture ingress. If there had been any presence of moisture inside the CSE, there should be sign of degraded insulation, corrosion and electrical leakage paths that could cause insulation breakdown. However, there was no such observation during the investigation, moisture ingress could be ruled out as a cause of failure.

6. **Maintenance**: According to CIGRE[1] recommendation on HV cable system, visual inspection is the most common maintenance requirement on cable terminations, which is effective in identifying abnormalities. Further condition checking by partial discharge detection should be applied only when the insulation condition of CSE is in doubt. As such the historical maintenance was on par with the international practices.

6. Status of Installation in System

The incident involved a 132kV oil-immersed type CSE for connection of a 500 sq.mm single core Copper XLPE cable commissioned in 1998 and has been in use for about 26 years. This model of CSE has been introduced to CLP's network since 1991, and currently there is a total of 74 sets in use in system.

The OEM had no requirement for any specific maintenance on CSE. CLP's maintenance regime on CSE includes periodic inspections which is covered in the RMU maintenance and substation inspections. Based on records, no abnormality found during the past substation inspection in November 2023.

The CIGRE suggests that the XLPE cable system is typically expected to have 40 – 50 years of service life under normal operating conditions, and visual inspection is the most common maintenance task on cable terminations, i.e. the cable sealing end. It is an established maintenance activity proved to be effective in detecting various kinds of abnormality. The recommendation is to perform visual inspection at least once per year.

No similar failure had been reported in the past history of the same model CSE thus far, indicating an extremely low failure expectation for this CSE model.

7. Follow Up Action

To step up efforts to allay the concerns of customers, CLP has taken immediate additional measures to further reduce the risk of power supply interruption to Tsing Yi area and to the rest of the system.

<u>Measures for Enhancing Supply Security in Tsing Yi area</u>

i. Inspect all four 132kV substations in Tsing Yi area, including plant condition by additional insulation gas sampling, cable oil pressure checks and 11kV patrial discharge monitoring system check.

   Completed on 25 January 2024. No abnormality was found.

[1] CIGRE (The International Council on Large Electric Systems) established in 1921, is a global nonprofit organization that focuses on high voltage electricity, with thousands of professionals from over 90 countries and 1250 member organizations, including leading experts in the field. Its Technical Brochure 825 "Maintenance of HV Cable System" recommends maintenance strategy for HV cable system.

ii. Conduct partial discharge testing on all 132kV RMU CSEs inside the four 132kV substations in Tsing Yi area.

Completed on 19 January 2024. No abnormality was found.

Measures for Monitoring 132kV CSE of The Same Model

iii. Conduct check on the rest 70 sets of 132kV CSE in other districts, for identifying any sign of silicone oil leakage, cable movement, and any abnormalities potentially affect equipment performance.

Completed on 6 January 2024. No abnormality was found.

iv. Continue partial discharge testing on all the rest 70 sets of 132kV CSE in other districts to assess conditions of CSE of the same model.

Target for completion within February 2024.

v. More frequent substation inspection for locations with 132kV CSE of the same model.

Long-Term Plan

vi. A comprehensive review of the maintenance regime of the power supply system.

vii. Explore innovation and technology solution for online condition monitoring.

8. **Attachments**

1.

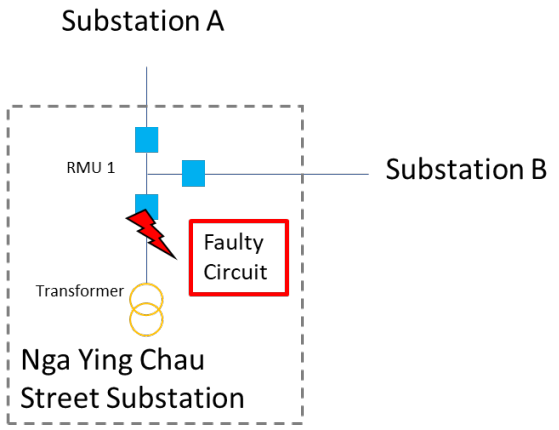


Diagram of the Ngau Ying Chau Street Substation

Transmission Overhead Line Tower Guide Wire Sagging Incident at Au Tau, Yuen Long

On 19 March 2024

INCIDENT INVESTIGATION REPORT

Submitted by:

Mr. Sam Law
Director – Asset Management

Date: 15th April 2024

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

On 19 March 2024, CLP's contractor, Jilin Province Power Transmission & Substation Project Company Limited (JPPC), was carrying out restringing work on a de-energized 400kV overhead line circuit (Shenzhen – Yuen Long No. 1 circuit) at Au Tau, Yuen Long for the purpose of upgrading the circuit. The circuit upgrading project commenced in December 2022 with restringing for a section between Overhead Line Tower 1 (T1) to Tower 9 (T9) of the circuit scheduled to take place between February 2024 and April 2024.

At around 12:21 hours, during the restringing of an Optical Ground Wire (OPGW), a dual functioning wire for lightning protection and communication, a guide wire that facilitated the pulling of the OPGW was inadvertently over-sagged between Tower 2 (T2) and Tower 3 (T3) and lowered to the level of the vehicular bridge underneath. The sagged guide wire which was not carrying electricity then got caught by a moving vehicle and was dragged forward for about ten metres which damaged two street light poles and interfered with a nearby 11kV equipment pole. There was no injury in this incident.

As a result of the interference to the 11kV equipment pole, 68 customers experienced a power interruption. At 12:30 hours, CLP and JPPC arrived on the scene and took immediate steps to lift the sagged guide wire and restore supply to customers. By 13:09 hours, power supply was restored to 47 customers, and the remaining 21 customers had their power resumed by 14:01 hours.

After the incident, CLP immediately instructed JPPC to suspend all restringing work and investigated the root cause to identify an effective improvement plan. The investigation revealed that the "double-pulley system" which is a fall prevention system required for crossing the highway had not been implemented at the restringing work of the OPGW by JPPC at the time of incident.

Furthermore, investigation also revealed that the restringing machine operator had adjusted the pulling tension of the restringing machine without an instruction from the lookout man, whose responsibility was to monitor the pulling operation of the restringing work and the degree of sagging of the wire being restrung. The site coordination was not the most effective due to a lack of a clear commander role who would have centrally coordinated the pulling tension by responding to site situation.

Immediately after the incident, CLP has taken immediate actions to review the implementation of work procedures and safety measures, as well as site supervision at the work site for the purpose of investigation into the root causes with JPPC. To ensure site safety, CLP has instructed JPPC to strengthen its site supervision, which includes: (1) ensuring that safety measures and proper work procedures are executed by designating a contractor responsible personnel to verify and monitor such implementation including a "double-pulley system" in the restringing work at high-risk areas, (2) introducing a central commander to issue and confirm all instructions given to machine operators, and (3) introducing a CCTV system to aid the central commander to exercise effective oversight of the site condition when high-risk activities are carried out.

Apart from the site supervision enhancement measures to be adopted by JPPC, CLP has stepped up its monitoring of the work of JPPC to ensure its effective execution of enhancement measures. Upon resumption of restringing work, CLP will step up routine checking with extra inspection by CLP's own safety officers on critical tasks. CLP will also carry out site checks on the central commander role and the CCTV system setup as recommended in this report to verify that JPPC's oversight of the work site and its coordination are properly carried out.

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1. Introduction

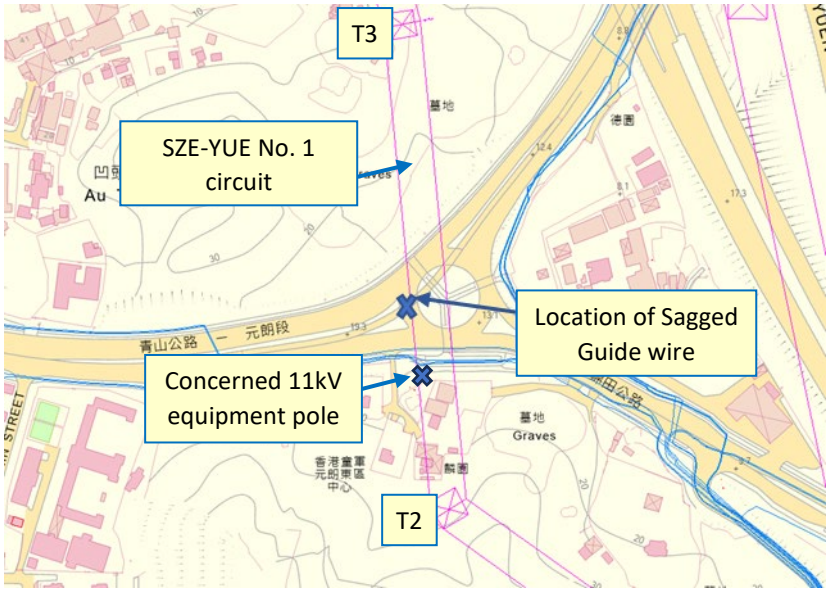
On 19 March 2024, CLP's contractor, Jilin Province Power Transmission & Substation Project Company Limited (JPPC), was carrying out restringing work for Shenzhen (SZE) - Yuen Long (YUE) No. 1 circuit for the purpose of upgrading the circuit. The JPPC work team was tasked with restringing an OPGW, a dual functioning wire for lightning protection and communication between Tower 1 (T1) and Tower 9 (T9) on that day.

At 12:21 hours, during the restringing work of the OPGW, a guide wire that was used to facilitate the pulling of the OPGW inadvertently over-sagged between T2 and T3 and lowered to the level of the vehicular bridge above the Au Tau Interchange in Yuen Long. The over-sagged guide wire then got caught by a moving vehicle and was dragged forward for approximately 10 metres which damaged two street light poles and interfered with a nearby 11kV equipment pole. There was no injury in this incident.

A total of 68 customers experienced a power interruption due to the tripping of the interfered 11kV circuit. At 13:09 hours, 47 customers had their power restored, and the remaining 21 customers had their power restored by 14:01 hours.

2. The Incident and Restoration Arrangement

Prior to the incident, SZE-YUE No. 1 circuit had been de-energised for the restringing work.



Location of Incident

The following is the sequence of events that occurred on 19 March 2024:

- At 09:30 hours, the JPPC team commenced the restringing work for the OPGW between T1 and T9.
- In the morning, CLP's inspectors attended both T1 and T9 to inspect the restringing machines set up change at the respective locations.
- At 12:18 hours, the restringing machine operator at T1 adjusted the pulling tension of the restringing machine without an instruction from the lookout man.
- At around 12:20 hours, the lookout man stationed between T2 and T3 noted the over-sagging of the guide wire and alerted the operator via walkie-talkie to increase the pulling tension.
- At 12:21 hours, the guide wire over-sagged to the vehicular bridge level and got caught by a moving vehicle. Subsequently, the guide wire was dragged forward for about 10 metres which damaged two street light poles and interfered with a nearby 11kV equipment pole causing supply interruption to 68 customers. No injuries were reported.
- At about 12:30 hours, CLP's inspectors, JPPC team and the Police arrived at the scene.
- CLP's inspectors conducted a site check to confirm the conditions of the guide wire and mobilized the JPPC team to lift the over-sagged guide wire.

- At 12:57 hours, CLP Emergency Response Team attended the site to inspect the interfered 11kV equipment pole.
- At 13:09 hours, the power supply to 47 affected customers was restored after isolating the 11kV equipment pole.
- At 14:01 hours, the supply to the remaining 21 affected customers was fully restored after replacing the blown fuses at the 11kV equipment pole.
- At 14:30 hours, the guide wire between T2 and T3 was lifted and restored to original position.
- At 15:15 hours, CLP instructed JPPC to suspend all restringing works until further notice.

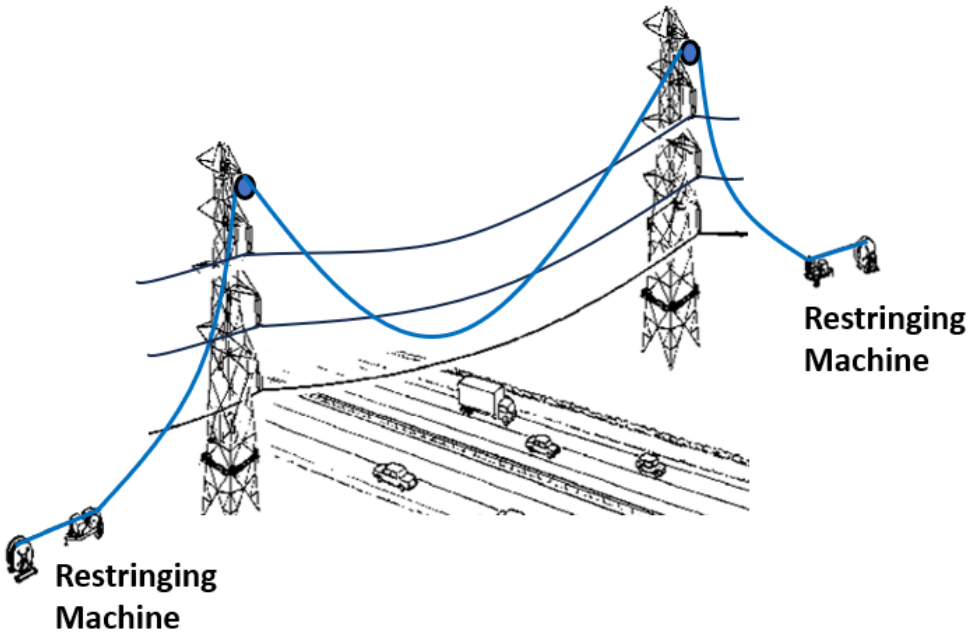
3. The Investigation

3.1 Background

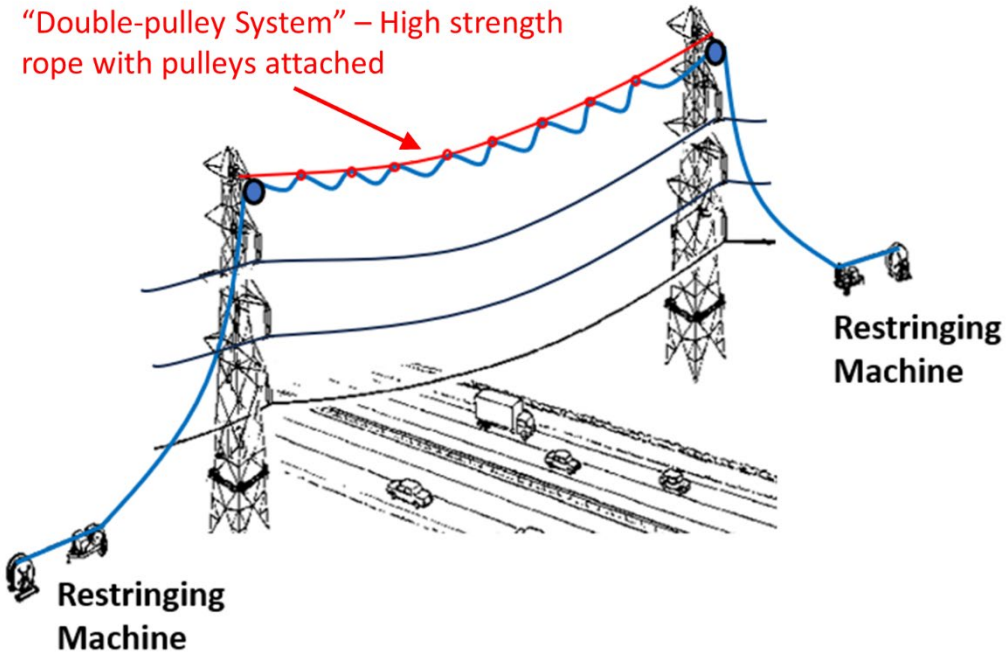
CLP appointed JPPC as its contractor to take up the overhead line upgrading project through a robust tendering process based on JPPC's proven track record in conducting overhead line projects both in and outside Hong Kong.

The project, which started in December 2022, targets to upgrade a number of 400kV overhead line circuits. As part of the project scope, overhead line conductors and OPGW of SZE-YUE No.1 circuit are to be restrung. JPPC is responsible for establishing method statement, risk assessment and work procedures, the provision of labour, and supply of materials and tools for carrying out the works. The relevant restringing section, namely the section between T1 and T9, was planned to take place between February 2024 and April 2024.

According to the method statement and risk assessment prepared by JPPC and reviewed by CLP, JPPC would adopt a "double-pulley system" as a fall prevention system to protect restringing work crossing high-risk areas like highways and railways. A "double-pulley system" consists of a high strength rope with pulleys attached to it to provide backup support in case a wire loses tension and sags. The working principle is illustrated in the diagrams below. Such "double-pulley system" is a fall prevention measure for overhead line work commonly adopted in the industry, a safe and practicable option for crossing highways regardless of day or night work. Despite lighter traffic, restringing at night would cause workers facing increased risk of falls due to reduced visibility, thus not implemented at the location concerned.



Over-sagged guide wire without a "double-pulley system"



Over-sagged guide wire with a "double-pulley system"

For the restringing work at section between T1 and T9, JPPC deployed four site supervisors to supervise the site work. CLP had inspectors to conduct extra site inspections to assess the contractor's safety performance and identify any area for

improvement. A few days before the incident while the overhead line conductors in the same section were being restrung, a site inspection by CLP's inspector revealed that the "double-pulley system" was in place.

3.2 The Incident and the Investigation

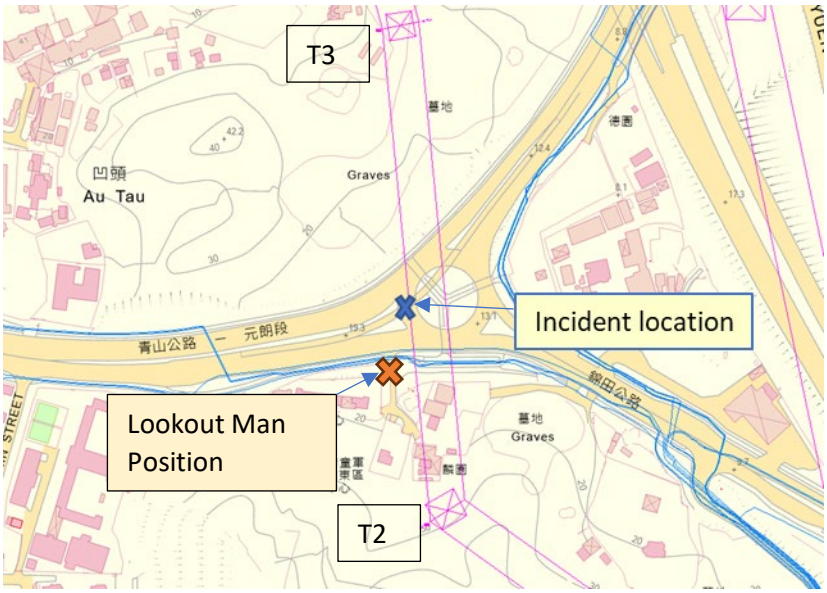
On 19 March 2024, the JPPC team scheduled to commence restringing the OPGW between T1 to T9 (which are approximately 3km apart). Before the commencement of the restringing work, CLP's inspectors attended both T1 and T9 to inspect the restringing machines set up change at the respective locations that morning, as it was critical for safe commencement of the restringing work. The restringing work commenced after the restringing machines were properly set up. Around noon time, the guide wire which facilitated the pulling of the OPGW inadvertently over-sagged between T2 and T3. The over-sagged wire was lowered to the level of the vehicular bridge and subsequently got caught by a moving vehicle.

An investigation was conducted to look into the causes of the over-sagging. It revealed that the required "double-pulley system" between T2 and T3 was not implemented at the time of the incident. As a result, there was no effective fall prevention measure in place that would stop the over-sagging of the guide wire.

To monitor the pulling operation of the restringing work and the degree of sagging of the wire being restrung, JPPC deployed a lookout man for each high-risk crossing to monitor the safe distance from ground throughout the restringing work and to instruct operators to adjust the pulling tension.

The investigation found that during the restringing work, the restringing machine operator at T1 adjusted the pulling tension without an instruction from the lookout man. The operator was overwhelmed by the seemingly over-tensioned guide wire and made an incorrect decision to adjust the pulling tension without an instruction.

The observation position of the lookout man between T2 and T3, however, was not at an optimal level which impaired his judgment of the distance of guide wire above ground. At the time he noted the over-sagging, his request to re-tension the guide wire via the walkie-talkie was too late to remedy the over-sagging.



Position of lookout man at line section T2-T3 on 19 March 2024

View of T3 and line section T2-T3 from position of the lookout man

4. Root Cause Analysis

The investigation reveals root causes of the incident being:

(1) The "double-pulley system" required in the risk assessment and method statement as an effective fall prevention measure for crossing high-risk areas like highways and railways had not been implemented due to JPPC team's complacency. Had such system been in place, the over-sagged guide wire would have remained suspended on the "double-pulley system".

(2) The restringing machine operator adjusted the wire tension without an instruction from the lookout man, whose responsibility was to monitor the pulling operation of the restringing work and the degree of sagging of the wire being restrung.

(3) The site coordination was not the most effective due to lack of a clear commander role who would have centrally coordinated the pulling tension by responding to site situation.

5. Follow-Up Actions

Immediate Actions

CLP took immediate actions to assess the site conditions with JPPC to secure the area and mitigate further risk. CLP had instructed JPPC to:

1) Lift the over-sagged guide wire for restoration to original position, to ensure safe clearance from the vehicular bridge.
2) Suspend all restringing works until completion of the investigation to conclude root causes of the incident.
3) Conduct a standdown of all work on the following day to re-examine safety culture.

Improvement Measures

After the incident, CLP had reviewed the implementation of work procedures and safety measures, as well as site supervision at the work site to investigate into the root causes with JPPC. To address the findings, CLP has instructed JPPC to take measures to ensure implementation of safety measures at work site and to improve the site coordination. At the same time, CLP will also step up our efforts to monitor the work of JPPC to ensure its effective execution of enhancement measures, these measures include:

1) Ensure execution of safety measures and work procedures at site

   JPPC has been instructed to designate a dedicated responsible personnel to verify and monitor implementation of safety measures and work procedures on site, including the installation of "double-pulley system" at highway and railway crossings for the restringing work. JPPC would provide enhanced training for their work team to highlight the importance of these measures and procedures.

2) Introduce a central commander
   JPPC has been instructed to introduce a central commander, who would be the commander-in-charge to issue and confirm all instructions given to machine operators.

3) Effective oversight of site conditions
   JPPC has been instructed to introduce a CCTV system as an additional aid to the central commander to exercise effective oversight of the site condition when high-risk activities are carried out.

Upon resumption of restringing work, CLP will enhance the frequency of routine checking with extra inspection by CLP's own safety officers on critical tasks, to ensure the above 3 JPPC improvement measures are implemented. All the above improvement measures would be completed within a week of this report submission.

As a longer term measure, CLP will also identify new technologies and digital applications to enhance visibility in managing contractor supervision work at work site, and to raise awareness by strengthening training and feedback.

400kV Voltage Dip Incident during Hill Fire in Shap Pat Heung, Yuen Long

On 30 March 2024

INCIDENT INVESTIGATION REPORT

Submitted by:

Mr. Sam Law
Director – Asset Management

Date: 26th April 2024

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

On 30 March 2024, a voltage dip incident occurred which involved CLP's 400kV overhead line (OHL) system connecting Yuen Long and Lai Chi Kok, although there was no interruption to power supply. The voltage dip incident was caused by a fault triggered by a hill fire in Shap Pat Heung, Yuen Long on the same day.

At 12:28 hours, the CLP real-time operation system detected a fault at Lai Chi Kok – Yuen Long No. 2 (LCE – YUE No. 2) 400kV OHL circuit, the circuit was automatically isolated by CLP's protection system to clear the fault. With the N-1 design of the 400kV supply network, the power supply was maintained and the circuit concerned was also restored through an auto-reclose feature of the 400kV OHL system. The fault, however, caused a brief voltage dip (L3 phase voltage dropped to 18%) for about 0.07 second.

At 12:35 hours, the Fire Services Department (FSD) notified CLP of a reported hill fire close to a CLP OHL tower in Shap Pat Heung, Yuen Long. The CLP OHL patrol team dispatched to the hill fire scene confirmed a hill fire had broken out, affecting an OHL section between Tower 50 (T50) and Tower 52 (T52) of the LCE – YUE No. 2 circuit. The patrol team stayed on standby at the scene to monitor the development of the fire and at the same time a helicopter patrol was also deployed to assess impact of the fire on our 400kV OHL circuit in the vicinity.

After the hill fire had passed the OHL section at around 18:00 hours, CLP immediately inspected the OHL facilities to ensure they were in a condition for safe operation. Post-fire OHL patrol by Small Unmanned Aircraft (SUA) on the next day revealed a flashover mark on a L3 phase conductor near Tower 51 (T51) within the hill fire affected area which coincided with the location identified by CLP's fault location system. There was no sign of remains of flying objects in the area. There was, however, a large area of burnt vegetation, and laboratory analysis also found high carbon content from deposits collected from high levels of T50 to T52 towers, indicating the presence of burnt particles at the conductor level which corelates the fault to the hill fire on 30 March 2024.

To ensure the continued integrity of the LCE – YUE OHL circuit and safe operation of our 400kV supply system, tower climbing checks and thorough cleaning of the affected circuit were further carried out on the following days.

Table of Contents

1. Introduction

On 30 March 2024 at 12:28 hours, the Lai Chi Kok – Yuen Long No. 2 (LCE – YUE No. 2) 400kV overhead line (OHL) circuit experienced a fault which was automatically isolated by CLP's protection system to clear the fault. With the N-1 design of the 400kV supply network, the power supply was maintained and the circuit was then restored by the auto-reclose feature of our 400kV OHL system. The fault caused a voltage dip with L3 phase voltage dropping to 18% for about 0.07 second.

Subsequent to a Fire Services Department (FSD) report case about a hill fire in Shap Pat Heung, Yuen Long, the CLP OHL patrol team dispatched to the scene confirmed a hill fire had broken out, affecting an OHL section between Tower 50 (T50) and Tower 52 (T52) of the LCE – YUE No. 2 circuit. Helicopter inspection was arranged for assessing the impact on the affected circuit while the patrol team stayed standby at the hill fire scene. After the hill fire had passed the OHL section of concern at around 18:00 hours, the patrol team immediately inspected the OHL facilities at a safe distance to assess their condition. There was no noticeable damage and partial discharge measurements suggested an acceptable level for operation.

Post-fire inspection and cleaning for insulators at the affected towers was performed on the following days to ensure the continued integrity of the affected circuit and the safe operation of our 400kV supply system.

2. The Voltage Dip Incident during Hill Fire

A brief voltage dip for about 0.07 second was recorded at 12:28 hours on 30 March 2024, with the lowest voltage dropping to 18% in L3 phase. The following is the sequence of events:

<u>On 30 Mar 2024:</u>

- At 12:28 hours, LCE – YUE No. 2 circuit tripped and successfully auto-reclosed.
- At 12:35 hours, FSD notified CLP about a call from a resident in Sung Shan New Village reporting a hill fire close to a CLP OHL tower in Shap Pat Heung, Yuen Long.
- At 12:42 hours, CLP notified EMSD about the incident according to established reporting mechanism.
- At about 13:00 hours, CLP collected data from fault location system to analyse possible fault location. A CLP OHL patrol team was also dispatched to the hill fire area for identifying any affected circuit.
- At 14:00 hours, CLP OHL patrol team approached the affected OHL section between T50 and T52 of LCE – YUE No. 2 circuit under safe conditions after coordination with relevant government departments at the scene.

- At 16:00 hours, aerial inspection by helicopter was arranged to assess impact of the fire on the OHL circuit. No noticeable damage was observed and the team stayed standby to observe the development of the fire.
- At 17:49 hours, fault location analysis suggested the fault occurred at a location between T50 and T52, coinciding with the hill fire area.
- At around 18:00 hours after the hill fire had passed the OHL section of concern, the patrol team took partial discharge measurements on ground level for insulators at T50, T51 and T52, finding all at acceptable levels to remain in operation.

On 31 March 2024:

- At 08:00 hours, more thorough aerial inspection and partial discharge measurement by Small Unmanned Aircraft (SUA) along the circuit were performed. A flashover mark was found on the L3 phase OHL conductor near T51.

On 2 & 3 April 2024:

- CLP tower climbing team performed detailed post-fire inspection and cleaning for insulators at T50, T51 and T52 of LCE – YUE No. 1 & No. 2 circuits.

2.1 The Hill Fire and Fault Location

According to Hong Kong Observatory (HKO), a "Yellow Fire Danger Warning" was issued and in effect from 10:30 to 18:00 hours on 30 March 2024. Trace rainfall was recorded but no lightning strike was reported. Further, 30 March 2024 fell on a long Easter weekend before Ching Ming Festival during which a lot of ancestor worshipping activities took place in rural areas.

According to a media report, a hill fire broke out in Shap Pat Heung, Yuen Long at around noon time on 30 March 2024. It covered an area of about 50 metres by 60 metres with a fire line stretching approximately 200 metres. The fire was only extinguished at around 01:30 hours on 31 March 2024. CLP's OHL patrol team present at the hill fire scene noted the fire line had passed an OHL section between T50 and T52 of LCE – YUE No. 2 circuit.

Fault location analysis suggested a fault had occurred at approximately 2.4km ± 0.2km from Yuen Long 400kV Substation, which was on an OHL span between towers T50 and T52. This coincided with the hill fire area affecting the LCE - YUE No. 2 circuit.

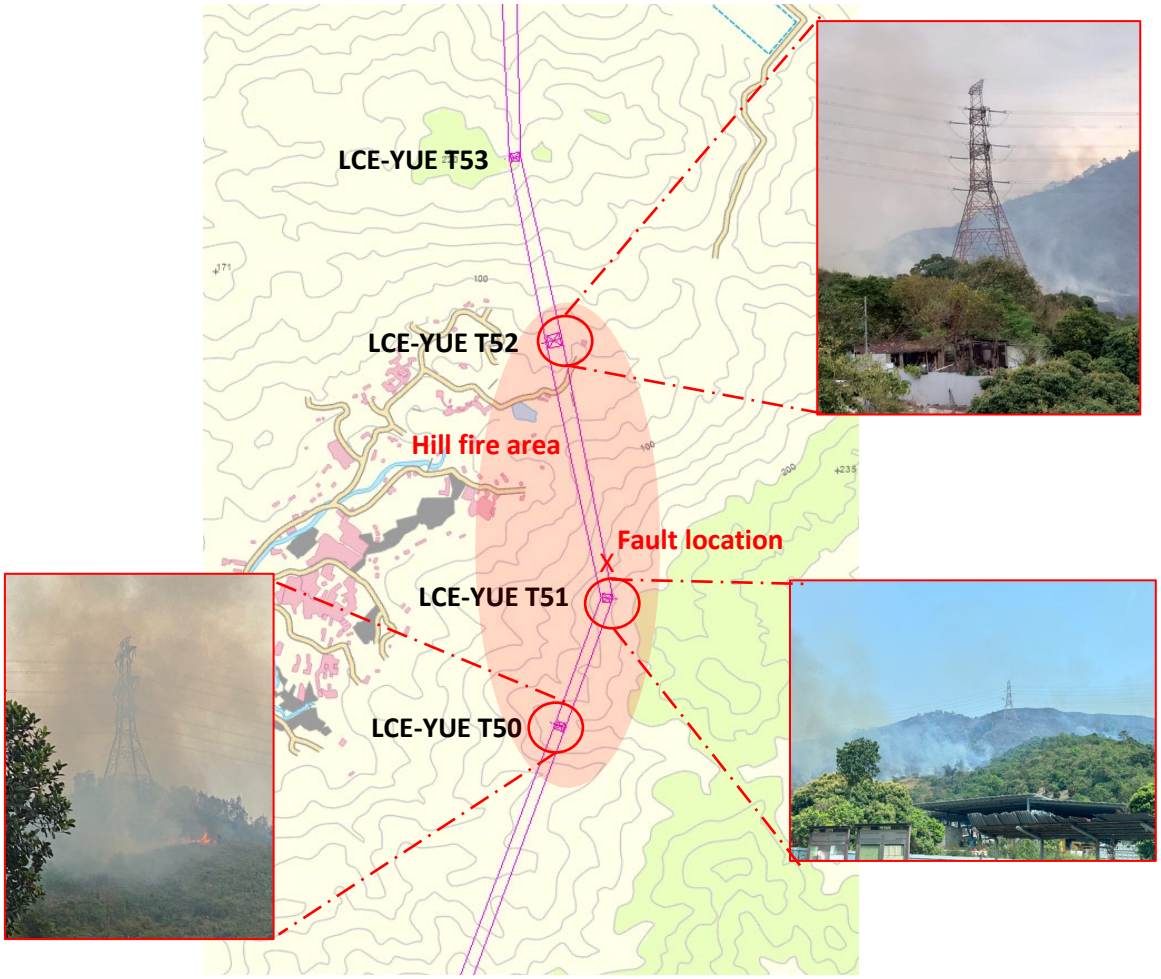


Figure 1: Affected area by hill fire

3. Post-fire Investigation and Findings

3.1 Post-fire OHL Inspection

After the hill fire was put out on 31 March 2024, thorough inspections by SUA and CLP's tower climbing team were conducted along T50 to T52 on 31 March and 2 – 3 April 2024 respectively.

The inspections revealed sufficient vegetation clearance under the affected OHL span and there were no remains of flying objects like kite wires or metal balloons in the vicinity but there was a large area of burnt vegetation. Graves were found scattered in the area near T50 to T52, so ancestor worshipping activities might have taken place.

Partial discharge measurements and close inspection on OHL facilities at the towers identified no damage. However, a flashover mark was found on the L3 phase conductor (the bottommost phase conductor) at 18m away from T51 (Figure 2). There was a burnt tree underneath the flashover mark, with about 7m clearance from the bottommost conductor (Figure 3).

Figure 2: Flashover marks on L3 phase conductor near T51

Figure 3: Burnt tree underneath the flashover mark on L3 phase conductor

3.2 Maintenance Record

Regular inspection and maintenance applies to CLP's 400kV OHL system, including regular insulator cleaning and ground patrol for condition assessment. The last insulator cleaning and ground patrol for the concerned OHL spans of LCE-YUE No. 2

circuit were completed in January 2023 and most recently in February 2024 respectively. No abnormality was reported.

3.3 Laboratory Analysis

Samples of deposits were collected from insulators at the high levels of T50, T51 and T52 for examination in the laboratory. Compositional analysis shows a high carbon content present in the deposits, likely originating from residues of burnt organic material. As compared to the samples collected from neighbouring towers T48-T49 and T53-T54, the carbon content was particularly high at T50, T51 and T52, indicating the space around T50 – T52 had been subject to a severely burnt environment with high levels of carbon particles present in the air sufficient to engulf the phase conductors of the circuit.

3.4 The Fault Point

The fault location analysis suggests a fault had occurred at approximately 2.4km ± 0.2km from Yuen Long 400kV Substation, which correlated with a flashover mark found on a phase conductor located 18m away from tower T51, which is around 2.2km from Yuen Long 400kV Substation.

In general, a safety clearance of 4.5m is to be maintained between OHL and trees to prevent electrical fault due to flashover. The post-fire OHL patrol noted a burnt tree underneath the flashover mark with a clearance of 7m from the bottommost phase (L3 phase) conductor.

Though the safety clearance was well maintained, the extensive carbon content in the surrounding air which is electrically conductive, together with the frame generated from the hill fire which accelerated thermal ionization could set the conditions for a short circuit path thus a flashover from the conductor to trees.

4. Root Cause Analysis

Based on the investigation finding, the voltage dip incident on 30 March 2024 was caused by a fault on CLP's LCE – YUE No. 2 OHL circuit. The fault was triggered by a hill fire that broke out in Shap Pat Heung, Yuen Long on the same day.

A flashover mark found on the bottommost phase conductor near T51 of LCE – YUE No.2 OHL circuit aligned with the fault location analysed by CLP's fault location system. There is a burnt tree immediately beneath the flashover mark with 7m clearance. Though a safety clearance of 4.5m was well maintained, laboratory tests however proved high levels of carbon particles present in the vicinity of T51 during the hill fire, together with the flame generated from the hill fire which accelerated thermal ionization, a short circuit path had been created for a flashover from the conductor to the tree. A fault therefore resulted and triggered the voltage dip incident on 30 March 2024.

5. Follow-Up Actions

Immediate Actions

CLP took immediate steps to ensure continued power supply and safe operation during the hill fire:

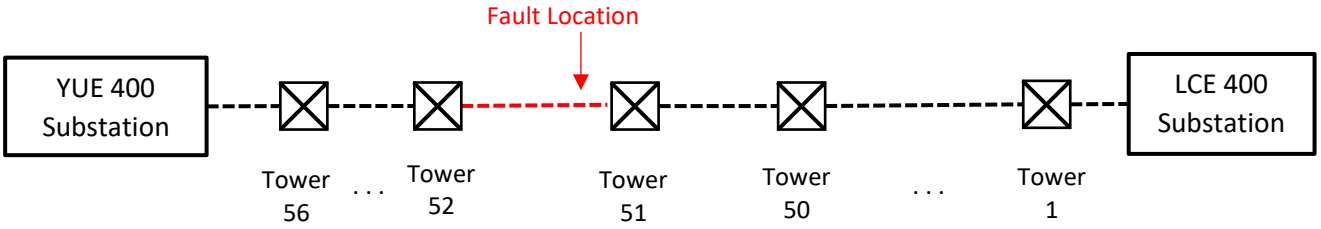
- The LCE -YUE No.2 circuit was restored by the auto-reclose feature of 400kV OHL system within 0.07 second. No interruption to power supply on 30 March 2024.
- Partial discharge measurements for insulators at T50, T51 and T52 were immediately taken at safe distance after the hill fire had passed through these towers on the same day in order to assess conditions for the safe and continual operation of the 400kV circuit.
- Thorough aerial inspection and partial discharge measurement by SUA along the affected circuit was performed on the next day to inspect integrity of the circuit and investigate the cause of fault.
- Insulator cleaning for T50, T51 and T52 of LCE – YUE No. 1 & No. 2 circuits was further carried out during 2 – 3 April 2024 to remove any hill fire ash.

Improvement Measures

As outdoor OHL systems are susceptible to external interference that results in voltage dips, CLP will continue with our precautionary measures against voltage dip due to external factors like hill fire, and raise public awareness about solutions for mitigating impact of voltage dip on customer side:

- Enhanced monitoring of OHL circuit at high-risk areas by more frequent vegetation patrol and condition assessment using SUA before and during grave sweeping and hill fire seasons.
- Continue to enhance communication with FSD for timely exchange on hill fire cases and voltage dip incidents.
- Support educational programme and community reach-outs to raise awareness about voltage dip and share engineering solutions for mitigating the impact of voltage dips.

6. Attachments



LCE – YUE No.2 Circuit

Legend

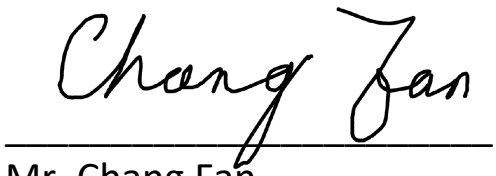
LCE400 Substation	Lai Chi Kok 400kV Substation
YUE400 Substation	Yuen Long 400kV Substation
LCE – YUE No.2	Lai Chi Kok – Yuen Long No.2 Circuit
– – – –	Overhead Line

Figure 4: Schematic Diagram of LCE – YUE No.2 400kV Circuit

400kV Voltage Dip Incident During Thunderstorm Warning On 6 April 2024

INCIDENT INVESTIGATION REPORT

Submitted by:



Mr. Chang Fan
Director - Business Strategy (Generation)

Date: 03rd May 2024

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

On 6 April 2024 at around 13:29 hours, two consecutive but momentary voltage dip incidents occurred in the 400kV transmission system which involved the detection of electrical discharges (thereafter named as "discharge") to earth due to lightning. The time between each voltage dip was around 10 seconds during which there was no interruption to the power supply.

At 13:29:26 hours, two Black Point Power Station (BPPS) C units (C5 & C2) were tripped. Around 10 seconds later, another C unit (C6) was also tripped. Out of the 3 tripped generating units, the corresponding 400kV transmission protection systems of 2 generating units (i.e. C5 & C6) were also activated to isolate the discharges.

CLP took immediate action to increase the output from other generating units to ensure that customers' demands were met. Investigation of the incident also commenced at the same time. Upon examination and assessment at site, no abnormality was observed at C2 and its tripping circuit could be reset. C2 resumed service at 15:08 on 6 April 2024. Units C6 & C5 resumed service on 11 April 2024 and 12 April 2024 respectively, after conducting comprehensive electrical tests with satisfactory results that confirmed their integrity. C6 & C5 did not require repair works other than the replacement of slightly damaged flexible conductors.

Based on the investigation, it is concluded that the voltage dips were not caused by equipment fault but rather due to lightning.

During the voltage dips, a thunderstorm warning signal was in force and lightning strikes were recorded at areas near BPPS. At BPPS, a lightning protection system (LPS) is in place which was designed according to international standards to protect the generation and transmission equipment.

According to the CCTV footage, discharges and lightning strikes took place within 10 seconds at and near to the C5 & C6 generator transformer compounds, which is unprecedented according to internal records. It is believed that lightning strikes caused discharges to earth at C5 & C6 which resulted in voltage dips on the 400kV transmission system. The discharges caused by lightning also triggered the operation of earth fault protection on the C5 & C6 generator transformers and inter-tripped the corresponding 400kV transmission Circuit Breakers to clear the discharges and protect the generation and transmission equipment.

Given we have not seen lightning strikes affecting this small area before, potentially indicating a higher chance of more extreme weather in the future, after testing the lightning masts and earthing pits, CLP will further conduct a more detailed testing on the existing LPS and will also explore and study the feasibility of enhancing the existing LPS to improve resilience against further lightning attacks in future.

Table of Contents

1. Introduction

Black Point Power Station (BPPS) was commissioned in phases starting from 1996 and consists of 10 combined cycle gas turbines (C1 – C8 and D1 – D2).

Each of the BPPS-C units has its own generation equipment for power generation and the power generated is transmitted through a generator transformer and other ancillary equipment to the 400kV supply network.

The generator transformers and ancillary equipment of the eight BPPS-C units are installed outdoors in separate open air generator transformer compounds.

The lightning protection system (LPS) was built at BPPS according to international standard. It includes 4 lightning masts at each open-air generator transformer compound to provide lightning protection to the equipment installed inside the transformer compounds. With the existing LPS in place, the residual risk of lightning strikes hitting our generation equipment is considered as low as reasonably practicable.

Figure 1 Layout of Black Point Power Station (BPPS)

2. The Incident

Two voltage dips which lasted for around 0.1 seconds on each occasion were detected at the 400kV transmission substation at BPPS (BKP) separated by around 10 seconds.

No personal injury from the incident was reported to CLP and there was no property damage observed other than to the flexible conductors inside the generator transformer compound of C5 & C6.

The following is the sequence of events for the first voltage dip on 6 April 2024:

- At 13:29:26.825 hours, the first 400kV voltage dip was recorded at phase L1.
- At 13:29:26.926 hours, C5 was tripped by the operation of protection system of its generator transformer and the corresponding 400kV Circuit Breakers ($^{\#1}$ CBs) at the 400kV transmission substation were also inter-tripped.
- At 13:29:26.935 hours, C2 was tripped by a trip relay without inter-tripping the corresponding 400kV transmission CBs.

The following is the sequence of events for the second voltage dip on 6 April 2024 which happened around 10 seconds after the first voltage dip:

- At 13:29:36.150 hours, the second 400kV voltage dip was recorded at phase L1.
- At 13:29:36.245 hours, C6 was tripped by the operation of protection system of its generator transformer and the corresponding 400kV CBs at the 400kV transmission substation were also inter-tripped.

The following was also observed in between the two voltage dips by the CCTV footage:

- At 13:29:26 hours, discharge occurred at C5 generator transformer compound.
- At 13:29:33 hours, lightning observed at the vicinity of C6 generator transformer compound.
- At 13:29:36 hours, discharge occurred at C6 generator transformer compound.

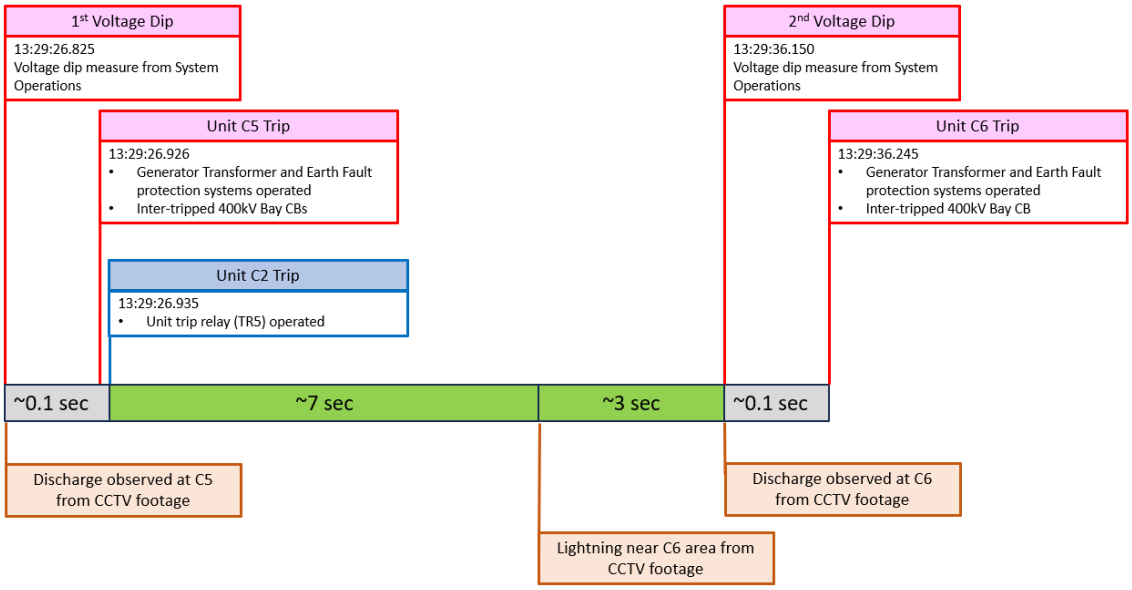


Figure 2 Timeline of Sequence of Events

Note #1 : Circuit Breaker (CB) is an electrical device to isolate an electrical fault to protect the equipment and electricity system

3. Restoration Arrangement

Out of the 3 tripped generating units, the corresponding 400kV transmission protection systems of 2 generating units (i.e. C5 & C6) were activated to isolate the discharges to earth. C2 was tripped by the operation of a trip relay without inter-tripping the corresponding 400kV transmission CBs.

CLP took immediate action to increase the output from other generating units to ensure that customers' demands were met. There was no interruption to the power supply.

Investigation of the incident by operational staff at BPPS also commenced at the same time. Upon examination and assessment at site, no abnormality was observed at C2 and its tripping circuit could be reset. C2 resumed service at 15:08 on 6 April 2024.

For C5 & C6, some localized burn marks and minor metal loss were observed at the flexible conductors of the generator transformer's High Voltage (HV) outlet [#2]. Some molten metal was found on surrounding electrical components (e.g. jumpers, ending rings and others). The slightly damaged flexible conductors were replaced and cleaning of surrounding electrical components were conducted after inspection and collection of samples.

At the same time, the generator transformers and 400kV cables of C5 & C6 were tested to ensure their integrity. Upon the thorough completion of tests with satisfactory results, C6 & C5 resumed service on 11 April 2024 & 12 April 2024 respectively.

Note #2 : HV outlet means high voltage connection between generator transformer and the 400kV cables

4. The Investigation

4.1 Investigation Findings

Right before the tripping of generating units and the occurrence of 400kV voltage dips, the output of BPPS generating units was stable and there was no maintenance work nor operational switching being conducted at the generator transformers and BPPS 400kV transmission substation.

At the same time, a thunderstorm warning signal was in force and lightning strikes were recorded at areas near BPPS. From the nearby CCTV footage, two occurrences with sign of lightning and discharge were observed at the C5 and C6 generator transformer compounds which coincided with the operation of C5 and C6 protection systems. In addition, another flash of bright light near C6 transformer compound was observed around 3 seconds prior to tripping of C6. It was checked and confirmed there was no engineering work in the vicinity that will emit bright light during the incident. Therefore, it is believed that the occurrence of bright light was a lightning strike hitting close to the transformer compounds.

Figure 3 Discharge of around 0.6 seconds at C5 Generator Transformer Compound

Figure 4 Lightning Observed at the Vicinity of C6 Generator Transformer Compound around 3 seconds prior to Discharge at C6

Figure 5 Discharge of around 0.8 seconds at C6 Generator Transformer Compound

After the voltage dips and unit tripping, inspection of equipment was carried out immediately and no debris nor leaked insulation oil were observed inside C5 & C6 generator transformer compounds.

Figure 6 C5 Generator Transformer Compound after Voltage Dip on 6 April

Figure 7 C5 Generator Transformer Compound after Voltage Dip on 6 April

Figure 8 C6 Generator Transformer Compound after Voltage Dip on 6 April

Figure 9 C6 Generator Transformer Compound after Voltage Dip on 6 April

Tripping of Unit C2

Upon immediate examination and assessment at site, no abnormality was observed at C2. No protection relay was triggered but one downstream tripping relay was found triggered and could subsequently be reset. Unit C2 resumed service at 15:08 hours on 6 April 2024.

Detailed examination and checking of unit C2 generator transformer protection circuit was performed with the support from the original equipment manufacturer (OEM) after the incident. The analysis confirmed that the protection relay was in normal condition without any sign of commanding the downstream tripping circuit. The triggering of a downstream trip relay is believed to be due to the detection of interference induced by the first voltage dip incident and thus causing the unit trip.

Tripping of Units C5 and C6

Subsequent to the incident, the lightning masts and earthing pits inside each of the generator transformer compound of units C5 & C6 were tested and confirmed to be in good condition.

After reviewing the station records, no direct lightning strike on major electrical equipment was reported in the more than 25 years since the commissioning of BPPS before this incident.

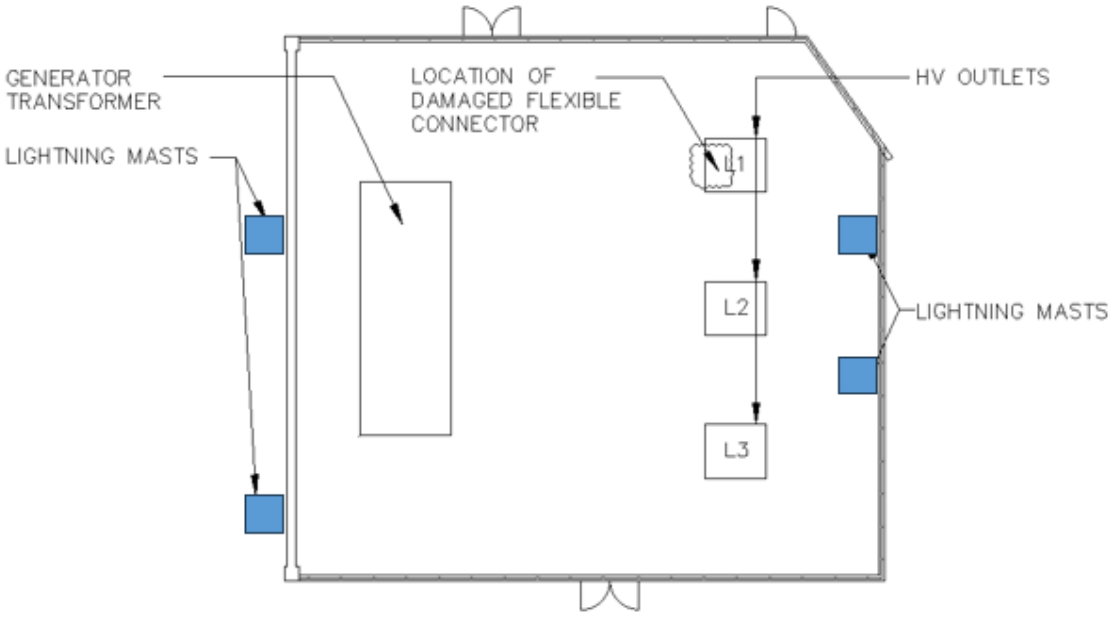


Figure 10 Layout of Electrical Equipment in a Generator Transformer Compound

Site inspections revealed that there was no damage to other equipment and installations inside the generator transformer compounds except some localized burn marks and metal loss at the flexible conductors of the generator transformers' HV outlet at unit C5 & C6 phase L1 respectively. Some metal patches could also be found at surrounding electrical components.

Upon metallurgical analysis by in-house laboratory, the burn marks were located at the outer surface of the flexible conductors and confirmed to be created by melting of aluminum (material of the flexible conductors) by high localized energy release. Given there is no significant physical or mechanical damage and the amount of metal loss were localized at the outer surface, it is believed that the slight damage was a consequence of the external lightning or discharge instead of internal equipment fault.

Also, the generator transformers and cables of C5 & C6 were extensively tested to check their integrity and confirmed that there was no equipment damage except slight damage to the flexible conductors, which were replaced for prudence's sake. Upon the completion of comprehensive tests with satisfactory results, units C6 & C5 resumed service on 11 April 2024 and 12 April 2024 respectively.

Figure 11 Localized Burn Marks at Flexible Conductors of C5

Figure 12 Patches of Metal on C5 HV Jumper

Figure 13 Localized Burn Marks at Flexible Conductors of C6

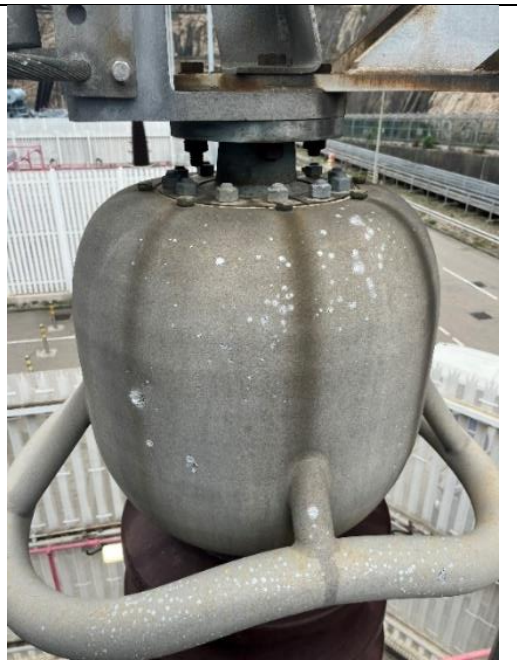


Figure 14 Patches of Metal on C6 Connector Head

5. Root Cause Analysis

The investigation concludes the voltage dips did not originate from equipment fault but rather are due to lightning.

Despite the presence of LPS, the CCTV footage clearly showed that an unprecedented occurrence of lightning and discharges within 10 seconds happened at or near unit C5 & C6 generator transformer compounds. It is believed that lightning strikes caused discharges to earth at unit C5 & C6 areas which resulted in voltage dips at the 400kV transmission system. The discharges caused by lightning also triggered the operation of earth fault protections on unit C5 & C6 generator transformers and inter-tripped the corresponding 400kV transmission CBs to clear the discharges and protect the generation and transmission equipment.

There was no evidence that a voltage dip or fault happened at unit C2, as the protection relay (P643) did not operate. The tripping of unit C2 was due to the detection of interference induced during the first voltage dip incident by one of the trip relays (TR5) at around 13:29:26.

5.1 Direct Cause for Voltage Dip:

In accordance with the international standard, the design of the LPS was based on a probabilistic approach to take account of the most likely scenarios for a lightning strike, which is a very dynamic natural phenomenon, meaning that lightning might still bypass the LPS on some very rare occasions. Despite with the presence of LPS, lightning strikes happened inside the open air C5 and C6 generator transformer compounds, something that has not happened since the building of BPPS.

However, the exact location of striking points could not be ascertained as no obvious or substantial damage points could be observed. Regardless of the exact location of the lightning strike, its presence together with the humid atmosphere could potentially create a more conductive path for a discharge from the 400kV system to earth.

Units C5 & C6 were then tripped by their earth fault protection system intended to clear the discharges and protect the equipment.

The reasons for believing the volt dips were caused by lightning strikes are as follows:

i) The tripping of generation units C5 and C6 were due to operation of their respective earth fault protection system. According to the design of the protection system, the discharges must happen between the high voltage side of the generator transformer and the CBs at the 400kV substation.

ii) According to the electrical test results and laboratory test results, the generator transformers and 400kV cable are in normal condition and have no sign of equipment fault.

iii) The CCTV footage clearly showed that there were two discharges almost at the same instant that generation units C5 and C6 were tripped. There was one more lightning strike between the above two instants at the nearby location.

iv) According to the Hong Kong Observatory, lightning was recorded in the Tuen Mun area around the same time.

v) The flexible conductors of the L1 phase of HV outlet of units C5 and C6 were found slightly damaged with localized burn marks. Given there is no significant physical or mechanical damage and the amount of metal loss was localized at the outer surface, it is believed that the slight damage was a consequence of the external lightning or discharge instead of internal equipment fault.

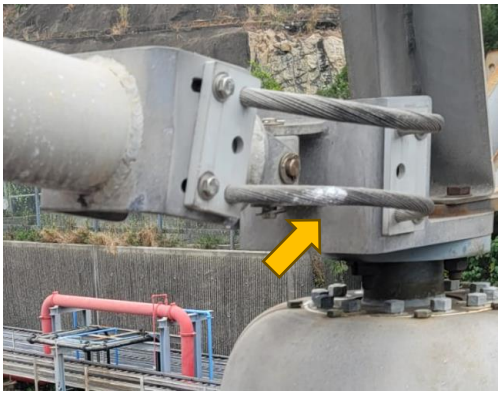


Figure 15 C5 Damage at Flexible Conductor near HV Outlet

Figure 16 C6 Damage at Flexible Conductor near HV Outlet

5.2 Exclusion of Other Possible Causes

Other potential causes were also analyzed to support the investigation conclusion:

1. **Mal-functioning of Lightning Protection System (LPS):** Routine inspection was conducted according to the maintenance plan. Effectiveness of the lightning masts and earthing pits were checked during the investigation and confirmed it is in normal condition. Mal-functioning of LPS is considered unlikely.
2. **Third-Party Interference:** Before the incident, there was no maintenance work or operational switching being conducted at the generators' electrical systems. Third-party interference can be ruled out.
3. **Intentional Damage:** No findings from CCTV nor maintenance work record could be identified at/ right before the incident. Intentional damage can be ruled out.
4. **Workmanship:** No major power equipment failure was observed during investigation and all electrical and laboratory tests confirmed the equipment is in healthy condition after the voltage dips. Workmanship issues could be ruled out.
5. **Overloading:** According to system records at the time, the output from the tripped generating units was only at part load. The failure of generator transformers due to overload can be ruled out.
6. **Fault at Upstream or Downstream:** The operation of protection system indicated that the discharge was between the high voltage side of the generator transformers and the CBs at the 400kV substation. Fault at upstream and downstream can be ruled out.
7. **Equipment Internal Fault:** All electrical test results and laboratory tests on generator transformers, 400kV cables and 400kV CBs were checked in normal condition. The slight damage at the outer surface of flexible conductors is believed to be the consequence of external lightning or discharge instead of internal fault. Equipment failure is considered unlikely.
8. **Mal-operation of Protection Systems:** No malfunctioning of protection systems could be found at C5 and C6 units during investigation.

6. Status of Installation in System

The LPS at BPPS was designed and built according to international standard. There are four lightning masts built (over 18 metres tall, or around double the height of the electrical equipment they protect) surrounding each generator transformer compound to provide lightning protection to the equipment installed inside. The bottoms of the lightning masts are connected to an underground earth mat to dissipate energy to earth when a lightning strike hits the mast. Generator transformer neutral earthing is separately connected to earth. Routine inspection of the LPS was conducted according to the maintenance plan.

The generator transformers are designed according to international standard.

C5 generator transformer was manufactured in 1996. The last refurbishment and condition assessment was performed in 2020. Refurbishment, mainly on mechanical components replacement such as gasket, piping and cooling fan system were performed based on the life assessment results, which were conducted by the OEM.

C6 generator transformer was manufactured in 1996. Refurbishment and assessment were performed in 2018 with work scope similar to that of C5.

Both the generator transformers of C5 & C6 have been working satisfactorily since their last maintenance without major defects or failure.

7. **Follow Up Action**

Subsequent to the voltage dips, the lightning masts and earthing pits at C5 and C6 generator transformer compounds were tested and no abnormality could be found.

Notwithstanding that this was an anomalous occurrence, CLP will explore and study in the medium term to further enhance the resilience of our generation and transmission 400kV equipment against lightning strikes. This will include a comprehensive testing and review of LPS and the associated earthing system.

C2 is found to be affected by the induced interference during the first voltage dip, although the protection system of C2 has been examined and confirmed by the OEM that it was in normal condition, the prevention of triggering of downstream trip relay due to interference will be further studied with the OEM in the medium term to balance between the need of timely and proper protection of generation equipment against the possibility of inadvertent activation of tripping.