**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).

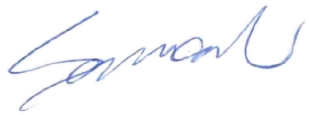
**Environment and Ecology Bureau**
**Electrical and Mechanical Services Department**
**February 2024**

**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

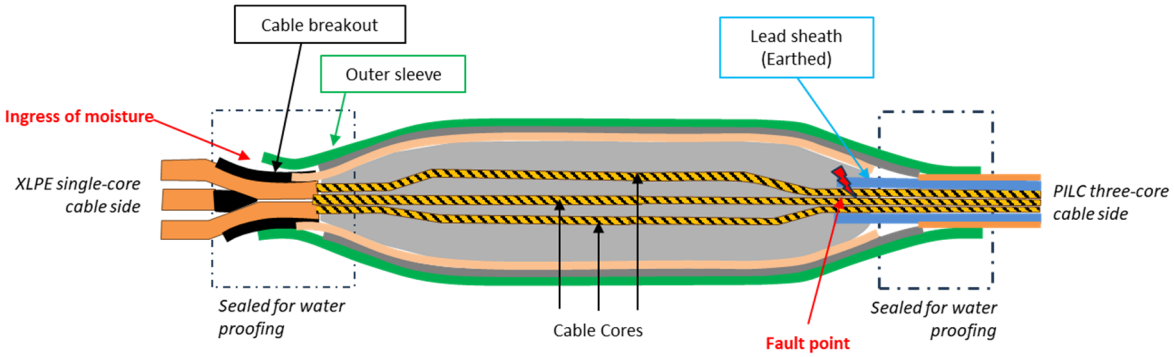
1. The faulty tri-joint connected a 150 sq.mm Aluminium PILC three-cores cable from On Mei House 'A' substation to a 95 sq.mm Copper XLPE single-core cables for termination to a transformer inside the On Mei House 'B' substation.
2. The faulty tri-joint was commissioned in 2000 thus had been in service 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

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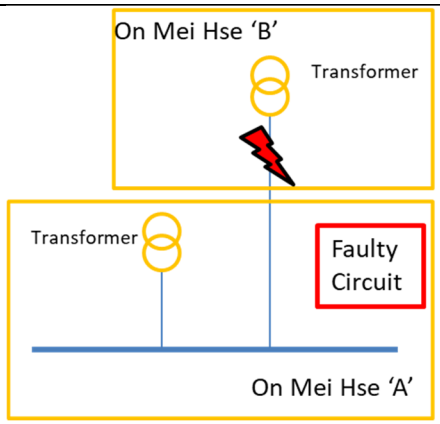
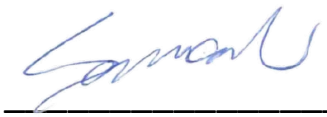
| 1. |  <br>11kV Network diagram of the faulty circuit |
| 2 |  <br>Environment of On Mei House 'B' Substation |

**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.

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## 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

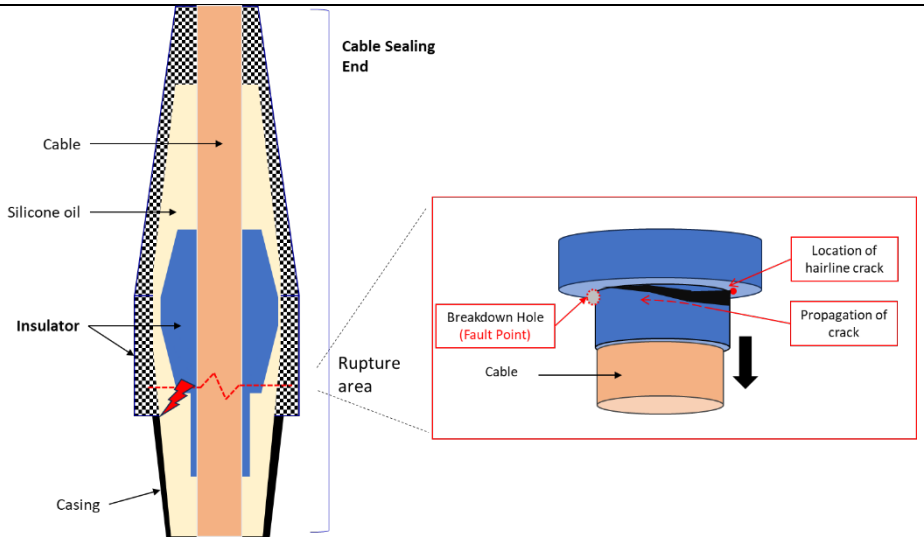
1. The faulty CSE was a 132kV CSE for connecting a 500 sq.mm single-core Copper XLPE cable to the 132kV RMU. The concerned CSE was commissioned in 1998, thus has been in service for about 26 years. The designed capacity of the CSE is 150MVA, and records indicated no overload in the circuit.
2. The insulation 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.

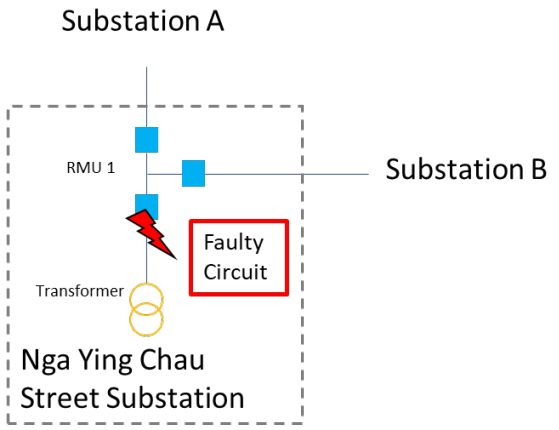



Diagram of the Ngau Ying Chau Street Substation