Legislative Council Panel on Transport
Subcommittee on Matters Relating Railways

Investigations into West Rail Incident on 14 February 2007

Introduction

This paper informs Members of the findings of investigations into a voltage transformer (VT) failure and the resulting fire above the roof of an operating West Rail train in February this year.

Incident

2. At 9.13 a.m. on 14 February 2007, following the failure of a voltage transformer mounted on the roof of a southbound West Rail train inside the Tai Lam Tunnel, an explosion and fire of that equipment resulted in the loss of traction power to the train. Direct communications between the train driver and the West Rail Operating Control Centre resulted in activation of the Tunnel Ventilation System to extract smoke in the direction opposite to an orderly evacuation of passengers towards Tsuen Wan West Station. Fire Services and Police were called to the scene, and together with KCRC staff about 1,000 passengers on the train were safely evacuated.

3. Eleven passengers were sent to hospital, 9 were discharged after examination, 2 hospitalized for overnight observation and subsequently discharged. Normal train service resumed at 12.54 p.m. after inspections by staff of KCRC and Hong Kong Railway Inspectorate.

Investigations

4. Two review panels were immediately set up by KCRC with independent experts as members and the support of the VT manufacturer.

5. Separate reports have been produced by the two panels (in Annexes I and II) following extensive working level contacts with all

involved parties including the Hong Kong Railway Inspectorate, Fire Services and the Police. The key findings and recommendations by KCRC are as follows:

Incident Handling

- KCRC's panel reviewing actions taken during the emergency found that KCRC staff with the support of other parties including the Fire Services and Police responded effectively and followed rule book procedures.

- Having taken into account the views of relevant Government departments including the Fire Services, and passengers' feedback, the panel made the following recommendations to the Corporation for improvements:

  (i) Emergency drills with the participation of relevant Government departments should be organized with complex scenarios to train and maintain the alertness of all parties involved.

  (ii) Communication between KCRC and Fire Services should be enhanced, in particular in channels of communication between personnel at different levels, short-form messages, trigger points for reporting to Fire Services, and dissemination of critical information.

  (iii) Additional directional signs inside Tai Lam Tunnel should be provided at relevant locations for passengers who may experience an emergency evacuation.

  (iv) Passenger education on emergency procedures should be ongoing.

Technical Investigation

- The technical panel found that the voltage transformer failure was a combination of an insulation imperfection hidden at the time of manufacturing and as an attributing factor high voltage surge arising from a severe lightning event while the train car was

in service.

- Additional measures were put in place immediately after the incident to continuously monitor each train-borne voltage transformers. These include using the train-borne computer to monitor the voltage level, a temperature check of every transformer by an infra-red device once every 3 days, and a weekly instrument check of the transformer coils.

- After the incident, every transformer was sent for a thorough laboratory check to confirm compliance with the appropriate electrical standards. The independent experts concur with the panel's finding that the use of the existing voltage transformers will not present any threat to passengers.

- Maintenance procedures recommended by the manufacturer were confirmed as having been met. KCRC will, however, step up the check of the transformer from once every three years to once every month. The high voltage performance of each transformer will be checked annually in laboratory conditions.

Conclusion

6. The Managing Board of the Corporation has accepted the findings and all of the recommendations in the reports for implementation, The manufacturer will provide the new type of oil-free and explosion-proof transformers. By 2008, all existing transformers of this type will be replaced in the KCRC workshop by the explosion-proof type.

Kowloon-Canton Railway Corporation

April 2007

Annex I

Report of the Incident Review Panel on the Train Fire inside West Rail Tai Lam Tunnel on 14 February 2007

April 2007
Kowloon-Canton Railway Corporation

CHAPTER 1

INTRODUCTION

1.1. At approximately 0913 hours on 14 February 2007, a southbound West Rail (WR) train from Tuen Mun (TUM) station was on its 0853 hours trip to Nam Cheong (NAC) station. When the train was midway on the down track inside the 5.5-km Tai Lam Tunnel (TLT), the Incident Train Driver (ITD) heard abnormal bang sound from the rear of the train, followed by loss of power supply to the train.

1.2. The ITD received reports from passengers that the train was filled with smoke. He also observed through the in-cab CCTV that there was dense smoke in the rear cars of the train. He brought the train to a standstill in the tunnel and initiated an emergency detrainment after obtaining approval from the West Rail Operations Control Centre (OCC).

1.3. KCRC staff worked together quickly to operate the various tunnel fire safety systems and also attempted to extinguish the fire that had broken out in a voltage transformer on the roof of the incident train. In general, the evacuation and rescue operations were efficiently handled jointly with the emergency services.

1.4. As a result, the emergency evacuation of some 1,000 passengers from the train inside the tunnel was conducted swiftly and smoothly without any major injuries or fatalities.

Appointment of the Incident Review Panel

1.5. This was the first tunnel fire incident occurring on West Rail since it opened for revenue services in December 2003. Although there were no major injuries caused to passengers, the incident had resulted in serious disruption to services. The KCRC Management believes that this fire incident warrants a formal review to identify any possible improvements.

1.6. An Incident Review Panel was appointed by KCRC’s Senior Director - Transport with membership as follows -

Leader	Mr. Anthony YAN Shiu-tseung, General Manager - East Rail Special Operations
Member	Mr. Louis LEUNG Kai-wing, Railway Safety Manager
Member	Mr. LEE Kam-sang, Senior Engineer-System Safety
Secretary	Mr. Kelvin YEUNG, Incident Review Officer

1.7. The terms of reference of the Incident Review Panel are set to -

(a) produce a factual account of the incident including the emergency evacuation, rescue operations and contingency arrangements introduced by all parties involved;
(b) review the adequacy of relevant rules and procedures, and effectiveness of their implementation;
(c) review the safety and efficiency of the emergency evacuation and all other recovery measures including but not limited to internal and external communications, and coordination with rescue authorities;
(d) review adequacy of train on-board safety equipment and tunnel fire safety provisions taking into consideration actual passenger reactions and KCRC/ Fire Services Department (FSD)/Hong Kong Police Force (HKPF) response in the incident; and
(e) make recommendations to improve the recovery and handling of similar incidents.

1.8. The panel has carried out extensive review and interviews with various key personnel and collected relevant information and data including video tapes, system logs and screen displays, photographs and videos in order to reconcile the data and provide a verified factual account of the incident and events. Subsequent to the incident, several system validation tests have been conducted to verify systems

performance and identify possible improvement measures.

1.9. This Report summarizes the events and observations, as well as conclusions and recommendations made by the Panel on this incident. This Report does not cover the technical investigation on the failure of the concerned voltage transformer which is carried out by a team of specialists and independent consultants and the result of which will be reported separately.

CHAPTER 2

INCIDENT REVIEW

Incident Outbreak

2.1. At approximately 0913 hours on 14 February 2007, a southbound WR train NAC015 from TUM station was on its 0853 hours trip to NAC station. When the train was midway on the down track in the TLT, the ITD heard abnormal bang sound from the rear cars of the train, followed by loss of power supply to the train. The Overhead Line (OHL) traction current supply on the down track inside TLT was de-energized.

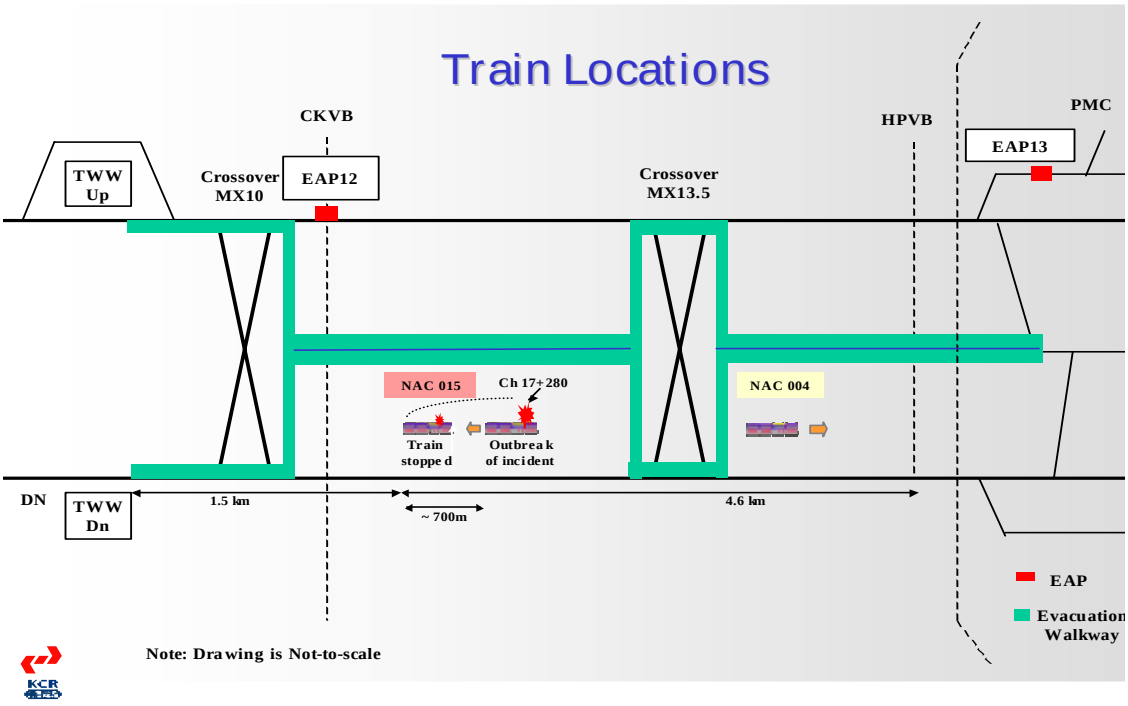
2.2. Inside the incident train, a number of Emergency Help Point (EHP) calls were triggered at this time. Passengers advised the ITD that there was heavy smoke inside the saloon. The ITD observed through the in-cab CCTV that there was heavy smoke inside the rear cars of the train. The ITD immediately pressed the Emergency Stop button to stop the train. Some passengers opened the hopper windows resulting that more smoke had gone into the saloon.

2.3. The ITD then reported to the Traffic Controller (TC) and requested for emergency detrainment. The train was eventually brought to a standstill inside the tunnel with the leading end of the train at approximately 1.5 km from Tsuen Wan West (TWW) station.

2.4. At 0914 hours, a fire alarm was triggered by smoke detectors in the down track tunnel and was sent to OCC, TWW Station Control Room (SCR) and FSD control centre. FSD responded immediately. After receiving the report from the ITD and confirming with him the situation inside the saloon as well as the condition of the passengers, OCC came into a complete understanding with the ITD on the direction of evacuation and the safety measures to be carried out to protect the passengers to be detrained.

2.5. The TC immediately executed a System Hold command to stop all trains at station platforms. The train that followed the incident train, NAC004, which had departed Kam Sheung Road (KSR) station and was entering into the tunnel, was instructed by OCC to stop immediately.

The train came to halt at a position about 100 m from the mid tunnel crossover MX13.5. The train driver closed the dampers in view of smoke coming from the front to prevent the ingress of smoke into the train saloon. A sketch of the locations of trains inside TLT at the time of the incident is shown below -



2.6. The reported situation from the ITD prompted the declaration of Emergency by the Senior Train Controller (STC) in OCC at 0915 hours.

2.7. The STC instructed the Electrical Control Officer (ECO) to operate the Tunnel Ventilation System (TVS) for extraction of smoke towards the northern portal and to the open air. Tunnel lights for both tracks were also switched on by TWW SCR staff. After confirming that the train running in the adjacent tunnel had gone past the incident train, TC approved the ITD to commence emergency evacuation of passengers towards TWW.

2.8. The ITD made announcements through the public address system of the train and advised passengers to remain calm, leave the train and proceed in the same direction of the train. At 0915 hours, he opened the train door for passengers to detrain.

2.9. At 0917 hours, OCC reported and provided further information to FSD Control Centre. At 0920 hours, a Red Alert was issued. The Emergency Transport Coordination Centre (ETCC) of Transport Department and the media were informed of the incident.

Evacuation and Rescue Operations

2.10. In response to the fire alarm from TLT, a team of fire brigade arrived at Chai Wan Kok Ventilation Building (CKVB) at 0918 hours, and was met by the Liaison Officer (LO) sent from TWW. The duty of the LO was primarily to confirm that all safety precautions were carried out before allowing rescue parties to gain access to the track, and to convey any requirements from the rescue parties to the Incident Officer (IO) at the Incident Control Point (ICP). Due to the rapid progress of the incident and the vast area covered, the LO required a few minutes to obtain confirmation from the OCC via the IO that all safety precautions were carried out and that it was safe for FSD officers to access the tunnel. On the way to the incident site, FSD officers met some passengers walking along the evacuation walkway of the tunnel. The firemen therefore directed those passengers to leave the tunnel via CKVB. Under escort of the LO, FSD and an unidentified passenger, a total of some 340 passengers was reported to have gone out of CKVB at 0944 hours.

2.11. A Passenger Care Officer (PCO) from TWW was instructed to evacuate the passengers from the platform so as to receive the detrained passengers from the incident train. He also assisted to set up the ICP at the down platform tail wall before entering into the tunnel to meet the detrained passengers and direct them back to TWW via the down track. The first detrained passenger arrived TWW platform at 0927 hours. Also at this time, a second PCO was posted at crossover MX10 to ensure that passengers would not cross to the up track by mistake and would only go in the direction of TWW along the tunnel on the down track.

2.12. At 0945 hours, a total of some 626 passengers had walked up to TWW. PCO confirmed that all passengers were clear of the tunnel.

2.13. The ITD, having directed all passengers to evacuate to TWW station, attempted to put out the fire with the assistance of a Passenger Services Assistant (PSA) traveling on train NAC015. A total of fourteen portable fire extinguishers was used.

2.14. Coincidentally, a Police Officer was on duty in the incident train. He identified himself to the ITD at the outbreak of the incident, reported the incident to the Police Console, and assisted passengers to leave the incident train.

2.15. FSD personnel approached the incident site from CKVB and EAP13 at the north portal of TLT. Meanwhile, the overhead line inside TLT was re-energized for OCC to dispatch train NAC004 (which was behind the incident train) in the reverse direction back to KSR platform. OCC also informed the ITD to update FSD that the overhead line was energized. Traction current supply for the tunnel section was de-energized after NAC004 had left the tunnel section for FSD to put off the fire using water got from fire hydrants installed inside the tunnel. After the fire was extinguished, FSD left the incident site at 1035 hours.

2.16. A total of 11 passengers was conveyed to hospital for examination, including 9 from CKVB/TWW, 1 from KSR and 1 from MEF. With the exception of two who were detained overnight in hospital for observation, all were discharged after examination. There were no major injuries or fatalities.

Recovery

2.17. At around 0940 hours, Emergency Rescue Teams (ERT) comprising members of staff from various engineering disciplines reported to the ICP.

2.18. After the fire was put off and FSD left the site at 1035 hours, Rolling Stock engineers inspected the damage to the voltage transformer and other roof-mounted equipment on the incident train.

2.19. At around 1135 hours, all ERTs had completed their inspection and confirmed that the up track was safe for resumption of

service. The emergency possession for the up track was surrendered at 1159 hours.

2.20. Inside the incident tunnel, OHL staff reported that overhead line equipment was normal. At around 1207 hours, Rolling Stock staff confirmed that the incident train was safe to be pushed to TWW Loop Track. Two assisting locomotives were coupled to the incident train and pushed it clear of the incident site. P-way staff also found some broken bolts and oil stains on the track. These were cleared and the track was confirmed safe for operation. Signalling staff conducted inspection on their equipment and confirmed no damage found.

2.21. At around 1231 hours, all ERTs confirmed that the down track was safe for train operation. All ERTs together with Hong Kong Railway Inspectorate (HKRI), were arranged to board the Emergency Rail Bus (ERB) at the incident side and conducted a Line Clear inspection towards KSR. At 1253 hours, Line Clear inspection was completed and the incident tunnel was confirmed to be safe for operations.

2.22. After close of traffic, engineering staff from High Voltage, P-way and Civil conducted a thorough inspection of the tunnel and track-side equipment with a view to identifying any possible secondary effect or long-term durability problems which might have caused by the fire and smoke. Nothing of concern was found. Besides, P-way staff also carried out a comprehensive cleaning of the oil left on the track.

Service Arrangements

2.23. The up and down tunnels were closed for passenger detrainment and rescue operations after the incident. After the incident train was pushed to TWW loop track, bi-directional working on the up line was introduced at 1230 hours. Through train service in both directions resumed at 1254 hours after the down line was also cleared.

2.24. During the incident, loop services were maintained at 6 to 10-minute intervals between NAC and TWW and between KSR and TUM. Emergency bus service was called by OCC at 0925 hours and was provided between TWW and KSR at 3 to 5-minute frequencies until 1330

hours to ferry passengers between the two stations. Most of the passengers who arrived at CKVB left the site on their own and a special bus was dispatched to carry the remaining 10 passengers to TWW.

2.25. Ticket gates at all stations were set to allow passengers to leave without charging fares between 0930 hours and 1300 hours. Passengers were promptly and effectively informed of the incident, train service impact and emergency bus arrangements during the incident.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

Recovery and Handling of the Incident

3.1. In general, staff and concerned parties responded efficiently according to the contingency procedures which have also been reviewed and considered adequate. The recovery and handling of the incident were carried out by staff and concerned parties diligently but there is still room for improvement.

3.2. The action of the ITD to stop the train and carry out an emergency detrainment in this incident, based on the following two considerations, was considered reasonable and understandable -

(a) It might not be possible to operate the train to the station ahead as the train had just passed the crossover in the middle of the 5.5-km TLT. There was still a long distance to the next station but the traction power was already lost; and

(b) Based on reports from passengers via the EHP and his own observation of saloon conditions via the in-cab CCTV, dense smoke was observed which could be harmful to passengers.

3.3. Throughout the incident, the OCC staff reacted promptly and operated the TVS within two minutes after the report was received. In addition, the OCC staff demonstrated their vigilance and professional judgment in this incident which are exemplified in the following operational decisions -

(a) Applied system hold for all trains in other platforms to prevent further trains from entering into TLT;

(b) Requested train driver of the following train NAC004 to stop the train to stay away from the incident train; and

(c) Maintained a close dialogue with the train driver and confirmed with him the traction supply status to ensure

safety of firemen carrying out fire fighting and for recovery of services.

3.4. These valuable lessons learnt should be shared with all other control centres and related staff.

Adequacy of Training to Staff

3.5. The incident reflected that WR staff are in general adequately trained in handling major incidents. The Corporation should continue to provide regular training and organize drills and exercises to upkeep staff's alertness and preparedness in handling specific emergency situations. More real-life yet challenging scenarios involving the use of multiple trains and loss of traction power supply with participation of KCRC staff and members of the public should be organized in the future.

Access of FSD / Rescue Personnel to Incident Site

3.6. To cope with the 5.5-km long TLT and speed up the access to the incident tunnel by emergency services, two ERBs are provided at TWW and Pat Heung Maintenance Centre (PMC), near to the two portals of the tunnel. The ERB is an on-track vehicle used for the transportation of rescue personnel and material to the incident site in TLT during an emergency if attendance of FSD is required.

3.7. During the incident, the ERBs were utilized by FSD to gain access to the incident site and the facilities were considered adequate. Regular drills and exercises should continue be conducted for KCRC and FSD personnel to enhance co-operation.

3.8. A follow up meeting with FSD, HKPF and HKRI was conducted on 5 March 2007. The possible areas for enhancing communication between KCRC and FSD have been identified. These include the channels of communication between personnel at different levels, short-form messages, trigger points for reporting, and critical information to be provided etc. Implementation of agreed improvement measures will be followed up in a newly established regular liaison meeting between KCRC and FSD, as well as drills and exercises.

Adequacy of Tunnel Emergency Facilities

3.9. The TLT is equipped with the latest fire safety systems and provisions to facilitate evacuation and rescue. The fire safety provisions were vetted by the relevant Government authorities and tested before opening of WR. Drills were conducted on a regularly basis to ensure the effective deployment of the systems and procedures.

3.10. The hardware inside the TLT were adequate for the incident. The fire detection system in the down track tunnel plant rooms was able to detect the smoke emitted from the incident train and send the alarm to FSD control centre promptly.

3.11. The tunnel lights for both up and down tunnels were switched on swiftly by station staff before the commencement of detrainment. The lighting measurements at the incident tunnel confirmed that the lighting level meet the prevailing international standard. In response to feedback from passengers, consideration could be given to enhance the illumination level at some specific locations.

3.12. The TVS worked well to remove the smoke and heat from the incident scene. The tunnel lights, evacuation walkways and cross passages all helped passengers to leave the incident site quickly.

3.13. The fire hydrant system was used by FSD to put off the transformer fire.

3.14. Based on passengers' feedback, additional directional signs along the tunnel and passenger information boards at EAPs should be erected to provide more information to passengers in the event of a tunnel detrainment.

Adequacy of Train On-board Safety Equipment

3.15. The WR EMUs are equipped with a number of advanced features to enable safe and efficient detrainment and effective communication between the train driver and passengers in an emergency. They were found adequate for the incident.

3.16. The integrated EHP and in-cab CCTV system provided real-time visual information to the train driver about the saloon conditions which assisted the train driver in making appropriate decisions.

3.17. During the loss of traction power supply, the EMU battery backup system was able to maintain full lighting for 90 seconds and then half lighting and mechanical ventilation system during the detrainment.

3.18. Portable fire extinguishers inside the train were used to help put out the fire.

Passenger Reactions and Behaviour

3.19. With clear information given to passengers through the public address system and with on-board staff and the Police officer providing assistance, passengers were able to detrain and leave the tunnel in an orderly manner. Passenger education on emergency detrainment and evacuation inside tunnels and on viaducts should be an on-going process. This can be done through pamphlets, videos and passenger information display systems.

CHAPTER 4

CONCLUSION

4.1. This WR TLT train fire incident on 14 February 2007 had put the system, the operators and the emergency services to the test. It is evident that the existing facilities, arrangements, procedures are adequate to handle a tunnel fire incident of this nature. In general, rules and procedures were followed by KCRC staff during the incident.

4.2. Emergency facilities including the tunnel ventilation system, fire detection and fighting systems, tunnel lights, means of escape for passengers, and means of access for rescue personnel had achieved the design intent.

4.3. It is recommended to -

(a) provide additional directional signs inside the TLT and passenger information boards at EAPs;

(b) enhance the illumination level at some specific locations;

(c) in the regular training and drills organized for staff and rescue parties, include more scenarios involving multiple trains which are immobilized due to loss of traction power supply;

(d) carry out passenger education campaigns focusing on emergency detrainment and evacuation in tunnels and on viaducts; and continue to involve the public in large-scale drills;

(e) review the channels of communication between the Liaison Officer, the Incident Officer and the Operations Control Centre, with a view to providing updated information and the progress of the incident to rescue parties;

(f) implement the improvement measures agreed with FSD to enhance communication between KCRC and FSD, including

the channels of communication between personnel at different levels, short-form messages, trigger points for reporting, and critical information to be provided; and

(g) refine the existing procedures based on the lessons learnt from this incident.

4.4. Lessons learnt from this incident should be shared with staff in internal publications and staff briefings. The importance of taking the following actions before commencement of passenger detrainment in a tunnel should be emphasized –

(a) ensure no other train movement inside the tunnel;

(b) activate the Tunnel Ventilation System;

(c) switch on the tunnel lighting;

(d) switch on the exit signs;

(e) broadcast the means and direction of evacuation; and

(f) if it is confirmed that the fire is outside the train, the train driver should close the air dampers to prevent smoke from entering into the train saloon.

Annex II

Report of the Technical Review Panel

on the Train Fire inside

West Rail Tai Lam Tunnel

on 14 February 2007

April 2007
Kowloon-Canton Railway Corporation

1. INTRODUCTION

This report is prepared by the Technical Review Panel on the result of investigation into the root cause of the Voltage Transformer (VT) on-fire incident in West Rail on 14 February 2007, the measures for monitoring and assuring the running integrity of the VT fleet, and the long-term solution.

2. TECHNICAL REVIEW PANEL

2.1 The Technical Review Panel was formed with the following terms of reference –

(a) review the measures implemented to ensure running integrity of the VT fleet;

(b) carry out a technical investigation to identify the root cause of the VT failure; and

(c) make recommendations on the remedial measures to be taken with a view to minimizing similar incidents from occurring in the future.

The Panel may call upon other experts in their particular fields, both locally and from overseas, to support the investigation activities.

2.2 The memberships of the Technical Review Panel is as follows –

(a) Ir Dr Tony K.Y. Lee
EngD, MPhil, CEng, MIEE, MHKIE, AP(HK)
General Manager – Rolling Stock (Acting)
(Leader of the Technical Review Panel)

(b) Ir Edmund K.H.Leung OBE JP
BSc(Eng), CEng, R.P.E.
FHKIE, FIMechE, FCIBSE, FIEAust., FHKEng
Consulting Engineer
(Advisor to the Technical Review Panel)

(c) Ir Prof. S.L.Ho
BSc, PhD, CEng, MIEE, MHKIE
Chair Professor of Electricity Utilisation
Department of Electrical Engineering
The Hong Kong Polytechnic University

3. THE INCIDENT

On 14 February 2004 at 0913 hours, a Voltage Transformer (VT) mounted on the roof of Car P306 of the West Rail train NAC015 caught fire. It tripped the overhead line supply and the train was brought to a stop by the driver for emergency detrainment of passengers.

4. VOLTAGE TRANSFORMER CONSTRUCTION

The VT is a passive device for detecting the presence of the 25kV overhead line supply and for providing a low voltage signal to assist the traction system in delivering optimum operational efficiency during motoring and regenerative braking. It draws extremely low power, equal to about half of the power consumed by a domestic type lamp bulb. It has a primary winding for the 25kV overhead line input and a secondary winding for the 100V output to the traction control. The primary winding is formed by connecting two stacks of cylindrical coils on top of each other. They are all moulded together tightly by resin with no cavities inside. The resin serves as the insulation media to prevent electrical flashover between turns and/or layers. The two resin-moulded primary coils are totally immersed in insulation oil and housed inside a 6 mm thick metal steel box, i.e. the VT shell, which is sealed and secured by substantial numbers of bolts and nuts. It is designed and manufactured in accordance with IEC standards.

5. EXAMINATION OF FAILED VOLTAGE TRANSFORMER

Forensic examination of the incident VT was carried out in the laboratories of Hong Kong Polytechnic University. The upper cylindrical coil of the primary winding, particularly the high voltage section connected to the incoming live conductor, suffered serious damage. It is clear that the resin melted and burnt together with its embedded fine gauge primary windings as a result of short-circuit. There are signs indicating that its insulation breakdown was initiated due to overvoltage. The resin-moulding surface of the lower coil of the primary winding indicated signs of bulging. When the lower coil was cut open for detailed examination, it was found that a number of windings were separated from the resin, thereby producing layers of cavities at the bulging areas. Such separation of resin from the coil would result from a prolonged period of over-heating.

6. FAILURE MECHANISM

Based on the forensic examination of the failed VT and fundamental electrical engineering principles of a transformer, it is concluded that the insulation resin layer between some coils turns at the upper primary coil connecting to the incoming live conductor had broken down at first due to voltage surge, resulting in shorted-turns. This then led to over-current on all the shorted-turns as well as in the remaining turns in the upper and lower coils. Such large current flow heated up the resin moulding, resulting in separation of resin from the coil, which would in turn give rise to more shorted turns and more heating. Such chain reaction continued, leading eventually to the melting down of the resin and the vaporisation of the insulation oil. When the internal pressure and temperature rise had built up sufficiently due to the chain reaction process, the transformer's lid was forced open and the vaporised insulation oil started to burn after its ignition point was exceeded.

7. CAUSE OF INSULATION BREAKDOWN

7.1 A comprehensive fault tree analysis was carried out to examine possible factors, which might lead to the insulation breakdown. Most had been eliminated through extensive investigations based on theoretical, circumstantial and forensic studies. The following factors are the remaining ones that require deliberations -

(a) production factor, such as manufacturing imperfections not detected by the factory routine tests; and

(b) external attributing factor, such as lightning strokes resulting in voltage surge etc.

7.2 In essence, the incident VT, particularly its insulation, was designed, manufactured and tested in the factory strictly in accordance with the procedures adhering to the industrial norm. Its production process involves critical steps demanding high human skills so as to maintain the specified design quality and to avoid bringing in some hidden imperfections, which could affect the integrity of the insulation property.

7.3 However, adherence to design standard and production control would minimize, but would not totally eliminate the possibility of having some insulation imperfections inside the VT. Such imperfections could exist even if the standard quality testing process has been implemented, and normally, themselves alone, will not lead to equipment failure. But when they are subjected to voltage surge, for example lightning, such hidden imperfections may surface and develop, triggering a fault. It is worth noting that in the past few years, Hong Kong had experienced a particularly adverse weather period with lightning strokes having a far larger intensity and more frequent occurrence than usual. Nevertheless, lightning strokes alone should not cause the VT insulation to fail. Therefore the failure of the incident VT must be a random occurrence resulting from the unfortunate combination of an insulation imperfection hidden at the time of manufacturing and as an attributing factor voltage surge arising from a lightning event.

8. RUNNING INTEGRITY

8.1 A thorough examination of every VT in the fleet had been carried out, including insulation test, high voltage test etc. All tests confirmed that the fleet is performing normally and there are no signs of other VTs showing any symptoms that could trigger any incident similar to the one on 14 February 2007. It is also confirmed that the VT fleet had been maintained properly and the car-builder concurred. It is thus concluded that the VT fleet is healthy and the failure of the incident VT is an isolated case.

8.2 Further assessment and examination had been carried out on other on-board train equipment. It is confirmed that they are working normally and there were no defect symptoms resulting from any effects of voltage surge. Also, proper protections for any voltage surges are in place and performing satisfactorily in accordance with accepted international standards. Train operations can thus proceed normally.

8.3 To assure the running integrity of the VT fleet, a monitoring regime has been derived and implemented after the incident, which is outlined as follows -

(a) Enhance the frequency of insulation test, previously once every 3 years as per manufacturer's instructions, which has now been increased to once every month;

(b) Use on-board train computer to monitor voltage level continuously during train service;

(c) Monitor external temperature every 3 days;

(d) Check transformer coil integrity weekly; and

(e) Carry out annual high voltage test under laboratory conditions to ensure the integrity of the VT fleet remains satisfactory.

9. CONCLUSION

9.1 It can be concluded that sufficient measures are in place to assure the running integrity of the VT fleet. Presently, there are no signs of other VTs showing any symptoms that could trigger any incident similar to the one on 14 February 2007.

9.2 The failure mechanism has been confirmed by theoretical and test data, supported by observations made on the failure parts and the monitoring data. The failure of the incident VT was a random event of an isolated nature, resulting from the unfortunate combination of an insulation imperfection hidden at the time of manufacturing and as an attributing factor voltage surge arising from a severe lightning event.

10. RECOMMENDATION

10.1 A number of measures have been put in place in assuring the running integrity of the fleet. However, to further enhance the confident to all stakeholders in the provision of superior quality train service and to regularize the long-term implementation of the monitoring regime, it is a prudent approach to replace all existing VTs on the fleet with a new oil-free and explosion-proof type transformer. This new type of transformer has been developed since 2001 after the first train with roof-top VTs were delivered, and has proven satisfactory service in Europe in the past few years. It also provides far greater endurance for lightning strokes.

10.2 The replacement of all existing VTs could be completed by 2008. Until then the enhanced monitoring and maintenance regime for the existing transformers will continue to ensure that the high level of passenger safety can be maintained.

END