Report 08-103, passenger Train 6294, electrical fire and collapse of overhead traction line, Mana station, Wellington, 18 April 2008

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passenger Train 6294

electrical fire and collapse of overhead traction line

Mana station, Wellington

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Executive Summary

Electric multiple unit passenger Train 6294 was stationary but attempting to depart from Mana station when an electrical fault on one of the traction motors caused a short circuit and fire in the train's main electrical equipment case. High current being drawn by the short circuit caused the overhead traction lines to part and fall onto the train.

The train was travelling between Paremata and Mana stations on the North Island Main Trunk, en route from Wellington to Paraparaumu, when the driver experienced problems with the traction motors. The train was a 2-car train set with one motor car and one trailer car and was being driven in the reverse direction from the trailer cab. After passenger exchange at Mana, the driver attempted to depart the platform but the train did not move. Each attempt to move the train resulted in an immediate traction motor overload. The driver was leaving the train to walk along the platform to the rear motor car when there was a brilliant flash above his head. The overhead traction lines parted and the loose ends dropped onto the train and the platform. The electrical equipment cabinet, just below the level of the platform on the motor car, was on fire.

Train 6294 was evacuated and the public were cleared from the area while the potentially live overhead lines were isolated and made safe. There were no injuries and the fire was extinguished before the Fire Service arrived at the scene.

The fault in the traction motor had been developing throughout the previous week, yet weaknesses in the fault-reporting system meant the developing fault went unnoticed, and frequent re-setting of the circuit breaker eventually resulted in it, together with the then-unprotected electrical line contactors, failing. With no electrical protection between the fault in the traction motor and the power supply, a very high electrical current passed between the overhead traction line and the train's pantograph, causing the line to melt and part.

(Note this executive summary condenses content to highlight key points to readers and does so in simpler language and with less technical precision than the remainder of the report for the benefit of a non-expert reader. Expert readers should refer to and rely on the body of the full report.)

Abbreviations

A	Ampere(s). A unit of electrical current flow.
EMU	electric multiple unit. Arranged in groups of 2-car sets, each with electric motor (EM) and electric trailer (ET) carriages
GPS	global positioning system
hr	hour(s)
km	kilometre(s)
km/h	Kilometre(s) per hour
kN	(kilonewton or 1,000 Newtons). This is a measure of force. A newton is the force required to accelerate a mass of 1 kilogram at a rate of 1 metre per second per second. An 11kN tension strain, as referred to in this report, is slightly greater than the tension applied to a vertical cable suspending a weight of 1 tonn (1,000 kg).
kW	kilowatts or 1000 watts. A measurement of electrical power.
m	metre(s)
MA	motor alternator. Direct-current motor-driven alternator used to generate 230VAC power for use within the train.
mm(s)	millimetre(s)
SCADA	A standard acronym for Supervisory Control And Data Acquisition: a computerised system that monitors the status of remote equipment and enables it to be controlled and monitored through a mimic displayed on a computer screen.
TAIC	Transport Accident Investigation Commission
TC	Train Control operator
TM	Train Manager
UTC	universal coordinated time
V AC	Volts (alternating current)
V DC	Volts (direct current)

Glossary

catenary	part of the electrified overhead line. In the context of this report the catenary is a cable suspended over the centre of the railway track between support structures. It forms a parabolic curve between the suspension points and provides the physical support to suspend a contact wire below it. It also provides the conduction path for current to flow from the traction supply network to the contact wire above the train.
circuit breaker	high-speed circuit breaker
contact wire	part of the electrified overhead line. A solid copper conductor suspended parallel with the railway line from the catenary wire and intended for being in sliding contact with the train pantograph. It facilitates the transfer of electrical traction power from the overhead line to the train.
controller	power brake controller. This is the main speed and braking control device used by the driver. See Appendix A for a more detailed description.
driver	locomotive engineer
Ohm	A unit of electrical resistance.
overhead line	the general term used to describe the suspended electrified line above the train, which includes the catenary and the contact wires plus all other associated equipment required to suspend it in the correct position.
parallel	an electrical term for multiple current paths. In the context of this report, parallel means an electrical arrangement of the traction motors to be in 2 separate lines so that current may flow through either line from the positive supply to the negative return potential.
pantograph	an extendable arm and contact slider assembly that electrically connects the train to the suspended overhead contact wire. Once in contact, the pantograph provides a current path from the overhead supply voltage to the traction motor system on the train.
series	an electrical term for a single current path. In the context of this report, series means an electrical arrangement of the traction motors to be in line so that current can only flow through each motor in sequence from the positive supply to the negative return potential.
Toll Rail	Toll NZ Consolidated Limited (Now Kiwirail)
train line	industry term for a common signal that is wired through the length of a train to be available for interlocking or display within each cab.
Tranz Metro	Tranz Metro Wellington

Data Summary

Train type and number:	passenger Train 6294	
Classification:	Electric multiple unit EM1373 / ET3373	
Year of manufacture:	1982 by Ganz-Mavag, Hungary.	
Date and time of incident:	18 April 2008 at 2331 [1]	
Location of incident:	Mana station, Wellington**.** North Island Main Trunk	
Persons on board:	crew:	2
	passengers:	approximately 25
Injuries:	crew:	nil
	passengers:	nil
Damage:	extensive damage to EM1373 and overhead traction lines down on the train and 3.7 km south.	
Operator:	Tranz Metro Wellington (Tranz Metro, a subsidiary of Toll NZ Consolidated Limited [2])	
Investigator-in-charge:	D L Bevin / BP Stephenson	

[1] Times in this report are New Zealand Standard Times (UTC+12) and are expressed in the 24 hour mode.
[2] New Zealand Railways Corporation took over as operator on 1 July 2008.

1 Factual Information

1.1 Narrative

1.1.1 On Friday 18 April 2008, Train 6294 was the 2300 scheduled commuter train from Wellington to Paraparaumu operated by Tranz Metro Wellington (Tranz Metro) with an electric multiple unit (EMU). The train consisted of powered car EM1373 and non-powered trailer car ET3373.

1.1.2 Train 6294 was crewed by a locomotive engineer suburban [3], driving from the cab in ET3373 and a train manager. The train was carrying about 141 passengers when it departed from Wellington at 2300. Approximately 20 passengers disembarked before Porirua and a further 90 or so at Porirua. Approximately 25 passengers remained on board when the train was to depart from Mana.

1.1.3 After departing from Paremata the driver notched up into 'parallel' [4] to increase speed, but the EMU traction motors overloaded and tripped out [5]. He responded by putting the train into 'coast' mode then resetting the traction motor overload. The traction motors reset, so he notched up into 'series' and the train accelerated, but when he notched into 'parallel' the traction motors again overloaded and tripped out.

1.1.4 At about this time (2328), train control queried the driver about possible problems he might be experiencing on the train. The question was prompted after train control received supervisory control and data acquisition (SCADA) alarms indicating that several of the traction substation circuit breakers at Kenepuru and Mana substations had tripped out and auto reset. The driver reported that the motor alternator (MA) on Train 6294 had tripped out but that there were no other problems.

1.1.5 Train 6294 was approaching Mana station when the driver changed his mind and notified train control that he was now experiencing traction motor overload trips and that he intended to cut out manually a set of traction motors in the rear powered car when his train stopped at Mana station.

1.1.6 On arrival at Mana the driver left the driving cab and walked along the platform towards the rear of the train, carrying out a visual inspection of the train along the way. He saw nothing unusual, so entered the driving cab in the rear car and proceeded to isolate traction motors 3 and 4, then returned to his driving cab at the front of the train.

1.1.7 After he received the 'doors closed' indication and the clear to depart signal from the train manager, he applied power, but the traction motors immediately tripped out without moving the train. He thought this was strange, because in his experience traction motors 3 and 4 were usually the cause of traction motor overloads and he had already isolated them.

1.1.8 The train manager joined the driver in the cab and the driver explained that he must have cut out the wrong traction motors but would try one more time to get moving. He reset the traction motor overloads then notched up to 'series' position, but the traction motor overloads immediately tripped out again. He reset the traction motor overload circuit then left the cab and walked to the doorway in the passenger compartment, intending to walk back along the platform to check the train again.

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[3] Throughout this report the locomotive engineer suburban is referred to as the driver.
[4] The position of the power brake controller lever sets the maximum speed to which the train will automatically accelerate up to. See Appendix A for more detail.
[5] Each bogie motor set was protected by traction motor overload device that could be manually reset by the locomotive engineer.

1.1.9 Just as he was exiting the train, there was a brilliant flash of light and the sound of something crashing on to the roof of the train. He knew immediately that the overhead traction line had fallen down. The time was approximately 2331.

1.1.10 Some people already standing on the platform called to him that the train was on fire. Once off the train he could see flames leaping up from the equipment case[6] on the platform side of the rear car, EM1373.

1.1.11 At that point the passengers on the train started to leave through the open doors. The driver asked passengers to remain on the train and went to the back of the train to get the fire extinguisher. As he walked back he saw the contact wire from the traction overhead line lying across the roof of the train and on the platform. He had to negotiate his way around it to re-board the train through the back doors.

1.1.12 After entering the rear car he went to the cradle where the fire extinguisher was stored, but it was gone. He turned to find the train manager, whom had just joined him after walking through the train. He was with a passenger, who was an off-duty Tranz Metro employee from the EMU maintenance depot and had taken the fire extinguisher. The driver directed him out of the train to extinguish the fire.

1.1.13 Another train was stationary at the adjacent platform on the down main line and was about to depart Mana station when the driver noticed flames coming out from under EM1373. Thick smoke was billowing across the track and obscured any forward vision, so the driver inched the down train away from the platform into clear air, then stopped. The driver secured the train and checked that her passengers were all right. She noticed that the overhead lines were down on the up train so advised train control of the fault and that the down train was clear of the incident.

1.1.14 By this time all the passengers had alighted from Train 6294 and were milling around on the platform watching the fire. The driver marshalled everyone off the platform away from the dangling and possibly alive overhead contact wire, then he returned to his driving cab and updated train control of the situation over the radio.

1.2 Emergency response

1.2.1 Train control contacted the on-call traction lineman and notified him that the overhead traction wire had collapsed at Mana and asked him to attend the site. The traction lineman was about one hour away, so he referred the train controller to a colleague for advice on how to isolate the overhead line remotely. The train controller was talked through the sequences on the traction control computer screen to remotely isolate the section of overhead line around the Mana station.

[6] The equipment cases are mounted just below platform level midway between the two doors.

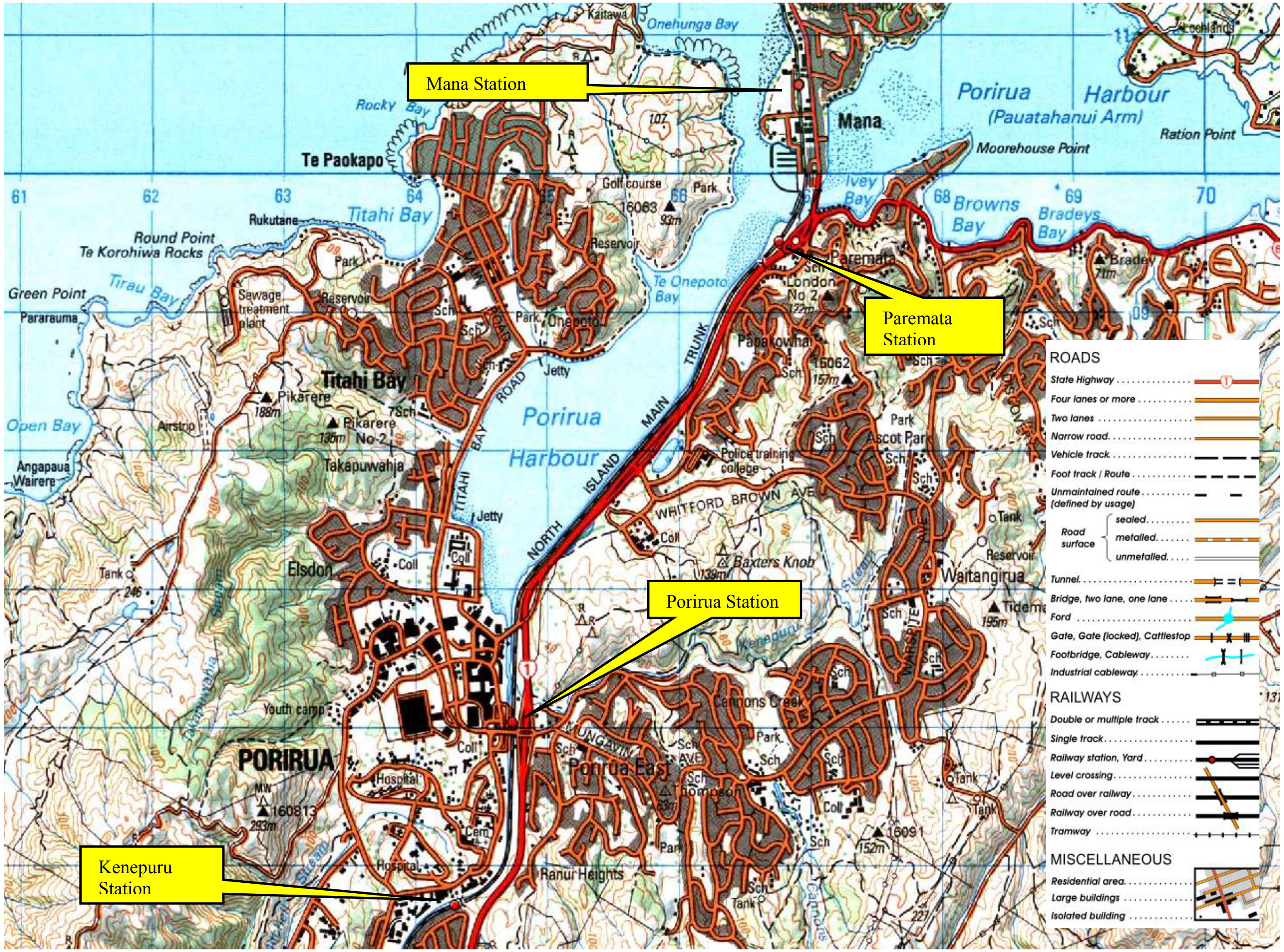

Figure 1
Location map
Map created using 'MapToasterTopo' software by Integrated Mapping licensed to the Transport Accident Investigation Commission

1.2.2 The train controller then instructed the down train driver to hold at Mana station.

1.2.3 The Fire Service was dispatched to the site at 2333 by the Central Fire Communications Centre in response to a call from the public advising of a train fire at Mana station. The Fire Service attended with 3 engines at approximately 2340. The Central Fire Communications Centre had also called the train controller to ask if he was aware of the train fire at Mana station, which he was not.

1.2.4 The fire was out when the Fire Service arrived but people were walking across the tracks between the 2 stationary trains. The Fire Service regarded the downed overhead line as live, so proceeded to tape off the danger areas to prevent people moving across the tracks or near the potentially live wires.

1.2.5 The Fire Service called the Police to assist with crowd control. Soon after the Police arrived, they decided that the Fire Service was adequately managing the situation and did not need Police assistance, so they left within 30 minutes.

1.2.6 When the traction lineman arrived, approximately one hour after the incident, he found the catenary and contact wires had burned through at a point directly above the pantograph stowage well on the roof of EM1373. He talked to the driver then met with the rest of his line crew, who had also arrived by then, to discuss isolation procedures and how to make the area safe.

1.2.7 The traction lineman then travelled south to the 19.53 km point on the track where the isolating switches 45 (down Main line) and 46 (up Main line) were located, which he planned to open. The traction lineman noticed that the overhead line had also collapsed onto the ground near these isolation switches so he advised train control and the traction supervisor.

1.2.8 The traction lineman continued to the substation at Kenepuru (16.42 kilometres (km) along the North Island Main Trunk line from Wellington station) where he isolated the power to the section of line from the south before returning to Mana substation to isolate the power from the north. He then returned to the Mana station to complete the safety isolation procedure by installing local earth connections either side of the train.

1.2.9 After the area had been made electrically safe, the driver opened the main equipment case to enable the Fire Service to check and ensure that all fire remnants had been extinguished. The Fire Service confirmed the fire was extinguished then handed the site back to the rail incident controller. The Fire Service departed the site by about 0115.

1.3 Overhead traction line and power supply

1.3.1 Traction substations were evenly distributed along the railway line and supplied a nominal 1500 volts direct current (V DC) to the overhead line through feeder circuit breakers[7]. The overhead line between substations was divided into sections terminating at the substations and fed from each end. A manually operated isolator could be placed near the middle of a section of overhead line so that track-side maintenance staff could isolate smaller sections of line if required. With this incident, the mid section overhead line isolator was called Switch 46.

1.3.2 EMUs drew their power requirements via the overhead line from the 2 substations nearest to the train location but in inverse proportion to the physical separation distance (Ohm). In other words, when the distance from the train to the adjacent substations was approximately equal, the load share would be equal, but when the train was closer to substation A than B, substation A supplied a greater share of the power to the train. The return current path was through the rails back to the feeder substation.

[7] Ontrack, Wellington electrified area system schematic, Dwg E.50459 sheet 2.

1.3.3 The overlap was the area where the overhead line contact wires from opposite directions were suspended close and parallel to each other so the pantograph could touch both at once. The lines were electrically connected through a local isolator switch, but were otherwise isolated from each other and fed from different substations. The overlap section continued far enough to enable both lines to be terminated onto an overhead gantry or strainer post and for the train to make a smooth transition across the switch area with the pantograph.

1.3.4 The network protection was designed to protect the overhead line network from sustaining permanent damage under electrical fault situations.

1.3.5 The feeder circuit breakers were configured with an auto-reclose feature that allowed a transitional fault to cause a trip but the circuit breaker would automatically reset (reclose) shortly afterwards. If the transitional fault had gone by the time the circuit breaker re-closed, it would remain closed and the overhead line would be alive; otherwise it would trip again. If too many auto-reclose events occurred in a short span of time, the circuit breaker would trip open and lock out until manually reset.

1.3.6 This was a standard power distribution safety feature for overhead lines to compensate for trees touching the lines or the clashing of conductors. In the rail situation the feeder circuit breaker trips were more likely to be due to too many electric trains running on the same section of overhead line, or one train with a fault, or an overhead line breakage that caused a live line to make contact with the ground.

1.3.7 The overhead traction line consisted of 2 main copper conductors, the catenary wire and the contact wire (see Figure 2). The catenary wire supported the weight of the contact wire and was connected to the contact wire with conductive feeder cables and vertical, steel hanger tie wires. The contact wire was intended to be in sliding contact with the pantograph on the train, so was vertically aligned to be parallel with the track. The contact wire was tensioned to approximately 11 kilonewtons (kN). The catenary wire was also tensioned but followed a parabolic curve between the poles and above the contact wire to provide the means to hang the contact wire parallel with the track using the suspended hanger tie wires.

1.3.8 A normally closed, manually operated isolator switch No.46 was located near the middle of the overhead line section between the Kenepuru and Mana substations. When the switch was opened, the Kenepuru and Mana substations could only supply traction power to the half of the overhead line their side of Switch 46. The normal state of this switch was closed.

(The diagram below is provided by the courtesy of KiwiRail)

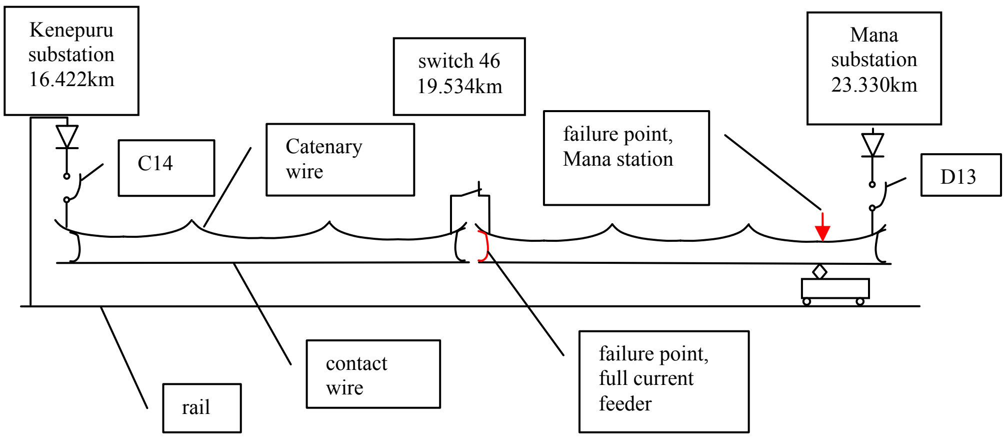

Figure 2
Power distribution network

1.4 Train electrical system

1.4.1 EMUs were made up of 2-cars sets comprising an electric motor (EM) powered car, which provided the motive power, and a non-powered electric trailer (ET) trailer car. The set could be driven from either of these cars depending on the direction of travel. Up to 4 of these sets could be joined to make up a 2, 4, 6 or 8 car train.

1.4.2 Each powered car was fitted with a pantograph. The pantograph style fitted to the EM1373 was a spring loaded device designed to extend upwards and maintain contact pressure against the overhead contact wire. The contact surface was a copper impregnated carbon block and the aluminium pantograph structure was part of the current conduction path down to the insulated cable entry into the train roof. The pantograph could be retracted pneumatically to isolate the train from the overhead power supply.

1.4.3 The electrical current flow from the overhead contact wire to the traction motor system passed through 3 protective switching devices and 2 overload current sensors before connection to the motors[8]. From the take-off point on the pantograph, current flowed through the pantograph structure, then by cable to a high-speed circuit breaker mounted under the EM car, then through 2 control contactors (line contactors LC1 and LC2) mounted in the equipment case on the lower side. All 3 devices had to be closed for power to be available at the traction motors. The power path split at this point to the 2 sets of traction motors with separate overload sensors fitted in each leg.

1.4.4 The circuit breaker was a self-contained protection device that automatically detected current flow through it and isolated the traction motors from the overhead power supply if they drew excessive current from the overhead line through the circuit breaker. This was intended to stop electrical faults within the traction motor system on the train from causing excessive damage to the respective EM traction motor system or to the overhead line network. It also provided an automatic backup to the normal electrical traction motor overload trip as described below.

1.4.5 The circuit breaker was manually controlled by the 'Trip' and 'Close' push buttons mounted above the driver's window. An associated local red alarm light indicated when the circuit breaker was open (see Figure 3). The Trip and Close pushbuttons were train-lined[9] so could be operated from any driving cab along the train, but the indication lights were only displayed in the local EM/ET cabs. The circuit breaker was normally closed while the EM was in service but would trip automatically whenever a local traction motor overload occurred.

1.4.6 The high-speed circuit breaker could only be closed manually using the Close pushbutton and only providing all the control logic conditions had been met.

1.4.7 Power to the EMU motors was normally switched off and on by the line contactors LC1 and LC2. These were connected in series with the circuit breaker and were automatically closed when the power brake controller (the controller) was in any position except 'coast' or 'brake'.

1.4.8 Ganz-Mavag EMU traction motors were fitted to each of the 4 axles on the EM car (2 axles on each bogie). The motors were 750 V DC but connected in series at each bogie set to match the overhead line supply voltage of 1500 V DC. The front and rear bogie sets would normally be operated in series or parallel with each other depending upon the power brake controller position the driver had selected in the cab.

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[8] EMU power schematic Dwg 59E-11011401 B

[9] When more than one set is joined to make train, the function is available in all sets via the train line connecting the sets. Also see glossary.

1.4.9 Direct current (DC) electric traction motors required regular maintenance, particularly with the moving parts like bearings, brushes and commutator. The motors were more prone to internal flashovers and more frequent traction motor overload trips when their brushes and commutator were nearing the end of their maintenance lifetimes. Overload trips owing to motor faults were normal and expected and commonly occurred. If a traction motor failed, the bogie motor set could be manually isolated by operating the traction motor cut out switch on the rear wall of the EM driver's cab (see Figure 4). The EM could then continue to operate under its own power using the remaining motor set, although with reduced power, limited acceleration and reduced maximum speed. If the EM were one of 2 or more sets joined, a pair of traction motors could be cut out without affecting the operating speed. This switch allowed the EM to be driven to the maintenance depot or continue with the present service with a traction motor fault.

1.4.10 For an explanation of the traction motor controls, see Appendix A

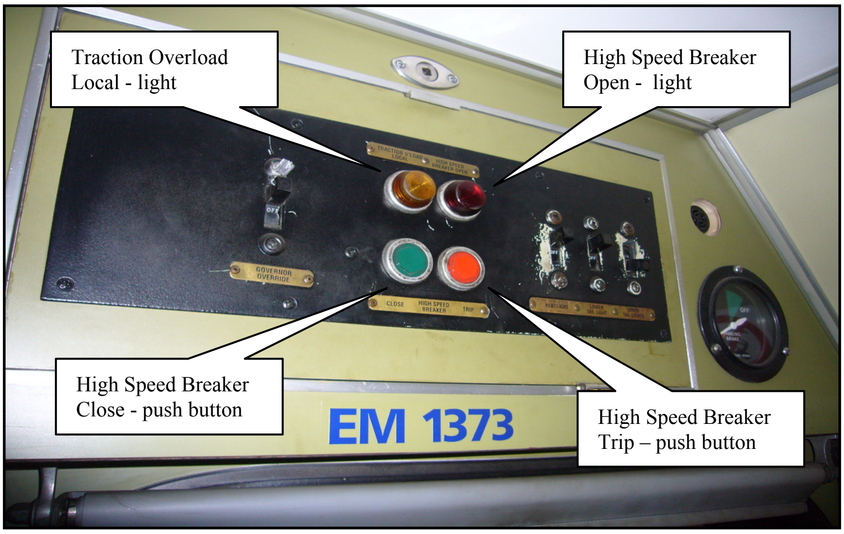

Figure 3
High speed breaker control and indication

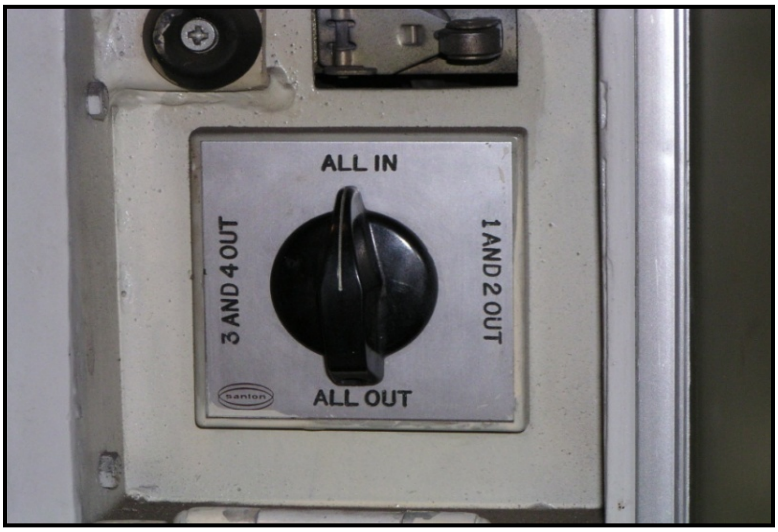

Figure 4
Traction motor cut out switch

1.5 Circuit breaker settings

1.5.1 The protection settings for devices in the power supply chain were set to higher levels of fault current the further away from the traction motor the protection device was located. This was normal and intended to provide discrimination of a fault by isolating it as close as possible to its actual location. The protection settings for the protective devices in the power supply chain are listed below in ascending order from the traction motor on the train to the remote traction substation. The first item is the traction motor full load current.

- Normal operating motor current = approximately 80 - 150 A per series motor set
- Maximum tested motor current = approximately 350 A per series motor set[10].
- Traction motor overload trip setting = approximately 450 A per series motor set [11]
- High speed breaker trip setting = approximately 900 A [12]
- Kenepuru substation feeder circuit breaker C14 = 2800 A at 1600 VDC [13]
- Mana substation feeder circuit breaker D13 = 2500 A at 1600 VDC [14]

1.5.2 The traction motor overload detection devices were set to operate just above the maximum rated motor current. This ensured that the driver had the earliest possible warning that a problem was developing in one of the motor sets by forcing the driver to take action.

1.5.3 The next protection device beyond the motor overload was the circuit breaker. The normal maximum current drawn from the overhead line by a single EM/ET set would be about 300 A when 2 bogie motor sets were running in parallel. The circuit breaker was set to trip at approximately 600 A above this load at 900 A or 200 A above the maximum rated motor current of 700 A (2 motor sets connected in parallel).

1.5.4 Substation circuit breakers were set to trip at approximately 8 times the normal maximum load that a single EM would draw at the maximum line voltage. This trip threshold current reduced (it followed a slightly non linear relationship) as the line voltage measured at the substation reduced. For example the Mana circuit breaker D13 setting was for 2500 A at 1600 VDC but it would also trip the circuit breaker at approximately 1500 A if the line voltage had fallen to 1000 VDC [15].

1.5.5 Allowing for usual traction activity, the substation circuit breakers at Kenepuru and Mana would not normally trip. The local train mounted traction motor protection devices would trip beforehand and isolate any faulty motors on a train well before the overhead line substation feeder circuit breakers approached their trip threshold. Secondly, while the train was running between any 2 substations the load current drawn by the train would be shared between them, so the respective substation feeder current would be further reduced.

1.6 Traction motor overload

1.6.1 Each bogie motor set had a magnetically coupled overload detection and trip circuit that would trip the control contactors LC1 and LC2 and the high-speed circuit breaker if a preset motor current limit were exceeded. This removed the drive power to both bogies and required manual intervention to reset it[16] .

[10] Ganz Mavag traction motor G316AZ characteristic curve, Document 133207 page 12
[11] GEC Traction motor overload trip setting. Document 220133 (issue 2) page 15.
[12] Ganz Mavag (2007). Secheron High Speed Breaker type UR-12-EDE-22-TC.
[13] Ontrack document CST 403 AWL 05.SCS, issue 1, pages 10 & 22.
[14] Ontrack document CST 403 AWL 05.SCS, issue 1, pages 10 & 25.
[15] Ontrack document CST 403 AWL 05.SCS, issue 1, pages 10 & 25.

[16] NZ Railways EMU Control circuit. Dwg 59E – 11011405D

1.6.2 A traction motor overload would be indicated by 2 separate alarm lights at the same time. A local alarm light would illuminate in the driver's cabs for that EM/ET car and a train line alarm light would illuminate in all drivers' cabs making up the train. The local alarm light was above the cab front window and labelled 'Traction Overload Local' (see Figure 3) and the train-line alarm light labelled 'Traction Overload Train' was located to the right of the centre dashboard console, just below the front window of the cab (See Figure 5). These alarm lights would indicate that a motor set on the train had tripped out owing to an overload. There was no indication which bogie motor set had tripped out but a driver could find the EM car with the fault by physically inspecting a driver's cab from each EM/ET set to see if the local traction motor overload and circuit breaker open lights were on. The driver could also reset the traction motor overload and circuit breaker from any driving cab and carry on with the journey.

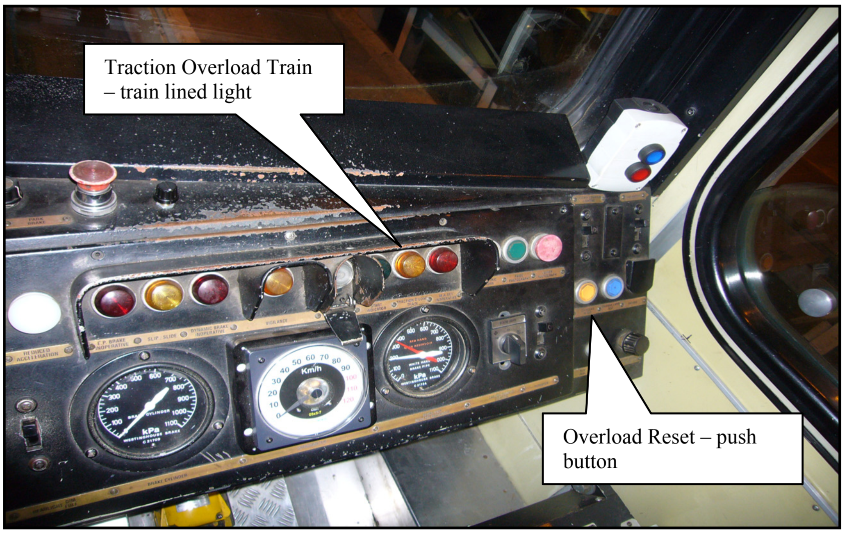

Figure 5
Traction motor overload and reset

1.6.3 The control system electrical interlocks [17] and standard operating procedures [18] required the driver to set the power brake controller to the 'coast' position, close the high-speed circuit breaker then press the 'overload reset' button on the right hand side of the dash board control console to reset the traction motor overload circuit trip.

1.6.4 If the traction motor overload trips recurred, it was likely that a more serious problem existed and a pair of traction motors would have to be electrically isolated from service or cut out. Fault-finding training notes for drivers [19] stated that, "If overloads trip more than two times it will be necessary to 'cut out' traction motors." A driver could easily find the EM car with the faulty motors, but there would be no indication which bogie set had caused the motor overload trip. There would be a 50 % chance of cutting out the faulty or the good motor pair. Drivers were trained to look for external signs of traction motor damage to help identify which bogie set should be cut out. They were also encouraged to phone the platform fitter at Wellington station on an 0800 number or the platform supervisor to discuss the situation and seek advice. On single EM/ET sets such as Train 6294, there were only 2 traction motor bogie sets so the choice of which to cut out was critical to the continuation of the service. On multiple EM trains, both bogie sets on an EM could be cut out and the service could continue with the faulty EM operating as a passenger car.

[17] NZ Railways Drawing 59E – 11011405D
[18] Tranz Metro Wellington (2003). Ganz – EM/ET. LEMU Driving Instruction Manual, p11.
[19] Tranz Metro Wellington (2004). Ganz Mavag – EM/ET. EMU Fault Finding – Ganz, Version 2.

1.6.5 If traction motor overload trips persisted after a pair of motors had been cut out, then either the good pair had been cut out or both pairs were faulty. The training instructions for these circumstances were to try reinstating the pair that had been cut out and cutting out the other pair. In a multi-car train a third option would be to cut out both pairs.

1.7 Damage to overhead traction lines

1.7.1 The remnants of the overhead line and the dropper cable connection from around Switch 46 were examined. The overhead line contact wire and the supporting catenary wire had been completely melted through at the point where the EM pantograph had been in contact with them while the train was stationary at Mana platform (see Figures 6 and 7). The loose ends of the overhead line dropped onto the train and the platform.

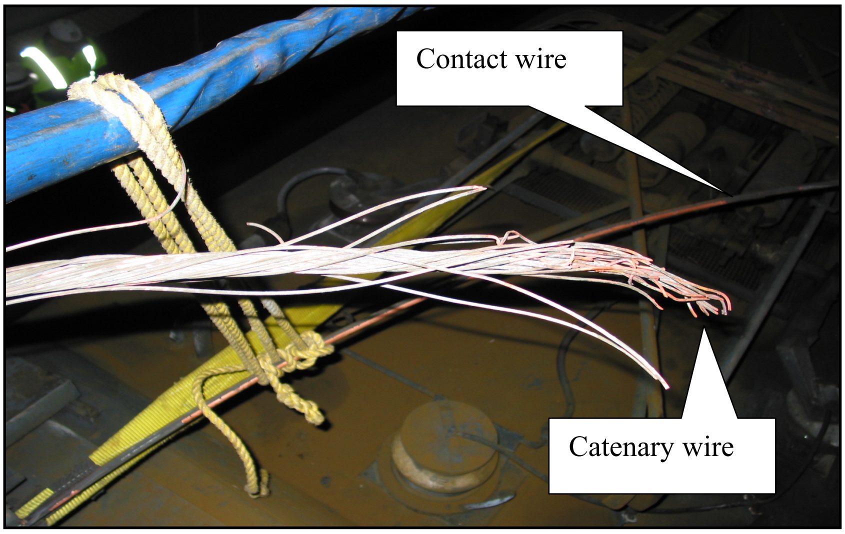

Figure 6
Broken overhead line at Mana
Photo provided by Tranz Metro for use by the Commission.

Figure 7
Parted overhead contact wire

1.7.2 The contact wire was 'necked' at the break (see Figure 7), which was a sign that the material had stretched under tension before parting. A break of this nature would be consistent with the line heating up under high electrical current, becoming ductile and stretching under normal installation tension and failing.

1.7.3 The section of catenary wire directly above the break point in the contact wire had also been severed at high temperature (see Figure 6). One side of the multi-stranded wire appeared to have been in contact with the pantograph and been supplying power to the EM through that contact resistance. The individual strands of the catenary wire had heated owing to the high current that had been conducted through them, then melted away leaving a blob of copper at the severed ends. All strands had rapidly separated in the same manner at approximately the same position until the catenary completely parted. At that point the overhead line would have been unsupported and the loose ends would have dropped towards the ground.

1.7.4 The driver's recollection of seeing a brilliant flash above him as he stepped out of the train onto the platform was typical of the visual effect of an electrical arc that would have been created from the contact wire and catenary parting in the manner described above.

1.7.5 The primary current conductor in an overhead line was the catenary wire. This was connected to the contact wire at regular intervals by full current rated feeder cables that were clamped onto the catenary and contact wires. The traction lineman described the overhead line as having fallen onto the track at the overlap near Switch 46. The remnants of the failed items were examined (see Figure 8) and it was found that the contact wire, just on the Mana side of Switch 46, had fused and separated within the feeder clamp where the full-current rated feeder cable connected to the contact wire. The contact wire was under tension so pulled apart and a loose end dropped towards the track. The catenary wire above remained intact.

1.7.6 The feeder cable was a larger diameter cable than usual but the connection of this feeder onto the contact wire was made with a clamp intended for the smaller standard cable size. The clamp consisted of 2 half shells that should have fitted snugly around both the feeder cable and the contact wire, which were then bolted together with 3 compression bolts positioned midway between the 2 conductors. The design of the 2 shells forced them to mate with the contact faces parallel. As the feeder wire had a greater diameter than that for which the clamp was designed for, the resulting clamp contact pressure on the contact wire at the bottom side of the clamped shells would have been reduced. This joint would have had a much higher electrical resistance than if it had been made with the correct-size feeder cable.

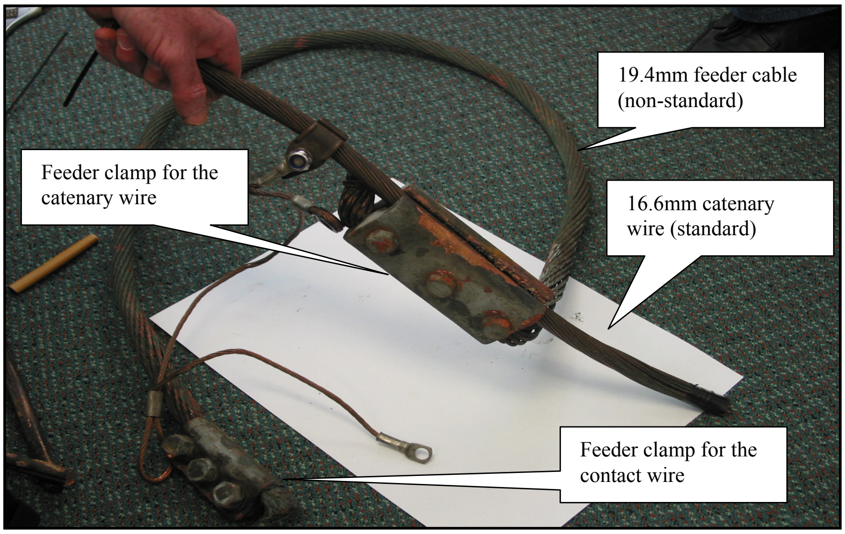

Figure 8
Feeder cable and clamp at switch 46

1.8 Damage to EM1373

1.8.1 An examination of the train revealed that the sliding carbon contact surface on the pantograph had been damaged by severe arcing, with pitting, grooves and splatters of molten copper present (see Figure 9). The support arms and joints of the pantograph showed obvious signs of excessive current conduction. At the point where the pantograph arm joined to a half height pivot bearing, the aluminium tube had melted and created a hole. (see Figure 11)

1.8.2 The No.1 motor on EM1373 was examined through the floor inspection hatch just outside the driver's cab. Soot deposits indicated that severe arcing had been occurring near the armature. The circuit breaker was inspected in situ and the circuit breaker arc chute showed signs of recent arc suppression but appeared to be intact. The equipment cabinet at the source of the fire was opened and examined. The 2 line contactors, LC1 and LC2, had been destroyed by the electrical fault current with much of the physical structure of these devices missing. Adjacent contactors were covered in carbon soot (see Figure 10).

Figure 9
Pantograph damage: Arc damage on contact surface

1.8.3 A damage report for EM1373 [20] was provided by Tranz Metro after the incident. The following list summarises the major faults found:

- traction motors 1 and 4 had low insulation test readings. (Comment: These motors are installed in separate bogies).
- motor cut out switch contacts were welded closed
- line contactors LC 1 and LC 2 in the main equipment case were destroyed from severe arcing
- high-speed breaker contacts were welded closed
- the main equipment case was holed and all items inside were smoke damaged.
- the pantograph structure was damaged from arcing

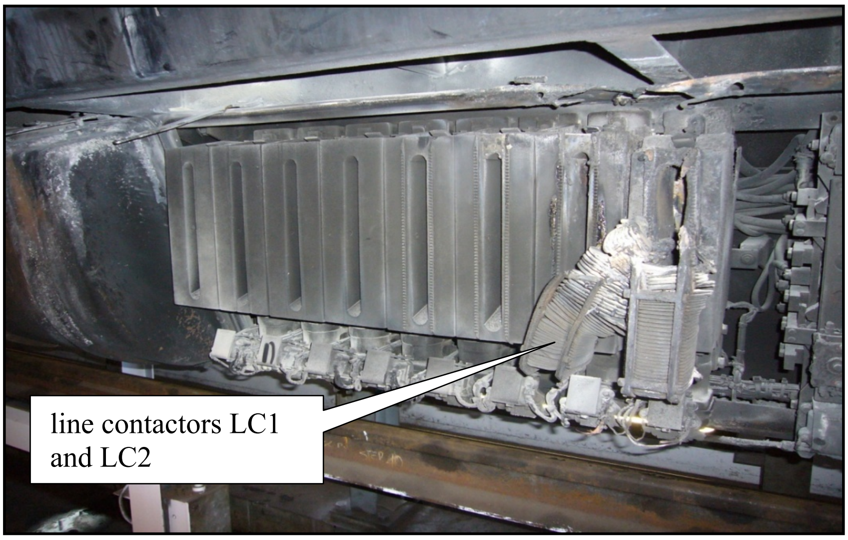

Figure 10
Main equipment case
© Transport Accident Investigation Commission

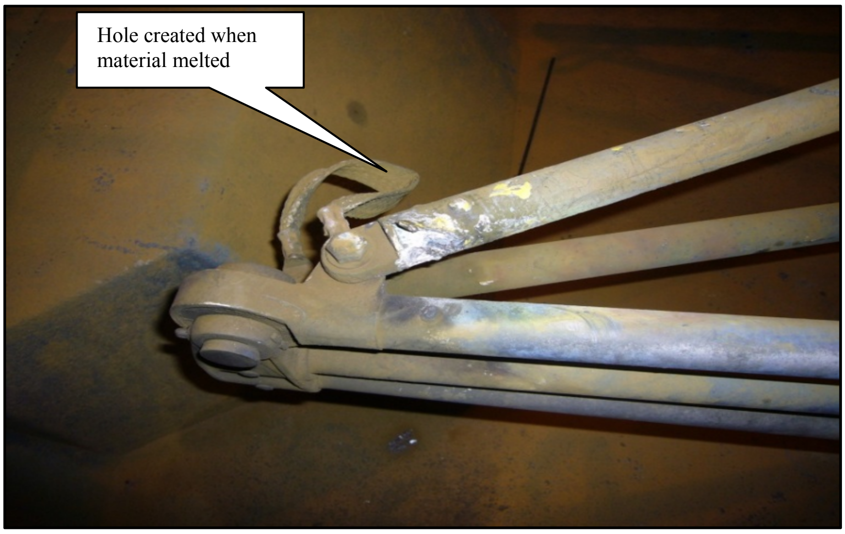

Figure 11
Pantograph damage
© Transport Accident Investigation Commission

[20] Tranz Metro (2008). Fitter's Incident Report

1.9 Personnel

1.9.1 The driver had 3.5 years' experience on the Wellington metro trains as a driver. Previous relevant experience had been 11 years with the rail signal maintenance team. On the day, the driver had started work at approximately 1600 and completed one return trip to Paraparaumu and two return trips to Johnsonville on other EMUs before taking Train 6294 to Paraparaumu.

1.9.2 The train manager had 3.5 years experience on the Wellington metro trains as train manager. Previous experience had been as a passenger manager full time for one year and part time for one year. On the day, the train manager had started work at approximately 1600 and completed 2 return trips to Paraparaumu before joining Train 6294.

1.10 Operational fault reporting

1.10.1 A 54D driver's maintenance log book was provided in the driver's cab of the motor car of every EM/ET set. The 54D was provided for drivers to record any faults with that set. The next driver taking the set was expected to check the 54D and become familiar with potential problems. In the morning before any trains left from the Wellington station platform, the platform fitter would inspect all 54Ds and arrange repairs or temporary restrictions. Minor faults would be fixed by the fitter at the time, but any that could not be fixed on the spot or that were major would be recorded in the fitter's notebook and later reported to the depot via email or phone call. The set could be shifted to the depot immediately if staff were available to work on it, or replaced by another set, or it could continue in service, depending on the nature of the recorded fault. The depot would otherwise carry out the repair when the unit was next scheduled there for regular maintenance.

1.10.2 If the train was able to be used but restricted in some manner, a yellow card would be placed in the cab and it would be scheduled to go to the depot for repair during the off-peak period. Traction motor faults, for example, could be yellow carded and the EM/ET set used as a passenger coach in part of a larger train to cover peak traffic times. There is sufficient power capacity in the EM traction motors to operate on a flat track like the Hutt Valley with a fully loaded 6 car set train with one EM's traction motors completely cut out of service. If the train was to be removed from service, a red card would be placed in the cab and it would be shifted to the depot for repair as soon as possible. The platform supervisor would be advised of all yellow or red carded trains so alternative arrangements could be made and drivers made aware of the possible limitations with their trains.

1.10.3 Tranz Metro driver training notes [21] stressed to trainees that all EMU mechanical faults should be recorded in the Loco 54D. In the meeting with 2 senior Tranz Metro training staff and a platform fitter on 13 March 2009, it was estimated that approximately 10 % of Tranz Metro faults were not recorded by the drivers in the 54D, but that the maintenance staff were usually made aware of them by verbal means. When a train was made up as a 2-, 4-, 6- or 8 car set, the driver would be expected to enter fault details in the respective EM 54D log. For example, if multiple traction motor overloads had occurred in the rear EM when driving from the front ET cab of a 6 car set, the driver would be expected to walk back along the platform or through the train to find which EM had caused the trip and log the event in that EM's 54D. The same would apply if the EM at fault was the rear of a 2-car set. Any 54D entry that had to be made in a cab other than the current driving cab, would therefore incur a delay to the scheduled time table.

1.10.4 Faults that occurred after the first service of the day were to be recorded in the 54D but may be advised to the platform fitter directly by the driver with a cell phone call to a specific 0800 number. This method of contact was often used to discuss problems on the train and to seek advice from the fitter. If the fitter was not available, the platform supervisor could be contacted by phone instead, or as well.

[21] Tranz Metro Wellington (2004). Ganz Mavag – EM/ET. EMU Fault Finding – Ganz, Version 2.

1.10.5 The EM1373 54D had only one entry for the period 14 to 18 April 2008. On 15 April 2008 an entry log noted that two traction motor overloads had occurred that day. The repair staff response had been, “Ta will monitor”.

1.11 On-board data logger

1.11.1 A Tranzlog event recording device was installed in EM1373. The local and train-line traction motor overload signals were monitored by the EMU Tranzlog event recorder.

1.11.2 The Tranzlog is a computerised event recorder that logs digital and analogue signals from various train parameters and position information derived from a global positioning system (GPS) receiver. At the end of a journey, the Tranzlog data can be downloaded and displayed on a computer running a display application that simulates the journey (see Figure 12). The train position from the GPS receiver is shown on a map as a travelling blue square and the dials and lights repeat the driver’s display indications. A list of alarm events can also displayed. The journey can be replayed in steps or run at various speeds.

1.11.3 Events recorded on the Tranzlog that were relevant to this incident were:

- local traction motor overload
- overload reset button activations (General Reset)
- motor control cut out switch – represented by a “Dynamic Brake Failure” alarm.

The high speed breaker status and its manual operating push buttons were also relevant but they were not recorded by the Tranzlog system at the time of the incident.

1.11.4 The Tranzlog data records were examined for the 4 days leading up to the incident at Mana. On 14 April 2008 there were no actual traction motor overload events during the 7 return trips made during the day. On the 15th there were 2 consecutive traction motor overload trips returning to Wellington on the Paraparaumu line while the train did 8 return trips during the day. On the 16th there were no actual traction motor overload events during 7 return trips made for the day. On the 17th there were 5 genuine overloads during the 6 return trips made that day. On the 18th there was one genuine overload during the day before the ones that immediately preceded the Mana incident.

1.11.5 There were numerous other similar events that at first glance appeared to be associated with traction motor overloads, but these were considered to be associated with other events. All associated events, together with a more detailed explanation, are listed in Appendix B.

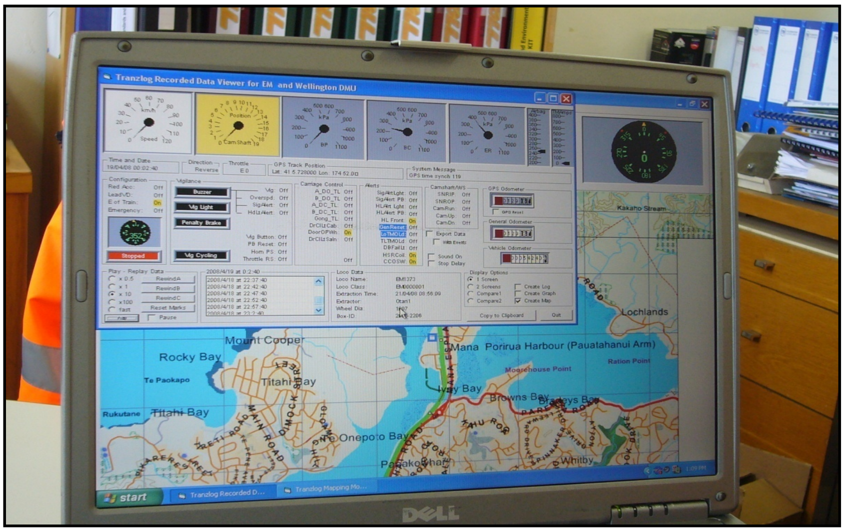

Figure 12
Tranzlog replay display
© Transport Accident Investigation Commission

1.12 Train control SCADA log

1.12.1 The SCADA system operated by Ontrack logged status events as they occurred in the Wellington metro rail network. A printout [22] of the substation circuit breaker activity at Kenepuru and Mana was reviewed.

1.12.2 The log period started at 2322 on 18 April 2008 and ran through to 0046 on 19 April 2008. The feeder circuit breakers for the overhead line from Kenepuru substation (C14) and Mana substation (D13) activated during the incident. A summary of this activity is presented in Appendix C.

2 Analysis

2.1 Event time stamps

2.1.1 The sequence of events was collated using time-stamped events recorded on the traction power network SCADA and the Tranzlog system installed on the train. The 2 systems were not synchronised to a common time reference such as the GPS signal, so there were slight differences in time stamps when events were recorded.

2.1.2 Based upon the last event where the overhead line fell down and the substation circuit breakers at Mana and Kenepuru tripped, the times are close. The overhead line fell down as the driver was leaving the train to inspect the traction motors and swap the motor cutout switch over to the other motor set. This time was approximately 2331 from the Tranzlog data. The network SCADA log recorded the Mana circuit breaker tripping at 2328, which would have been slightly after the time the lines came down. This led to the conclusion that the GPS-synchronised Tranzlog time datum was approximately 3 minutes and 50 seconds ahead of the SCADA time. This error has been allowed for in the description of events, the tabled events and the time line.

2.2 Tranzlog data events

2.2.1 During the week preceding the Mana incident, traction motor overloads were frequently occurring on EM1373. The events downloaded from the Tranzlog and shown in Appendix B were not all associated with genuine overloads, but at least 7 of them before the 18 April 2008 were.

2.2.2 General Reset push button activity was also examined. Several of the events noted in the Appendix had occurred near to an associated event, such as a local or train-lined traction motor overload. Other General Resets occurred for no apparent reason. General Reset activity had not occurred near direction changes over the days of data examined. The reason for this is not clear without delving into the exact nature of the power supply and connections to the Tranzlog inputs, but it seems to support the idea that the traction motor overload events at direction changes were probably linked to what the driver was doing with the train rather than being a genuine fault indication.

2.2.3 Whatever the cause of the traction motor overload events, if the maintenance staff had been aware of the number of traction motor overload activities that occurred during the week it might have flagged to them that the Tranzlog input wiring needed some modifications to eliminate false indications or that there was a genuine problem with the traction motors on EM1373. The opportunity to use the Tranzlog for predictive maintenance investigations on this EMU was not taken by Tranz Metro or Toll Rail at the time of the event.

[22] Ontrack 18 April 2008. TranzRail Traction power network, historical event report (System Do [iQuest]).

2.3 Sequence of events

2.3.1 The following description is a possible and the likely scenario based upon the facts known to the investigative team along with some educated assumptions, but it may not be exactly what happened or in the exact sequence. The facts clearly prove that the overhead lines came down owing to an electrical fault that was allowed to develop in the traction motors on the train. The on-board protection systems sustained collateral damage so were unable to isolate the fault at a lower, more manageable level. The fault escalated until the protection systems at the next level activated. By that stage the train had suffered significant electrical fault current damage and most of the protective electrical switchgear had been disabled [23]. By the time the remote substation protection isolated the fault, the damaged traction motors and switchgear on the train had been destroyed.

2.3.2 A fault had developed in one of the traction motor sets in EM1373 at least 3 days prior to the incident as indicated by the Tranzlog historical data record of traction motor overload activity. Traction motor faults are a normal and expected occurrence with standard responses.

2.3.3 Some of the traction motor overloads shown in Appendix B appear to be false, while others appear to be genuine indications. False indications may have arisen when the overhead traction supply was isolated, so extended stops in Wellington or other terminal direction-change stations have not been counted. The downloaded Tranzlog data records show that on the 14 April 2008 there were 2 x traction motor overload events related to direction changes while the train did 7 return trips during the day. On the 15th there were 2 more such events plus 2 consecutive traction motor overload trips returning to Wellington on the Paraparaumu line while the train did 8 return trips during the day. On the 16th there were 3 traction motor overloads associated with direction changes on 7 return trips. On the 17th there were 2 traction motor overload associated with direction changes and 5 genuine overloads during the 6 return trips made that day. On the 18th there were 2 traction motor overloads associated with direction changes and one genuine overload during the day before the ones that immediately preceded the Mana incident.

2.3.4 The only 54D records over this period were the double trips on the 15 April 2008. The driver recorded that EM1373 had 2 traction motor overloads while operating as southbound Train 6273. None of the 5 genuine trips on the 17 April 2008 was logged. EM1373 was not taken out of service or restricted to light duties so was available to travel as a single set on the most arduous route in the Wellington electric network.

2.3.5 On the night of 18 April 2008, Train 6294 left Wellington for Paraparaumu at 2300. This was a single EM/ET set with no known faults of any significance. The train operated normally to Porirua and reached over 90 kilometres per hour (km/h) on the straight before Paremata. The driver was cruising at 95 km/h, shifting the controller between 'series', 'parallel', 'weak field' and 'coast' positions to maintain speed.

2.3.6 Two faults existed on the train. One of the 2 pairs of traction motors was drawing more current than normal. This fault caused the motor protection system (traction motor overload) to operate more often than usual. A second fault was developing but was undetected. This was the permanent damage caused to the high-speed breaker. It is likely that this damage to the high-speed breaker was caused by successive drivers in control of EM1373 resetting the traction motor overload trips without allowing adequate cooling periods in between each trip and the fact that the fault that caused these trips was allowed to remain.

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[23] Tranz Metro Depot (2008). Fleet engineer incident report: Electrical damage to EM1373.

2.3.7 The last time the high-speed breaker functioned correctly was just opposite Papakowhai, where a traction motor overload occurred just after the driver shifted the controller [24] into 'weak field'. From this point on, the electrical fault on the train could not be automatically contained within the train so impacted upon the wider traction power supply network. The nature of the high-speed breaker fault is not clear, but it did not trip directly soon after that point when it should have. It is possible that the direct tripping mechanism in the high-speed breaker had failed or the power contacts had been physically welded together. The effect was that the high-speed breaker was no longer able to protect the train from an electrical fault and probably was unable to be opened to isolate power to the train.

2.3.8 The driver shifted the controller to 'coast' and reset the traction motor overload which closed the high-speed breaker, LC1 and LC2. As soon as the traction motor overload had reset, the driver selected level 6 braking, which isolated the 2 motor pairs from the overhead supply by opening line contactors LC1 and LC2. It also operated the electro-pneumatic brakes.

2.3.9 Line contactors LC1 and LC2 should have opened and the high-speed breaker remained closed when braking was selected, but it is likely that they were near failure or in a severely stressed condition and that at least one pair of traction motors was drawing excessive current. The line contactors may have flashed over as they interrupted the motor current, sustaining more arc damage and possibly shorting to earth. The high-speed circuit breaker did not appear to have operated as it should have and the fault current was significant because both substation feeder circuit breakers for that section of overhead line tripped.

2.3.10 The direct current trip settings of the substation circuit breakers were 2800 A at Kenepuru and 2500 A at Mana. According to the TranzRail historical event report for the traction power network, both feeder circuit breakers at Kenepuru and Mana tripped at this time, removing power to the overhead line. The fault current would have been in the order of 4000 A at the train to trip both feeder circuit breakers at once. It is likely that the contact wire near Switch 46 also failed at this time as a portion of the fault current from Kenepuru substation flowed through the substandard joint.

2.3.11 The substation circuit breaker trips were noticed back at train control and the train controller suspected that Train 6294 was the cause. The driver was braking to come into Paremata so his train was not demanding power from the network, but he did notice the motor alternator (MA) trip off. The MA supplied 230 VAC to the on-board systems within the cars. The substation feeder circuit breakers reset automatically after 30 seconds and re-livened the overhead network, giving the driver the impression that whatever he had just done on the train had fixed the problem with the MA. The substation circuit breakers did not trip again after resetting, which was probably because line contactors LC1 and LC2 were open for braking.

2.3.12 The train was parked at Paremata with the controller left in the first step of braking.

2.3.13 The driver received the clearance signal to depart the station and selected 'weak field' with the controller. The train had accelerated to 52 km/h by the time the control system stepped up to cam switch position 15, which is the last stage of parallel arrangement before reducing the field current. The traction motor overload tripped at this point and was reset by the driver. If line contactors LC1 and LC2 had still been operational they would have had to interrupt the full current of this fault and thus would have sustained more damage. Normally the high-speed breaker would have carried the brunt of this interruption but it had already been disabled during a previous failure.

[24] Power brake controller as described in the Glossary.

2.3.14 The driver reset the traction motor overload and selected 'series'. Just after crossing the Paremata bridge the train was travelling at 55 km/h when the driver selected 'parallel'. This immediately caused another traction motor overload trip. The General Reset procedure was carried out, which cleared the trip signal and the train was coasting at 60 km/h. Braking was selected to level 6 and the train slowed down for the stop at Mana. The Mana substation feeder tripped again at this point, then automatically reset after 30 seconds. The fault current through the train would have been close to 2500 A for the Mana feeder circuit breaker to trip. It was likely that fault was caused by a flashover around LC1 and LC2 when they opened after braking was selected.

2.3.15 The train stopped at Mana and the doors opened at 2329.13. The controller was left in the braking position 6 while the train was parked. The substation circuit breakers did not trip and the traction motor overload did not operate.

2.3.16 The driver walked to the rear motor car to cutout a set of traction motors and returned to his cab. The motor cutout activity was not directly monitored by the Tranzlog, but would have normally been indicated as a dynamic brake failure alarm. This alarm was not recorded, but a train-lined traction motor overload did occur about 30 seconds after the doors opened. Normally a train lined traction motor overload would be associated with a local traction motor overload but none were detected at the time. If the driver had been quick he could have walked from the front cab to the rear and back again (about a 90 metre [m] return trip) in approximately 77 seconds. There was a period of 68 seconds between the door opening and closing at Mana, twice as long as other stops that night. It is possible that some inputs to the Tranzlog were inhibited by the wiring damage that was occurring in the equipment cabinets so that when the motor cutout switch was activated, the train-lined traction motor overload was the only signal detectable.

2.3.17 At 2330.41 the driver selected 'series' position with the controller to leave Mana. The traction motor overload tripped immediately without moving the train. He reset the protection and tried to restart the train within 10 seconds. The traction motor overload immediately tripped again. He placed the controller in level 6 braking and left the cab. As the traction motor set had just sustained 2 consecutive overloads, and several more in the preceding few minutes, the 2 motors would have been very hot. It is likely that the motor windings had shorted out owing to insulation failure and could not produce enough magnetic force to rotate the armature. If this had been the case, as soon as the traction power was connected to the motor set, the motors would almost have represented a short-circuit between the overhead traction supply line and the earth return rail, which would have resulted in an immediate traction motor overload trip.

2.3.18 As the high speed circuit breaker had already failed closed, the 2 line contactors LC1 and LC2 were the last devices in line to isolate the traction motors. They should have opened to isolate the traction motors when braking was selected, but were likely to have sustained such significant flashover damage since the train had left Paremata and while it was parked at Mana station, that they had also failed closed and were unable to isolate the power supply. The traction motors would have effectively remained connected to the overhead power supply at this point and been uncontrollably cooking from the rising fault current. The Mana substation feeder tripped and reset, but the Kenepuru feeder was able to remain feeding the fault owing to the higher line impedance. There is no doubt that the fault current at this time would have been heavy because of the damage incurred within the next few seconds.

2.3.19 The overhead line was carrying the full fault current from both substations and passing it through a single point of contact with the pantograph to the train. That point of contact would have been heated enough to cause permanent damage. For example, if the fault current had been in the order of 1500 A and the contact resistance 0.1 ohm, the heat developed across the resistance would be 225 kilowatts [kW] (Ohm). That is enough heat if applied to a small section of copper rod like the contact wire, to melt it. The fault current was probably well in excess of this level because both substation feeder circuit breakers would trip within a few seconds of each other.

2.3.20 The doors were reopened at 2331.13. When the driver exited a few seconds later, the overhead contact wire fused and the EM's equipment cabinet was on fire. The driver reported that a few seconds later, the catenary wire also fused and one end of the overhead line fell onto the train. The Kenepuru and the Mana feeder circuit breakers would have both tripped about the same time the overhead line fused; around 2331.46.

2.3.21 The Ontrack historical event report of the traction power network showed that the Mana feeder circuit breaker registered such a large direct current trip at 2331.46, and within such a short period from previous trips, that it tripped and locked out. The Kenepuru feeder circuit breaker was still feeding the fault while the overhead line was intact, but through a higher impedance so the fault current magnitude was lower. The Kenepuru feeder circuit breaker tripped at 2331.49 then automatically reset after 30 seconds, by which time the overhead line had parted, so re-livening the line on that side of the break.

2.4 The occurrence

Instrumentation

2.4.1 The instrumentation in the cab provided only limited information to the driver about the traction motor system. Whenever a traction motor overload occurred in a remote EM/ET set in a multi-set train, the driver in the driving cab would only see the train-lined traction motor overload warning light. The local traction motor overload and high-speed breaker status lights would also be on in the driving cabs of the respective EM/ET set, but only the traction motor overload signal would be repeated in all cabs via a train-line signal. Pressing the General Reset button with the controller in 'coast' would clear the traction motor overload alarm and indicate to the driver that the train was fully operational, when the high-speed breaker in the remote EM/ET could still be in a tripped state, isolating that EM's traction motor set. The train could still be operated, but the only indication to the driver would be a slightly slower acceleration rate from normal, as covered in the driving notes [25]. The remote high-speed breaker could be reset by pressing the high-speed breaker Close push button, which is train-lined from the driving cab, but it would not change the status indication or provide positive feedback to the driver that anything had occurred. In a single set, all indications of the high-speed breaker and the traction motor overload were available to the driver.

2.4.2 The traction motor cut out switch is provided to cut out a faulty motor pair so the other pair could still be used to move the train. The driver would have no instrumentation to identify which pair may be faulty so would have to make a selection, then try driving the train. If the traction motor overloads persisted, the other pair was faulty and the motor cut-out switch had to be changed over again.

2.4.3 On the night of 18 April 2008, the driver had one traction motor overload occur before Paremata and some sort of problem with the MA. Indications were that the train was operating satisfactorily but the MA may have had a problem. Upon leaving Paremata there were 2 more traction motor overload trips. This was nothing unusual for these trains, but 3 of them in a row would have been a concern with a 2-car train. The instrumentation was indicating to the driver that the train was working normally.

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[25] Tranz Metro Wellington (2003). Ganz – EM/ET. LEMU Driving Instruction Manual, p11

Electrical switchgear on the train

2.4.4 It was not normal for the substation circuit breakers to trip owing to a traction motor overload on a train or for the overhead line to fuse and fall to the ground. The high-speed breaker would normally detect a train load current overload and trip when it reached 900 A, but for the 2 substation circuit breakers to trip at the same time as the train approached Paremata, the current would have been closer to 4000 A at the train. These events alone prove that the electrical fault on EM1373 was unusual. Standard protection systems installed on the train should have detected and isolated this fault well before it caused a problem to the electrical overhead supply network. The question of how and why it got to that state is of more value to the Commission's purpose than the intricate details of what failed and when.

2.4.5 The damage caused by the event at Mana was significant and the extent not seen before at the maintenance depot. This made it almost impossible to determine the initial problems in the electrical switchgear. It was clear from the evidence, including the Fleet Engineer Incident Report, that the substation feeder circuit breakers had tripped owing to a problem on the train and that a logical conclusion from this was that the high-speed breaker on-board protective device had not operated. This was really the initial failure event that led to the end result.

2.4.6 The high-speed breaker activity was not recorded by the Tranzlog at the time, [26] but EMU Control Circuit Dwg 59E-11011405D shows that it was interlocked with the local traction motor overload to open every time one occurs. The electrical stress experienced by the high-speed breaker contacts interrupting up to about 900 A of motor current owing to a traction motor overload while the motors are configured for parallel operation, would eventually take its toll. If too many interrupts occurred within a short period, the high-speed breaker would be likely to suffer permanent damage. The driver training notes included a warning about waiting for the high-speed breaker to cool before resetting if it had tripped 2 or 3 times. The high-speed breaker on EM1373 would have been severely stressed after passing approximately 4000 A before Paremata, sustaining 2 traction motor overload trips while the motors were configured in parallel of at least 450 A after Paremata and another substation circuit breaker trip near 2500 A while approaching Mana, all within the space of 2 minutes.

2.4.7 The maintenance programme for the high-speed circuit breakers required that they be checked during a 'D' Check [27] every 75 000 km, which would have occurred between 6 and 12 months on EM1373 at the rate it was travelling in April 2008. The work carried out was to inspect for damage and clean away the arc deposits, which was in line with the manufacturer's instructions but the manufacturer required more frequent 3 monthly inspections. An estimated lifetime of the high-speed circuit breaker based upon operations was not available at the time this report was written, but EM1373 has been in service for 27 years. Traction motor overloads were reported by the Wellington Depot Manager as being responsible for 40 % of in service faults for the Wellington EMU fleet, so the circuit breakers would have been interrupting fault current quite regularly. The combination of the age and frequent operation of the circuit breakers could indicate that the lifetimes of some units in service were nearing the end.

2.4.8 The poor instrumentation associated with the high-speed breaker, the lack of monitoring by the Tranzlog and the lack of significance associated with a high-speed breaker trip by people interviewed for this investigation indicate that the high-speed breaker tripping was not regarded by Tranz Metro as a major concern. It is actually a safety-critical component in the train protection system and its impending failure was not detected in this situation.

[26] KiwiRail Professional Services Group (2009). Tranzlog connector numbering and wire allocation DC DBR Loc V5. EM & ET Unit.
[27] Toll (2007). Ganz Mavag Electric Multiple Units. 'D' Maintenance check – Loco 454, revision H.

2.5 Individual actions

Response to traction motor overloads

2.5.1 The indications to the driver on approaching Paremata and later Mana were that the train had a traction motor problem. The high-speed breaker light might have been on but resetting it was a normalised procedure associated with the General Reset and would not mean anything different to the driver. The driver followed standard procedures with safety in mind and decided to stop at Mana to cut out a pair of traction motors. He could have stopped on the track and walked through the train, but this would have delayed the trip and possibly raised concerns among the passengers. It would have been a greater risk to his safety and delay to the service if he had stopped on the track at night and walked along the ballast to inspect the motors. Without any knowledge of the pending failure of his train, his best option was to continue to Mana.

2.5.2 Once at Mana, the driver proceeded with haste to cut out the motors but his choice was based upon his impressions of the pair of motors that most commonly failed. There appears to be no logical reason to believe that one pair is more likely to fail than the other but the belief exists and it changes between different people.

2.5.3 Now that the driver had experienced 3 traction motor overload trips in less than 3 minutes, it should have flagged a high risk if another occurred. It is understandable that he tried another reset after the first trip when attempting to depart Mana, because the service had already been delayed and he would have had to walk back to the rear of the train to operate the motor cut-out switch again.

2.5.4 The driver responded to the situation as he had been trained to do.

Emergency response

2.5.5 With a fire near the back of his train and the potentially live cables from the overhead traction line draped across his train and on to the platform, the driver was faced with somewhat of a dilemma. His actions under the circumstances were well-intentioned and predictable. The driver's first thoughts were to keep the passengers on the train to protect them from the live cables, but the passengers understandably did not want to remain on board a train that was on fire, so they disembarked.

2.5.6 From the description of events, the driver was trying to coordinate everything, but he had a train manager to assist. Sharing resources would have been a more effective way to manage the situation, for example the driver could have continued to deal with the risk to passengers from live overhead lines down on the platform while the train manager dealt with the emergency response.

2.5.7 The current Tranz Metro driver training syllabus includes an awareness of the safety hazards that exist on the rail network and guidelines on managing the risks to the public. Drivers and train managers are taught to work as a team with the driver focussing on the safe running of the train and the train manager on the safety of the passengers. If it comes to a choice, the driver has seniority. Initial training includes a course on electrical awareness for all crew, then drivers go through a more detailed course learning how to manage particular hazards such as where the overhead line may have collapsed onto the train. Once out of the initial training, individual crew are tested every 8 months by a safety observer travelling with them and they sit a written safety test every 2 years.

2.5.8 Emergency response by operational crew needs to be automatic for them to process the quantity of incoming data, grasp the emergency situation then deal with it in the most effective manner. This response can be improved with practice and an adherence to the principles of crew resource management. Between the initial driver training course and the ongoing refresher checks, crew may only be required to consider the risks to the passengers and public on the rare occasions when they personally experience them as crew. The current Tranz Metro refresher training is dealt with in isolation from other crew input, so the team aspect of train operations so essential for effective crew resource management cannot be covered effectively.

2.5.9 In this case at Mana, 2 emergency situations were presented at once, one where crew were trained to get passengers off the train and the other where they were trained to keep them on. The result was that in spite of the best intentions of the crew, neither was managed well and the public initially took care of themselves.

2.5.10 The one outstanding factor that could be improved is crew resource management. That is basically how the crew work together as a team, making the most effective use of each other, information and equipment to achieve a safe operation. The Commission has made several safety recommendations about crew resource management training in the rail industry. The standard of crew resource management displayed during this emergency justifies that the current safety recommendation (026/08) (Transport Accident Investigation Commission (TAIC), 2007) in relation to a fatality at Ohinewai, remaining open.

2.5.11 Generally the first response in case of fire is to raise the alarm before fighting the fire; that way at least help is on the way in case initial attempts to extinguish the fire are not successful. This did not happen at Mana. The train controller was not aware that there was any fire until he was contacted by the Fire Service. He thought he was only dealing with a lines-down event.

2.5.12 Once the Fire Service arrived on the scene, and later, the Police, the emergency was well controlled. Before their arrival, and if the train had been fully loaded as it had been a few stations earlier, the train crew might have struggled to control the situation, particularly if they had been unsuccessful in extinguishing the fire.

2.5.13 The incident, although in the end well handled, could have been controlled better with a plan and good use of the resources available.

2.6 Risk controls

54D drivers log

2.6.1 The driver's log remains in the EM cab and is used to record any faults experienced with the train for later repair by the maintenance team. Drivers are expected to complete the log during each trip, wherever it is located in the train. Longer 4-, 6- and 8 car sets are used during peak periods that could require the driver to walk more than a 40m return trip to enter a fault in the log. A traction motor overload, for example, can be reset from any driving cab so the train is able to continue without the driver leaving the cab. Completing the 54D is therefore discouraged by contradicting operational requirements to maintain time schedules and the need to concentrate upon the task at hand of driving the train, but emphasised in classroom training sessions as being essential.

2.6.2 During recent interviews, Tranz Metro staff claimed that approximately 10 % of faults were not logged in the 54D. The information still seems to get through to the maintenance staff by more casual and informal methods despite the lack of information in the 54D. The risk with this casual method of fault reporting is that it depends upon verbal communications and enables confusion to creep in and information to be lost.

2.6.3 Train 6294 was an extreme example of what could happen as a result of the poor adherence to the official reporting methods through the 54D but it is probably not typical because a Mana incident has not reoccurred in the past 18 months. It does highlight the potential difficulties with completing the 54D and suggests that a review of the present system would be of value to Tranz Metro and the general public.

Traction motor overload responses

2.6.4 The traction motor overload system was fitted to the Ganz-Mavag EMUs for early warning to the drivers of a problem with the traction motors. Too many trips would indicate that the traction motor was nearing the end of its current service life and needed maintenance. The threshold for raising this as a fault for the drivers is 2 or more events near to each other [28]. Potentially a driver could experience 2 events 30 minutes apart on each leg of a 2.5 hour return trip and not report them. If another driver took the set immediately after and experienced the same number, there would be no need to record them either but the EM would have experienced 4 traction motor overloads in the same day.

2.6.5 If the threshold has been reached and the 54D completed, the maintenance staff might not regard it as an in-service failure until other drivers report the same fault. The maintenance depot staff consider that a higher number of events is a suitable threshold because there are so many traction motor in-service failures. The Wellington Depot Manager stated that the current rate of traction motor in-service failures reported to the maintenance depot is approximately one EMU per day. Many of these can be repaired and returned to service, but there are approximately 15 traction motor failures per year that require major work beyond the scope of the depot.

2.6.6 Routine analysis of the Tranzlog equipment fitted to trains could be a valuable source of data for diagnosing emerging maintenance issues. The Tranzlog monitors the traction motor overload signals, so records are available for the maintenance staff to interrogate an EMU data logger and get a better understanding of how many traction motor overload events may have been happening. This is rarely carried out for various reasons, but it is possible. The equipment is capable of being remotely interrogated and with a small amount of additional hardware; Tranz Metro maintenance depot staff could remotely interrogate the Tranzlog data across the whole EMU fleet from their office. At the moment it is interrogated by direct connection to a laptop, but usually only after an event.

2.6.7 The effect of these responses is that the true number of traction motor overloads occurring is not known and the maintenance actions rely upon the occurrence of a bigger problem before an EMU is restricted or sent off for maintenance. A more proactive approach between the maintenance and operational staff using existing Tranzlog information and driver feedback would likely identify traction motor problems before they become in-service failures.

2.7 Organisational influence

2.7.1 It was reported to the Commission that under the ownership of the Tranz Metro operation current at the time of this incident, the traction motor maintenance policy was one of replace on failure. KiwiRail stated that more recent maintenance policy includes refurbishment of complete bogie sets on an 8-year cycle and a planned refurbishment of full EM/ET train sets. There is also a 4-stage cyclic set of regular maintenance inspections for the fleet based upon distance travelled. This investigation did not delve into the reasons why a replace-on-failure policy was followed, but the effect that remnants of that policy have on the overall efficiency and safety of the operation deserves some comment.

[28] Tranz Metro (2003). LEMU Driving Instruction Manual – Ganz – EM/ET, page 11 and EMU Fault Finding (2004) –Traction motor overloads

2.7.2 At a glance the failure of a traction motor on an EM car might not appear to be a safety issue. There are often several EMU cars in a multi-set train, so the failure of one set can be rectified by simply cutting out the affected motor set and continuing with the journey. In the worst case of a double failure on a single-set train, the train stops and passengers complete their journey by another mode, with obvious quality-of-service issues.

2.7.3 The on-board overload protection systems protected the network from train faults and vice versa, in theory. However, as this serious incident shows, those protection systems can fail with potentially disastrous consequences.

2.7.4 If traction motor failures were allowed to become the normal way of initiating traction motor maintenance, then traction motor failures would be the norm rather than the exception. At some point in time, the safety of the entire system would then rely upon the high-speed circuit breaker preventing a common traction motor fault escalating into another Mana event. Such a maintenance philosophy would raise the importance of the last physical defences in the electric traction system in the train to being highly safety-critical equipment; such as the high-speed breaker. It would also raise the risk profile across the Tranz Metro fleet of EMUs. A robust inspection, preventative maintenance and replacement programme for this equipment would therefore become critical to the safety of the entire operation.

2.7.5 Typically, an efficient service operation would have a robust preventative maintenance programme that minimised breakdowns. Not only would this have the benefits of improving reliability, efficiency and reducing in-service failures, it would likely reduce overall costs as well. Maintenance expenditure would be more predictable than peaky responses to in-service failures and resource demands more consistent. Tranz Metro, under KiwiRail ownership, has taken steps towards a more preventative maintenance programme but there is potential to go further with data analysis, more effective driver feedback and more rigorous monitoring and maintenance of the high-speed circuit breakers.

2.7.6 Such a maintenance programme would mean that reliance on the last line of defence in the system, such as the high-speed circuit breaker, would become the exception rather than the norm; the risk profile would be reduced.

2.7.7 The Commission has reported on the standard of maintenance in the Auckland metropolitan rail system in report 06-110, (Transport Accident Investigation Commission (TAIC), 2006). In that report it was recommended to the Chief Executive of the New Zealand Transport Agency that he addressed the safety issue whereby:

> There is recurring evidence indicating that the standards of maintenance of rolling stock on the national rail network as demanded in Veolia's and Toll Rail's safety cases is lower than preferable and reasonable in that for example:
>
> - Manufacturer's inspection, repair and maintenance instructions are not always documented and followed
> - Safety-critical components are not always identified and documented
> - Work instructions for maintaining safety-critical equipment are not always issued, and work on safety-critical components is not always signed off by someone other than the maintainer
> - Some maintenance is not recorded (015/08)

2.7.8 From examining the maintenance aspects of this event, some of those matters raised in the previous recommendation are relevant to this occurrence as well. Because this safety recommendation remains open, the Commission will not be re-issuing it, but draws the Chief Executive's attention to it again.

3 Findings

3.1 Train 6294 suffered an electrical fire when extremely high current was drawn from the overhead traction supply to a serious fault in one of the train traction motors. The high current was not interrupted by the protection devices on the train because they had failed due to their being repetitively reset under serious fault conditions.

3.2 The overhead traction wires parted in 3 places causing the lines to fall to the ground. The reason for their parting was the excessive current heating the wire above its melting point where it contacted the train pantograph, and through a high-resistance joint caused by incorrect assembly.

3.3 The fault in the train traction motor had been developing for a number of days, but the monitoring and maintenance system had not resulted in intervention before a serious failure occurred.

3.4 The safety-critical high-speed circuit breaker on EM1373 failed to operate and protect the train from more serious damage, which was most probably due to reset activity after frequent traction motor overloads without allowing an adequate cooling period between resets.

3.5 The operator's maintenance policy tending to be more reactive than proactive meant that the failure of traction motors had become an accepted norm rather than an exception, which increased reliance on technical defences in the train electrical system to prevent this type of event escalating. This raised the risk profile of the entire train operation to be reliant upon the last line of defence.

3.6 With traction motor overloads being a frequent event in the normal day-to-day train operation, the on-board alarm and monitoring system did not assist the driver to understand fully and manage such faults with their train. Additionally the indications in the driver cab differed depending on whether the EMU was operating alone or connected with others to form a longer train.

3.7 The 54D fault recording and monitoring system used on the Tranz Metro trains was ad-hoc, was not completely followed, and did not achieve its intended purpose of reporting faults and informing drivers of the serviceability of their trains.

3.8 The current requirements for train event recorders (or data loggers) as defined in the National Rail System Standard NRRS/6 have been developed between the data logger vendor and the customer for the diesel electric locomotives, but have not been updated for electric traction trains. Safety-critical equipment fitted to electric traction trains is therefore not monitored because it does not have to be monitored. Although not a factor contributing to this incident, there is also no independent technical standard for train data loggers in New Zealand that defines a common format for data monitoring.

3.9 Although the management of the emergency response to this occurrence was in the end effective, the risks to the public could have been reduced if the crew had been trained and skilled in appropriate crew resource management techniques and therefore more prepared to manage the crowd.

4 Final Safety Recommendations

On 18 December 2009 it was recommend to the Chief Executive of the New Zealand Transport Agency that he address the following safety issues:

4.1 The system for recording faults on Tranz Metro trains was not user-friendly, was not being followed all of the time and did not achieve its purpose of reporting faults and informing drivers. (032/09)

4.2 The Tranz Metro maintenance policy was biased towards being reactive rather than proactive and did not include identifying and monitoring the performance of safety-critical components such as high-speed circuit breakers. (033/09)

4.3 The automatic train status information presented to drivers in the driving cabs of Tranz Metro trains did not give the drivers adequate information about the status of critical on-board systems. (034/09)

4.4 The current performance standard for train event recorders (or data loggers) as described in the National Rail System Standard NRSS/6 needs to be updated to include safety-critical equipment on electric traction trains and technical standards for how such information is recorded. (035/09).

On 21 January 2010, The Rail Safety Manager of New Zealand Transport Agency responded:

> We intend to work closely with KiwiRail with an aim to implementing and closing these recommendations as soon as practicable.
>
> Discussions on them will commence on publication of the report and will be ongoing. Any outstanding Transport Accident Investigation Commission (TAIC) recommendations also form an integral part of our annual safety assessments of the rail industry.
>
> When these discussions are concluded and the appropriate evidence has been gathered, we will be liaising with TAIC with a view to closing this safety recommendation.

Approval on 19 December 2009 for publication

Hon W P Jeffries
Chief Commissioner

Appendix A Description of the EM traction motor system

1 The train moved forward when the driver had selected the desired terminal speed by moving a power brake control lever to the 'field series, 'shunt' (also termed parallel) or 'weak field' positions (See Figure 13). The automatic control system then accelerated the train to the maximum speed possible with that selected position. The driver could select the top speed selection ('weak field') from a stationary position if desired, and the automatic control system would step the traction motor configuration through each stage to achieve the maximum acceleration rate to the maximum speed. If the train reached the desired speed earlier than expected or the driver wanted to slow down, the 'coast' position would be selected for a period. Braking could also be applied if required.

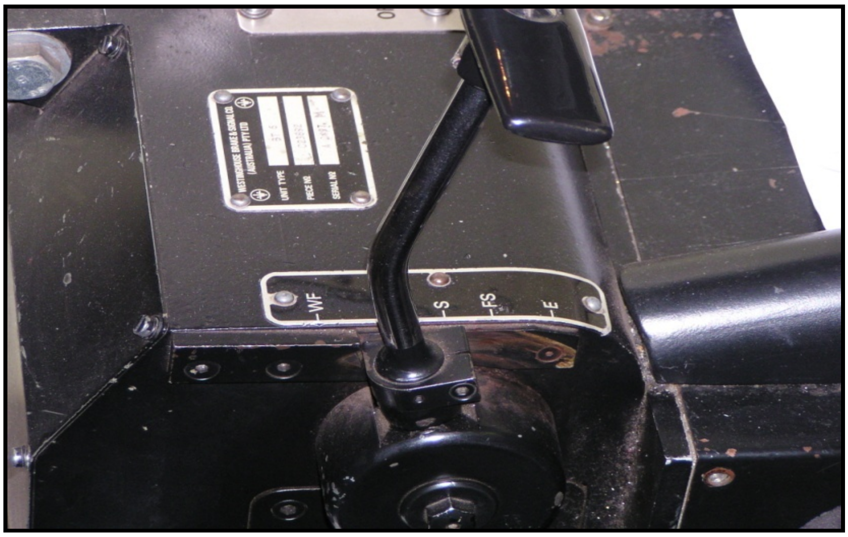


Figure 13
Power brake controller in 'coast' position
© Transport Accident Investigation Commission

2 The traction motor speed control system was a standard series-parallel control system. The control system switched the 2 bogie motor sets into series or parallel with each other to alter the maximum voltage across the motors. It then switched fixed resistor banks into circuit to alter the maximum current through the rotor and field windings. Each step change selected with the power brake controller created a motor configuration that had a different predefined maximum speed. Within each main step there were several smaller notch steps that were automatically selected as the train accelerated. The cam switch was at the centre of the control system and provided the required switch contacts to select the appropriate combination of motor configurations and resistors at each notched step. The control system would reset the cam switch to the start position if the train stopped, so that it would always restart from the same position, then notch around the speed steps to the maximum speed as selected on the power brake controller.

3 The current through a series wound DC motor would be very high upon starting. As the motor sped up, the current would reduce because the motor would produce a proportionally greater internal back EMF (electro motive force [29]) with speed that would oppose the motor current. Eventually the motor current would stabilise at a low point when the output torque matched the motor shaft load. The low point in motor current would be sensed by the series-parallel control system and used to automatically initiate each step change of the notching relay.

[29] Back EMF in an electric motor is the force generated when a conductor is moved through a magnetic field. It opposes the motor current that rotates the rotor.

4 The initial motor configuration to pull away from a platform would be with all 4 motors in series (field series position) which provided 375 VDC across each motor. The next stage of acceleration (shunt or parallel position) required the motors to be configured into 2 parallel strings of 2 motors in series, which increased the voltage across the motors to 750 VDC. The maximum speed selection was achieved with the power brake controller in the 'weak field' position. This was where the motors were configured into the same parallel arrangement as in the 'parallel' position, but the field winding current would be reduced with a shunt connected resistor bank.

5 The resistor banks could also be used to provide rheostatic (dynamic) braking down to approximately 20 km/h, below which friction brakes were more suitable. Rheostatic braking has been disabled in the Tranz Metro EMUs from soon after they were commissioned into service because of operational problems. They are still switched out of service.

6 The power brake controller is moved back from the 'field series' position to apply 6 steps of electro-pneumatic braking then into the 'E' emergency braking position.

Appendix B Tranzlog events

The following events were obtained from the Tranzlog data files. The events were recorded by the Tranzlog data recorder fitted to EM1373 during the days preceding the Mana incident. Only the local traction motor overload alarms and the General Reset activity have been repeated in these tables as they are the recorded events most relevant to the circumstances of the incident.

- The time is shown in 24 hour format decimal point seconds and the time in brackets is the approximate duration of the stop at the station where the direction change occurred.
- The designation "up" or "down" indicates the direction in which the train was travelling when the logged event occurred.
- The 'GR' is the General Reset button that is pushed by the driver and the event in brackets after it is the reason it was pushed. The reason is either a local traction motor overload , a train lined traction motor overload (another EM car), or the General Reset was not associated with either event.
- The blue highlighted events are ones that definitely indicate a problem with the traction motors on EM1373.
- The yellow highlighted events are ones that are likely to have indicated a problem with the traction motors.
- The non-highlighted events appear to be associated with securing the EMU by isolating the overhead supply.

13 April 2008

Parked in the Wellington Western yard all day. No trips, no distance travelled.

14 April 2008

Return trips this day on Paraparaumu line 6 and Upper Hutt line 1. Approximately 635 km travelled.

Item	Time	Event	Location
1	0627.40	traction motor overload	Wellington station – direction change (11 min)
2	0715.20	traction motor overload	Upper Hutt station – direction change (26 min)
3	1425.06	traction motor overload	Paraparaumu station – direction change (10 min)
4	1529.57	traction motor overload	Wellington station – direction change (33 min)
5	1645.14	GR	Paekakariki – up (train traction motor overload)
6	1742.09	traction motor overload	Wellington station – end of trip
7	1755.38	traction motor overload	Wellington station - direction change and restart (21 min)
8	2002.13	traction motor overload	Wellington station - direction change (59 min)

15 April 2008

Return trips this day on Paraparaumu line 7 and Upper Hutt line 1. Approximately 707 km travelled.

Item	Time	Event	Location
1	0628.30	GR	Epuni – down (isolated)
2	0638.46	GR	Korokoro – down (isolated)
3	0855.22	GR	Kenepuru – up (isolated)
4	1306.07	traction motor overload	Wellington station – direction change (26 min)
5	1427.43	traction motor overload	Paraparaumu station – direction change (8 min)
6	1531.10	traction motor overload	Wellington Station – direction change (31 min)
7	1726.10	GR	Linden – down (isolated)
8	1742.44	traction motor overload	Wellington station - stopped
9	1756.35	traction motor overload	Wellington station – restart (19 min at station)
10	1932.54	traction motor overload	South Plimmerton station – down
11	1933.00	GR	Plimmerton – down (local traction motor overload)
12	1935.11	GR	Mana bridge – down (local traction motor overload). Multiple events
13	1936.18	traction motor overload	South of Paremata station – down
14	2002.43	traction motor overload	Wellington station – direction change (60 min)
15	2158.28	traction motor overload	Paraparaumu station – direction change (8 min)
16	2237.53	GR	Kenepuru – down (isolated)
17	2259.32	traction motor overload	Wellington station – stopped for night

16 April 2008
Return trips this day on Paraparaumu line 6 and Upper Hutt line 1. Approximately 518 km travelled.

Item	Time	Event	Location
1	0549.01	traction motor overload	Wellington station – direction change (20min)
2	0612.58	traction motor overload	Taita – direction change (10min)
3	0652.07	traction motor overload	Wellington station – direction change (24min)
4	0820.83	traction motor overload	Wellington station – direction change (46min)
5	0956.20	traction motor overload	Paraparaumu – direction change (9 min)
6	1106.53	traction motor overload	Wellington station – direction change (25 min)
7	1143.13	GR	Grenada – up (isolated)
8	1226.04	traction motor overload	Paraparaumu – direction change (11 min)
9	1716.46	GR	Kenepuru – up (isolated)
10	1745.00	GR	Wellington - up (isolated)

17 April 2008
Return trips this day on Paraparaumu line 5 and Upper Hutt line 1. Approximately 494 km travelled.

Item	Time	Event	Location
1	1156.39	GR	Paekakariki – down (isolated)
2	1158.54	traction motor overload	Pukerua Bay - down
3	1159.09	GR	Pukerua Bay – down (local traction motor overload)
4	1202.12	GR	Muri – down (train traction motor overload)
5	1240.31	traction motor overload	Wellington station. Parked for 39 min then shifted to the Western yard. Shifted back to the platform for the 1400 to Paraparaumu
6	1458.28	traction motor overload	Paraparaumu – direction change (5 min)
7	1707.07	GR	Raumati – up (isolated)
8	1740.35	GR	Mana –down (isolated)
9	1856.32	GR	Police College – up (isolated)
10	1927.03	traction motor overload	Paraparaumu – direction change (8 min)
11	1935.56	GR	Paraparaumu – down (isolated)
12	1959.42	traction motor overload	Pukerua Bay - down
13	2000.47	GR	Muri – down (local traction motor overload)

Item	Time	Event	Location
14	2010.19	traction motor overload	Mana - down
15	2010.32	GR	Paremata – down (local traction motor overload)
16	2010.48	traction motor overload	Mana – departing down
17	2010.51	GR	Paremata – down (local traction motor overload)
18	2017.31	traction motor overload	Kenepuru station – departing down
19	2017.44	GR	Kenepuru – down (local traction motor overload)

<u>18 April 2008</u>
Return trips this day on Paraparaumu line 2 completed and Upper Hutt line 2. Approximately 407 km travelled.

Item	Time	Event	Location
1	0702.05	traction motor overload	Papakowhai – up
2	0743.39	GR	Arohata – down (isolated)
3	1014.40	GR	Wellington – up (local traction motor overload). Multiple events
4	1031.59	traction motor overload	Wellington Western yards
5	1034.27	traction motor overload	Wellington Western yards
6	1034.43	traction motor overload	Wellington Western yards
7	1657.00		Shifted back to Wellington platform
8	1657.59	traction motor overload	Wellington station
9	1733.53	traction motor overload	Upper Hutt station – direction change (2 min)
10	1920.31	traction motor overload	Upper Hutt station – direction change (11 min)
11	2325.58	traction motor overload	Papakowhai - up
12	2326.03	GR	Paremata – up (local traction motor overload). Multiple events
13	2327.49	traction motor overload	Leaving Paremata station - up
14	2327.54	GR	Paremata bridge – up (local traction motor overload). Multiple events.

Item	Time	Event	Location
15	2328.18	traction motor overload	Past Paremata bridge -up
16	2328.33	GR	Mana – up (local traction motor overload). Multiple events.
17	2330.41	traction motor overload	Attempting to leave Mana station
18	2330.49	GR	Mana – up (local traction motor overload). Multiple events.
19	2330.59	traction motor overload	Attempting to leave Mana station
20	2331.00		Lines came down

Appendix C Substation circuit breaker activity (SCADA)

The following table was created from the SCADA log of the substation activity on the day of the incident. Circuit breaker C14 is located at the Kenepuru substation and feeds the overhead line for the up line track towards Mana. Circuit breaker D13 is located at Mana substation and feeds the overhead line for the up line back towards Kenepuru. Note that the SCADA time is 3 minutes and 50 seconds behind the GPS time

Time Recorded	Time Corrected	Circuit Breaker	Kenepuru Substation Operation
2322:43	2326.33	C14	Fault trip
2323:16	2327.06	C14	Auto reclose after 30 seconds
2327:59	2331.49	C14	Fault trip after about 4.75 minutes
2328:32	2332.22	C14	Auto reclose after 30 seconds
2353:31	2357.21	C14	Tripped under instruction by control room operator
			Mana Substation Operation
2322:44	2326.34	D13	Fault trip
2323:12	2327.02	D13	Auto reclose after 30 seconds
2324:35	2328.25	D13	Fault trip after about 1.3 minutes
2325:04	2328.54	D13	Auto reclose after 30 seconds
2327:26	2331.16	D13	Fault trip after about 2.5 minutes
2327:55	2331.45	D13	Auto reclose after 30 seconds
2327:56	2331.46	D13	Fault trip immediately and hold out[30]

[30] The SCADA log showed another reclose and trip immediately, within 400 milliseconds; this is probably contact bounce on the interposing relays.

Appendix D Timeline of events

The time line shows the events that occurred to the train from when it left Wellington station at 2300 on Friday night on the 18 April 2008 to about 2.5 hours after the incident.

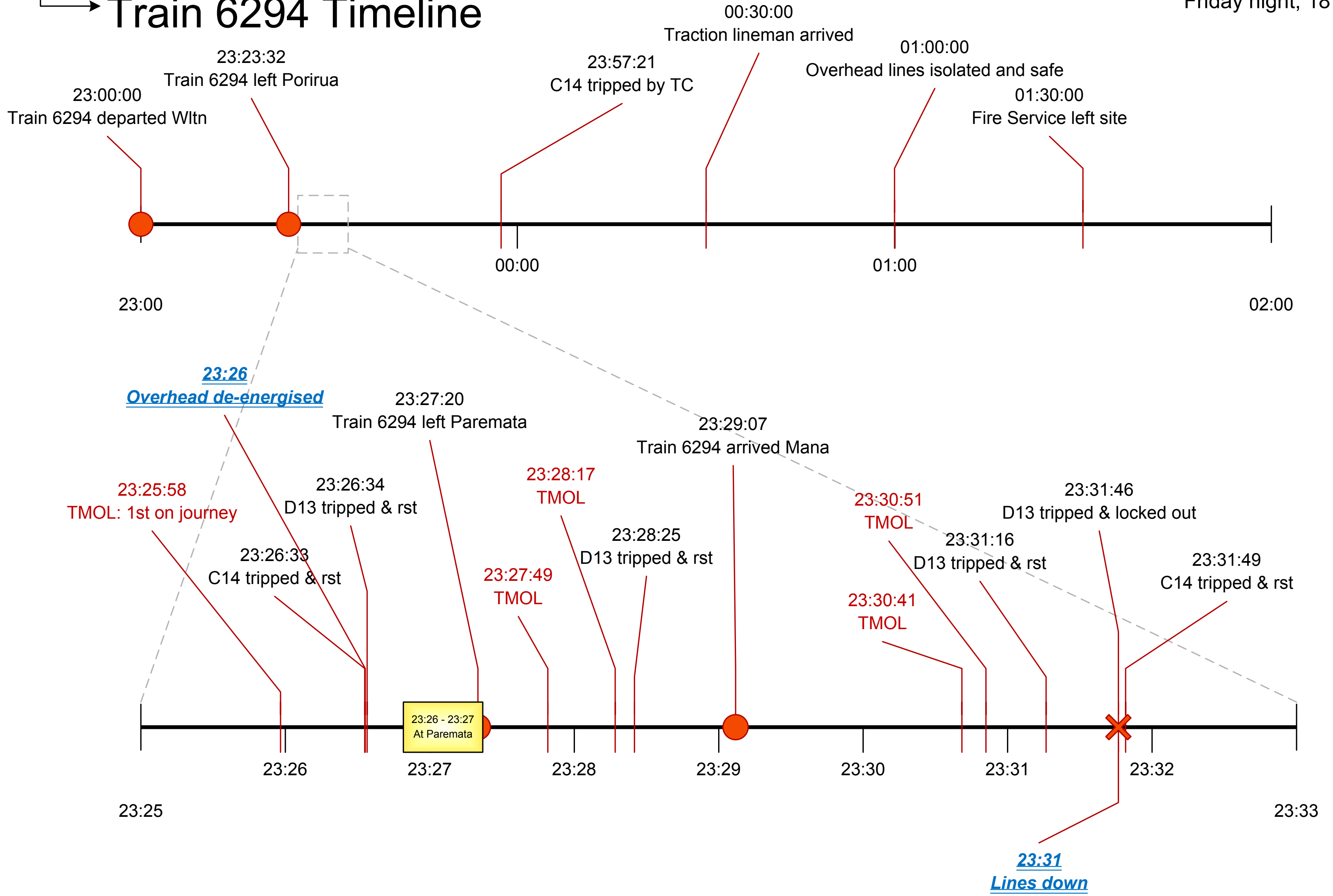
Refer to the power distribution network (Figure 2) and the location map (Figure 1) for greater context. Circuit breaker C14 is the feeder CB from Kenepuru and D13 the feeder CB at the Mana substation.

The underlined blue events are where the overhead line was de-energised. The red dots represent station arrival or departing times and the orange bar represents the stop at Paremata station.

The times are positioned to the second, but the time displayed shown in 4- or 6-digit format representing hour.minute or as hour.minute.second respectively.

Train 6294 Timeline

Friday night, 18 April 2008



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06-106	Report 06-106, express freight Train 826, signalling irregularity, Cora Lynn, 31 July 2006
07-108	express freight Train 720, track warrant overrun at Seddon, Main North Line, 12 May 2007
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06-110	passenger train 4045, uncontrolled movement, between Britomart and Quay Park Junction, 9 October 2006
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05-116	collapse of Bridge 256 over Nuhaka River, Palmerston North-Gisborne Line, 6 May 2005
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