Report 08-203

Passenger Ferry
Monte Stello

Loss of Power

Tory Channel

2 May 2008

The *Monte Stello*

Contents

Figures

Abbreviations

^{o}	degree(s)
AC	alternating current
avr	automatic voltage regulator
DC	direct current
ECDIS	electronic chart display and information system
I/O	input/ output
kW	kilowatt(s)
kt	knot(s)
m	metre(s)
Maritime NZ	Maritime New Zealand
PLC	programmable logic controller
SOLAS	International Convention for the Safety of Life at Sea, 1974
VHF	very high frequency

Glossary

automatic voltage regulator	a device which maintains a steady output voltage and frequency of a generator, by altering the excitation current of the generator
bus (electrical)	derived from bus-bar, connection(s) between electrical devices
bus-bar	thick strips of copper that conduct electricity within a switchboard
circuit breaker	an electrical switch designed to protect an electrical circuit or machinery from damage in the event of an overload or fault condition
con	direct the steering of a ship
discrimination (electrical)	provided in an electrical distribution system when a lower rated circuit breaker or fuse located closer to a fault, operates before a higher rated circuit breaker or fuse which is further away from the fault. This isolates only the faulty circuit minimising disruption to the rest of the system
ethernet	widely used communication protocol between computers
fathom	length of 6 feet or approximately 1.83 m
fuse	a safety device consisting of a strip of wire that melts and breaks an electrical circuit if the current exceeds a pre-determined level
hawse pipe	steel tube within the structure of a ship, through which the anchor cable runs from the anchor windlass to the sea. The anchor shank is normally housed within the hawse pipe
knot	one nautical mile per hour
lane metre	a lane is a strip of deck 2 metres (m) wide. A lane metre is an area of deck one lane wide and one metre long
Mapway connection	proprietary communications protocol used between computers
shackle	length of anchor cable equivalent to 15 fathoms or approximately 27.42 m
switchboard	a device that directs electricity from one source to another
Unitel connection	proprietary communications protocol used between computers

Data Summary

Ship particulars:

Name:	*Monte Stello*
Type:	Passenger ferry
Class:	SOLAS passenger ship
Limits:	New Zealand coastal
Classification:	Lloyds Register
Length:	126.96 m
Breadth:	21.0 m
Gross tonnage:	11 630
Built:	1979
Propulsion:	Twin Pielstick PC 2.5 V12. 5700 kW each driving a controllable pitch propeller
Service speed:	19.5 knots (kts)
Owner/operator:	Strait Shipping Limited
Port of registry:	Wellington
Crew:	New Zealand
Date and time:	2 May 2008 at about 1450[1]
Location:	Tory Channel
Persons on board:	crew: 28 passengers: 169
Injuries:	crew: 0 passengers: 0
Damage:	Nil to hull or machinery
Investigator-in-charge:	Paul Bird

[1] Times in this report are New Zealand Standard Time (UTC + 12 hours) and are expressed in the 24-hour mode.

Executive Summary

On 2 May 2008, the Bluebridge passenger and freight ferry *Monte Stello* was transiting Tory Channel in Marlborough Sounds en route from Picton to Wellington when it suffered an electrical power failure, resulting in a loss of both propulsion engines. The emergency power system started automatically and supplied power to critical systems. The ship was brought up to its starboard anchor about 250 m from the shore line.

Power was restored and the ship proceeded back to Picton where the passengers and freight were put ashore to allow the ship to return empty to Wellington to investigate the cause of the power failure.

Two diesel generators were supplying power to the ship when first one, then the other, tripped off the power distribution bus-bars. Additionally the programmable logic controller (PLC) for the engine room alarm monitoring system developed an irreparable fault, but it could not be established if this was linked to the power failure or was a separate event. The cause of the diesel generators tripping off the bus could not be conclusively determined.

Safety issues discussed include: the difficulties in maintaining equipment on ships when information on maintenance and modifications to systems have not been passed on from previous owners; equipment and system drawings do not match the installation; and manufacturers of equipment and systems consider them obsolete and no longer support them.

A safety recommendation was made to the Director of Maritime New Zealand (Maritime NZ) that this report be sent to the International Maritime Organization (IMO), bringing to its attention the safety issue that there is no mandatory requirement for continuity of ships maintenance records and system diagrams when ships change ownership, and inviting it to refer this report on to the appropriate committee for its consideration.

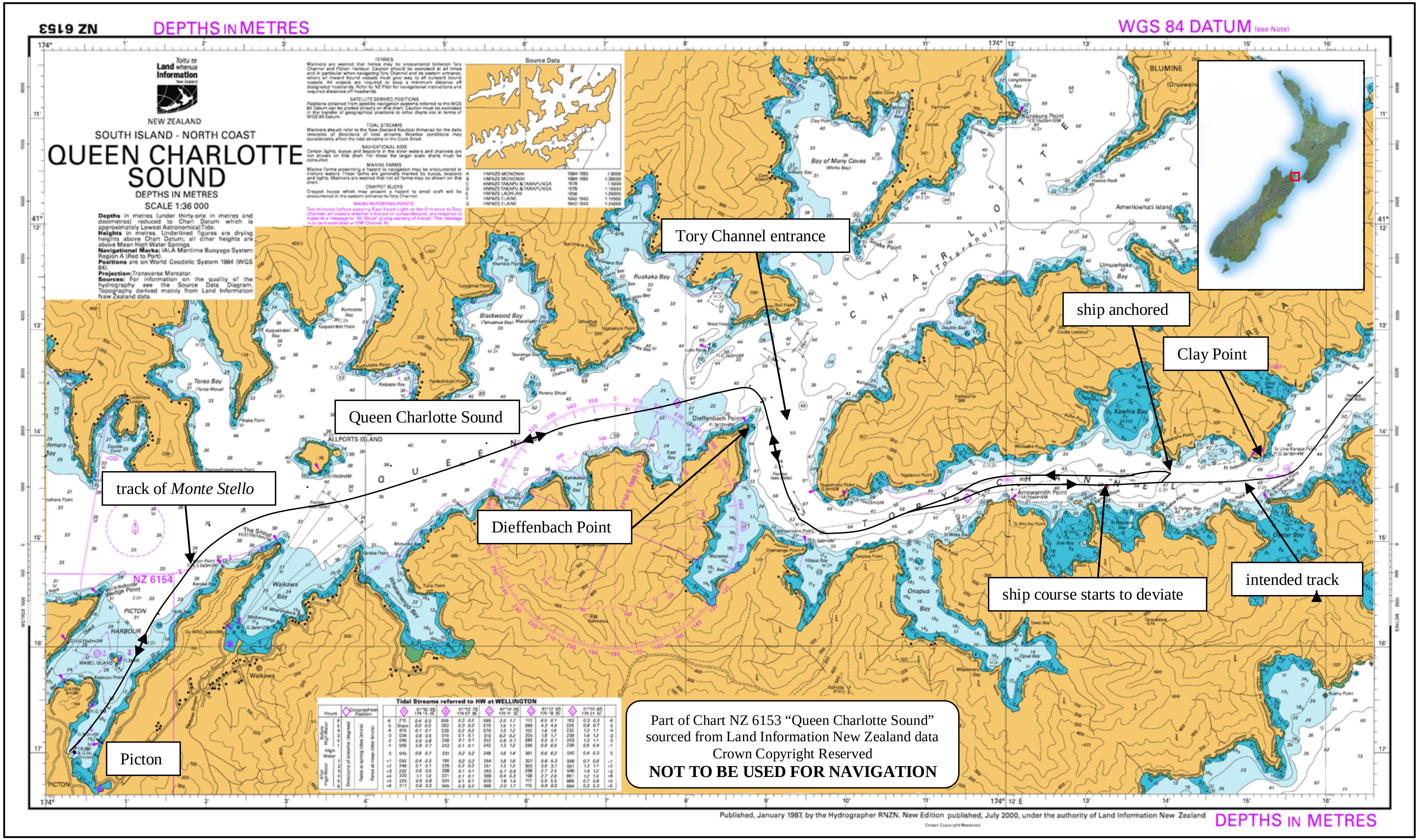

Figure 1
Chart of general area and approximate track of ship

1 Factual Information

1.1 Narrative

Bridge perspective

1.1.1 On 2 May 2008 at about 1128,[2] the Bluebridge passenger ferry *Monte Stello* arrived in Picton having completed a voyage from Wellington. At about 1400, the ship had finished loading passengers and freight ready for the return voyage. The ship had a full load of trucks and cars, 169 passengers and 28 crew on-board.

1.1.2 At about 1400, the ship departed Picton for Wellington. The weather was clear and dry, the wind recorded as westerly about 10 knots (kts).

1.1.3 The Master was conning the ship, and with him on the bridge were the second officer, a helmsman and a lookout. The ship's main engines were on bridge control and the engine room was manned by the chief engineer, the third engineer and an engine room rating.

1.1.4 The ship followed on its intended track along Queen Charlotte Sound and into Tory Channel, making about 15.5 kts against an incoming tide (see Figure 1). At about 1445 there was a sudden loss of electrical power and the ship's main engines, steering and navigation equipment shut down.

1.1.5 The master immediately set the bridge port and starboard engine pitch controls to zero and communicated with the engine room on the intercom system. He advised the chief engineer in the control room that he wanted the ship's engines available as soon as possible. The chief engineer replied that he did not know the cause of the black-out because all alarms in the engine room were indicating a fault condition, making immediate diagnosis difficult.

1.1.6 The master observed that the port steering motor running light was on, indicating that the ship's emergency generator had started, restoring power to the emergency switchboard from which the port steering motor was supplied. The master ordered the helmsman to try and maintain the ship's previous heading as the ship was still making way through the water. The ship had been on a course of about 090º with the helm in the amidships position at the time power to the steering pump was lost.

1.1.7 The second officer in the meantime had started answering the various bridge alarms that were initiated owing to the loss of power to the bridge. He said that he had heard the ventilation fans slow, and thinking the ship was going to black-out changed the steering control from the wheel to the non-follow-up control mode. In this mode the steering was operated by buttons on the helm console rather than by the wheel. He said that he did a quick check that the helm responded to the operation of the buttons, but left the rudder in amidships as the course was still 090º before attending to other alarms.

1.1.8 The helmsman attempted to use the steering wheel to maintain the course as instructed. He noticed that the helm did not respond, but did not tell the master.

1.1.9 The master rationalised from the chief engineer's response that the engines would probably not be available immediately. He radioed the duty seaman responsible for standing-by the ship's anchors when the ship was to pass through the entrance of Tory Channel. The duty seaman had gone to his station early, and when the master learned this he asked the seaman to walk back the starboard anchor to the water level in readiness to be deployed if necessary.

1.1.10 The duty seaman was not able to walk back the anchor because there was no electrical power to operate the winch, so the master asked him to stand by in readiness to drop the anchor directly from the hawse pipe.

[2] Times in the narrative section are taken from the ship's bridge and engine room log books.

1.1.11 The master noticed that the ship's course was drifting to port and the ship was on a heading of about 050º towards the north side of the channel. Concerned about the ship running aground the he ordered the duty seaman standing by on the forecastle to let go the starboard anchor. The master estimated that he gave the order was given about 2 minutes after the black-out had occurred.

1.1.12 At about 1452 the duty seaman on the forecastle released the starboard anchor windlass brake and then reapplied the brake. He repeated this action twice more releasing approximately 3 shackles or 82.26 m of cable into about 40 m of water before retreating a safe distance from the winch as he had been instructed to do by the master.

1.1.13 The master chose the starboard anchor because it was the upstream anchor and he expected that the ship, under the influence of the tide would fall away from the anchor and the northern shoreline. The starboard anchor arrested the ship's forward motion by about 1455, so there was no need to deploy the port anchor.

1.1.14 The master estimated that the ship had come to rest lying across the incoming tide on a heading of about 040º with the anchor chain lying at about 070º. Readings taken from the electronic chart display and information system (ECDIS) at the time showed the ships bow to be about 250m from the shore.

1.1.15 At about 1455, satisfied that the ship was in no immediate danger, the master called Picton Harbour Radio on the ship's very high frequency (VHF) radio advising that the ship had blacked-out and that it was anchored close to Clay Point (Te Uira-Karapa Point). Picton Harbour Radio acknowledged the call saying that a tug was available if required and then waited for further information. The master then telephoned the designated contact person ashore at Strait Shipping to advise them of the situation and the company gathered its technical personnel to form a response team.

Engine room perspective

1.1.16 When the ship departed Picton the chief engineer and third engineer were in the control room having prepared the engines following the normal engine room departure procedure checklist. The ship's 2 diesel generators (generator numbers 3 and 4) were running on load in parallel on the main bus-bars (numbers 1 and 2). The starboard shaft generator was supplying the bow thruster through number 3 bus-bar (see Figure 2).

1.1.17 The departure went normally, and once the ship was clear of the berth the master turned off the bow thruster. The ship continued with the 2 diesel generators supplying electrical power and the shaft generator connected to number 3 bus-bar but with no-load.

1.1.18 Once the ship had cleared Picton harbour, following his normal routine the third engineer went into the engine room and started to check over the running machinery and record the various operating readings of the main engines required for the engine room log book.

1.1.19 At about 1430, the ship heeled owing to the large course alteration as it rounded Diffenbach Point, and this activated the sump low lube oil level alarm of the port generator diesel engine and the starboard engine room bilge high level alarm. The third engineer added extra lube oil to the port generator sump and started to pump the bilge to prevent further nuisance alarms. Within 5 minutes both alarms had cleared and these events were recorded on the engine room alarm printer.

1.1.20 The third engineer then went into the diesel generator room to continue his checks and to record operating readings for the engine room log book. He said he observed no abnormalities and was about to return to the control room when he heard what he thought was a reduction in speed of port diesel generator (number 3), then an increase in speed before it tripped off load. A short time after this the ship blacked-out. The third engineer made his way back to the control room to find out what had happened and to assist the chief engineer.

1.1.21 At the time of the power loss the chief engineer was reviewing log sheets on the port side of the control room when he heard what he thought was a main switchboard circuit breaker drop out and then re-engage in the generator panel located on the starboard side of the control room. As the he approached the generator panel to investigate the source of the noise he had time to observe that number 3 diesel generator was not connected to the board and number 4 generator was supplying all the power to the switchboard. Soon after noting this, number 4 generator circuit breaker tripped and the ship blacked-out.

1.1.22 The black-out caused the main engines to stop owing to the operation of protection devices resulting from a loss of power to the electrically-driven main engine lube oil pumps.

1.1.23 The chief engineer immediately advised the master of the situation and requested he put the main engine pitch controls to zero, which the master had already done. The emergency generator started automatically after the black-out.

1.1.24 The first alarm recorded on the engine room alarm printer was the high cooling water outlet temperature on the port main engine followed immediately by the low cooling water inlet temperature on the same engine. These alarm channels were numbers 0001 and 0002 of the channels monitored by the data logger. The alarm printer continued to print out most of the alarm channels in numerical order over the next few minutes as a result of the power loss. Unable to discern the initial cause of the black-out from the alarm event log, the chief engineer advised the master that he did not know what had caused the black-out.

1.1.25 The chief engineer at the generator panel noted that number 4 generator engine was still running and attempted to manually connect this generator to the main bus-bars one and 2, but was unsuccessful. He again rang the bridge to advise the master that he was still unable to restore main power. The master told him that he was going to anchor the ship. The chief engineer noted that both the reset lights on the generator panel were illuminated (a reset light was normally illuminated when either a mechanical or electrical trip had operated on a diesel generator). He pushed the reset button, but it remained illuminated.

1.1.26 The emergency switchboard was being supplied by the emergency generator and the chief engineer considered connecting it to the main switchboard so he could start some of the main engine ancillary pumps and restore propulsion. Before he could initiate this plan the master phoned the control room to advise that the anchor was holding and the ship was in no immediate danger.

1.1.27 The second engineer had been off duty in his cabin when he became aware the ship had blacked-out and he went to the control room to assist. The chief engineer told him and the third engineer to go the generator room to check the diesel generators while he tried to identify why they would not go back on the bus in the control room.

1.1.28 The chief engineer stopped what he thought was number 4 generator and then followed the black-out procedure checklist, and this time the generator connected to the bus. The trend monitoring for the power management system showed that it was actually number 3 generator that he restarted and connected to the board. Power was restored at about 1459 and about 15 minutes later number 4 diesel generator was connected to the main switchboard.

Post power loss

1.1.29 The master on the *Monte Stello* became concerned that if the ship was still anchored when the tide turned at about 1920 it might not clear the coast. After discussion between the master, harbour master and the Strait Shipping managers ashore, it was decided at about 1525 to arrange a tug from Picton to attend the ship in case propulsion was not restored. The tug *Kukuri* was assigned the task, but was engaged in other duties and not due back in Picton until about 1645.

1.1.30 After discussion between the technical staff ashore and on-board it was decided to split bus-bars 1 and 2 in the main switchboard (open CB1) so that one generator was supplying each bus-bar independently. The rationale was to provide redundancy of electrical supply if a fault developed in one of the generators. Once the shipboard systems had been tested successfully the ship would return to Picton.

1.1.31 The alarm monitoring system was still not functioning and the engineers set up a watch-keeping system to monitor the running machinery locally. The engine room audible and visual alarms were still sounding in the engine room, but the engine room staff could not silence them.

1.1.32 At about 1608 the chief engineer had tested to his satisfaction the main engines, restarted the bow thruster and transferred control back to the bridge. The anchor was hauled up and the ship was underway by 1610. The master then manoeuvred the ship back into the main channel and the ship headed back to Picton at a reduced speed of about 12 kts.

1.1.33 The voyage to Picton was uneventful. When the ship rounded Diffenbach Point the tug *Kukuri* was sighted off Picton Point and it was agreed that the tug would stand-by where it was. The ship berthed in Picton at about 1739 without further incident.

1.1.34 The passengers and freight were discharged from the ship and the electrician who had been on-board the company's other ship (*Santa Regina*) boarded the *Monte Stello* to assist the engineers on-board. The ship then vacated the berth and anchored in Picton Harbour.

1.1.35 The electrician isolated the engine room audible and visual alarms but was unable to re-boot the alarm PLC. The electrician noted alarm lights pulsing on the PLC input and output cards due to a faulty supply voltage. He suspected that the PLC processor was corrupted and advised the company superintendent accordingly.

1.1.36 At about 2000, the cause of the power loss had not been determined, but the systems on board seemed stable. It was agreed with Maritime NZ permission to allow the ship to return to Wellington with only the crew on-board at reduced speed via the northern entrance of Queen Charlotte Sound.

1.1.37 The ship arrived in Wellington on 3 May at about 0220. The ship returned to service on 7 May after repairs had been completed to the alarm monitoring system.

1.2 Ship and company information

1.2.1 The *Monte Stello* was built in 1979 by 'Societe Nouvelle Des Ateliers et Chantiers' in Le Harve, France. The ship was originally built for 'Societe Nationale Maritime Corse-Mediterranee' who operated freight and passenger services between Marseilles and Corsica.

1.2.2 On 1 January 1994, the *Monte Stello* was on a voyage from Marseilles to Porto Vecchio, Corsica when it grounded on rocks off Sardinia. Although the ship was declared a constructive total loss, it was eventually refloated on 2 May 1994 and taken for repair.

1.2.3 In 1996, the ship was sold to the Lithuanian Shipping Company, Kaleida. The ship was renamed *Palanga* and entered service between Klapeida and Keil and then later Stockholm and Karlshamn.

1.2.4 In 2001, Lisco Baltic became the registered owners and the *Palanga* was transferred onto DFDS Tor Line services between Esbjerg and Harwich and then Lubeck to Ventspils. This was followed by a brief charter to Transmediterranea that engaged the ship on a service between Las Palmas and Tenerife.

1.2.5 In January 2006, the *Palanga* was sold to Strait Shipping in New Zealand and reverted to its original name of *Monte Stello*. The ship was inspected by representatives of Strait Shipping at Las Palmas dry dock.

1.2.6 The *Monte Stello* arrived in New Zealand during March 2006, and was refitted in the VT Fitzroy dry dock in Auckland before entering service in August 2006, operating between Wellington and Picton.

1.2.7 The *Monte Stello* had a freight capacity of 970 lane metres and was certified to carry 369 passengers.

1.2.8 Strait Shipping started operating Cook Strait freight ferry services in 1992. In 2003 the company began the Bluebridge passenger service across the Cook Strait and at the time of the incident they operated 2 passenger ferries (the *Monte Stello* and *Santa Regina*) sailing between Wellington and Picton. The company also operated a freight-only vessel, the *Kent*, which serviced various ports on the New Zealand coast.

1.2.9 The *Monte Stello* was registered in New Zealand and operated under New Zealand Maritime Rules designated as a SOLAS ship, because it was over 45m in length and operating outside restricted limits. This meant that the SOLAS regulations at the time the rule was implemented applied, plus any subsequent new SOLAS regulations that had been adopted when periodic amendments to the Maritime Rules had been made.

1.3 Electrical power supply and distribution

Electrical power distribution

1.3.1 Main electrical power on the *Monte Stello* was provided by 2 diesel-driven generators, and 2 shaft-driven generators. Each shaft generator was driven by one of 2 main engines, which also drove a constant speed propeller with controllable pitch.

1.3.2 The 4 generators could be connected (with some configuration limitations) to supply any of the 3 main bus-bars in the main switchboard located in the control room. The emergency switchboard was located in a remote compartment from the engine room, together with an emergency diesel generator that would start automatically in the event of a loss of power to the emergency switchboard. The emergency generator maintained supply from the emergency switchboard to critical systems if the power supply from the main board was interrupted (see Figure 2). The emergency generator had a smaller capacity than the other generators and could not be connected (paralleled) on the same bus with them.

1.3.3 On the *Monte Stello* the electrical distribution system allowed various options of supply to the 3 main bus-bars. Owing to the difference between the diesel-driven generators and the shaft generators loads and control characteristics it was not normal practice to run a diesel and shaft-driven generator in parallel for sustained periods of time because they were unable to equally share the load.

1.3.4 The normal configuration for supplying electrical load to the main switchboard on passage was to have both diesel generators running in parallel supplying number 1 and 2 bus-bars which were then connected through the bus-tie CB 1. The preferred shaft generator was then used to supply the isolated number 3 bus-bar. The emergency switchboard was fed from numbers 1 and 2 bus-bars.

1.3.5 Bus-bars 1 and 2 fed the main distribution systems on the *Monte Stello*, which included auxiliary pumps and systems required for operation of the ship's main engines. Bus-bar number 3 supplied power to the ship's bow thrusters, normally used for manoeuvring in close quarters, and the ship's stabilisers which were used in rough sea conditions to reduce rolling.

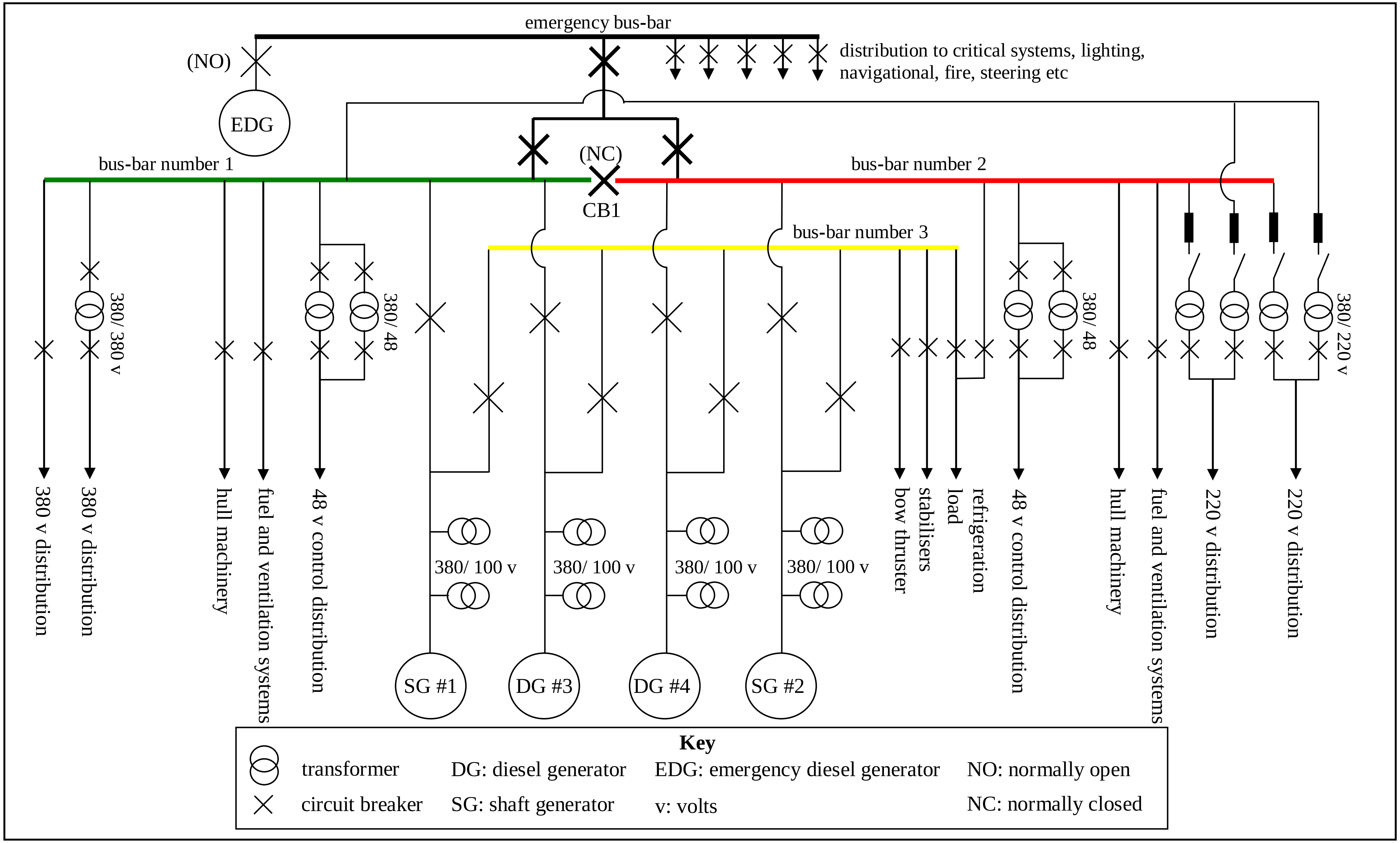

Figure 2
***Monte Stello* electrical distribution diagram**

1.3.6 The normal electrical load on bus-bars one and 2 while the ship was on passage was about 500 kilowatts (kW) and the full load capacity of each diesel generator was 780 kW. Although one diesel generator could adequately supply the full electrical load at sea, the second diesel was utilised to provide redundancy and continuity of supply in the event of a malfunction of the other diesel generator.

1.3.7 The generator and mechanical load from the propeller on each main engine was monitored to ensure the main engine was not overloaded. If necessary the propeller pitch on an engine could be reduced to lower the total load on an engine. Normally the bow thrusters were used at low manoeuvring speeds, so there was plenty of spare capacity available on the running shaft generator to operate the bow thruster.

Diesel prime movers

1.3.8 Each auxiliary generator was driven by a 6-cylinder Crepelle SN 2 diesel engine running on marine diesel fuel. Each engine was equipped with a lube oil pump, cooling water pump and fuel pump, all engine-driven.

1.3.9 Each main propulsion diesel engine was a V12 Pielstik PC 2.5 which ran on intermediate fuel. The lube oil, cooling water and fuel systems for each engine had a pair of electrically-driven auxiliary pumps. The normal practice was to run one of each pair of pumps and have the other as a stand-by pump. In the automatic mode, the stand-by pump would start in the event of a failure of the running pump or reduction in system pressure. The stand-by pump in each system could be started manually if required.

1.3.10 The power supply for each pair of auxiliary pumps for both the main engines was arranged so that one pump was supplied from number 1 bus-bar and the other from number 2 bus-bar. This meant in the event of a malfunction on say number 1 bus-bar then number 2 bus-bar could still supply power to one complete set of pumps for each main engine. The other electrical systems on-board were similarly split between number 1 and 2 bus-bars. A failure of electrical power supply to bus-bars 1 and 2 would stop both the main engines.

Connecting a generator to the switchboard

1.3.11 In order to run more than one alternating current (AC) generator on a bus with another generator that was already connected to the same bus certain conditions had to be met. The incoming alternator voltage and frequency had to be the same as the machine already connected to the bus. The incoming machine was connected at the instant when the alternating wave forms of the two alternators were synchronised and this moment was displayed to the operator by a device called a synchroscope which compared the electrical output parameters of the two alternators. The required circuit breaker was then closed connecting the incoming alternator to the bus. The synchronising of the 2 generators could be done manually or automatically.

1.3.12 On the *Monte Stello* generators were connected to and taken off the bus manually using controls on the main switchboard in the control room. These controls allowed the operator to start and stop the generator prime movers and open and close circuit breakers. Instruments on the switchboard displayed to the operator the various running parameters of each generator necessary for connecting a generator to the bus and any fault conditions that existed.

1.3.13 The normal procedure to connect a generator to the bus was to start the generator prime mover. As each generator had two circuit breakers (one to either bus-bar number 1 or 2, and one to bus-bar number 3) the desired circuit breaker was selected by pushing the appropriate pre-select button. The push buttons to connect generators onto numbers 1 and 2 bus-bars are shown in the Figure 3. A set of identical buttons mounted in adjacent panels of the switchboard were used to connect a generator to number 3 bus-bar. When the conditions for synchronising had been met the circuit breaker was closed using push buttons.

1.3.14 Under normal operation a generator was disconnected from the bus by first reducing the load on the generator and then opening the circuit breaker using another push button.

1.3.15 Figure 3 is a photograph of part of the main switchboard where the generator controls and instruments were fitted.

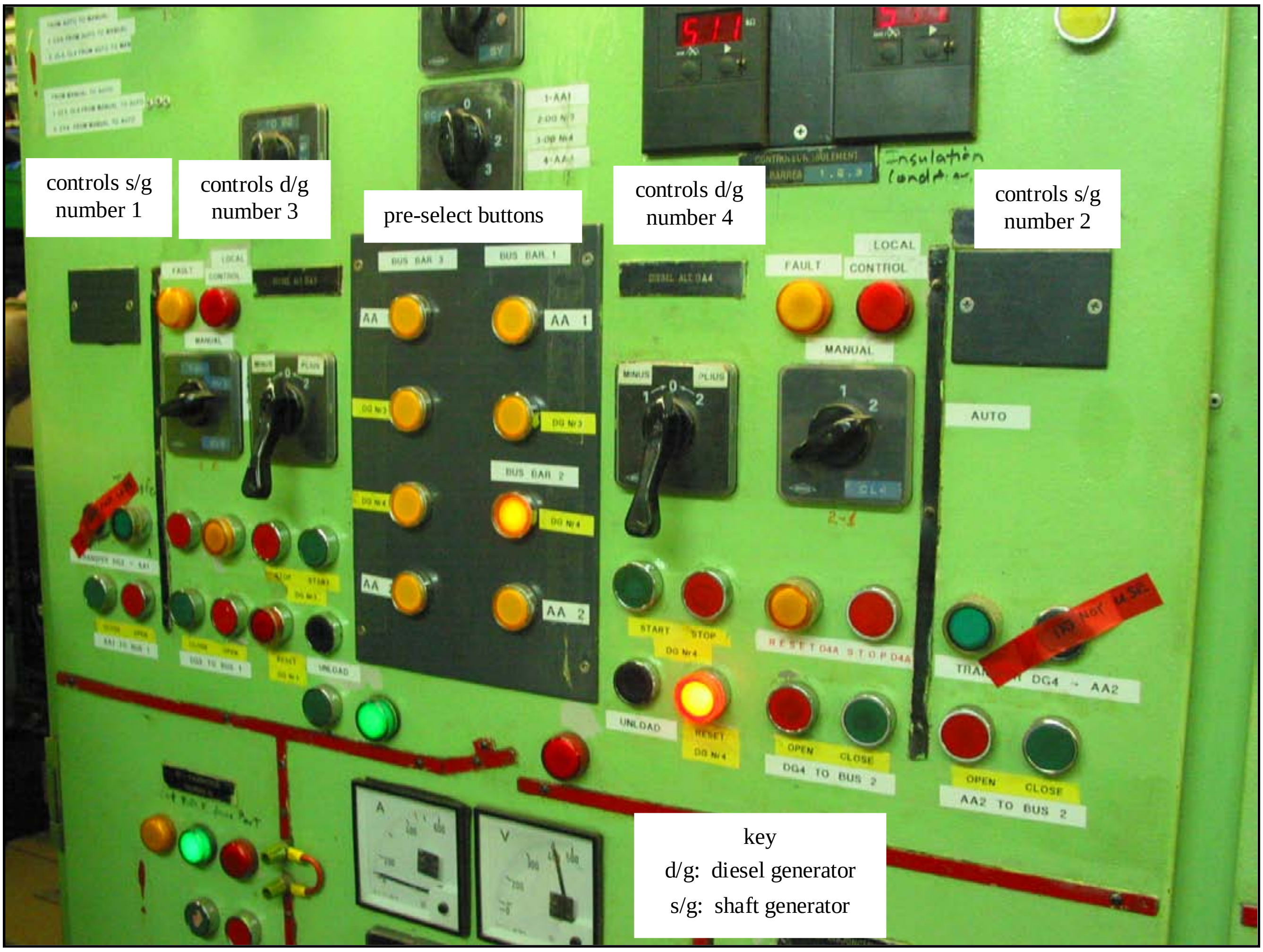

Figure 3
Main switchboard generator controls

1.3.16 The photograph in Figure 3 was taken after the incident and before repairs were made to the alarm PLC. At the time diesel generator number 4 was connected to bus-bar number 2 and feeding bus-bar number 1through the bus tie CB1 (see Figure 2). The reset light for number 4 diesel generator was illuminated indicating a fault with the generator which would normally prevent its operation, as was the case during the power failure.

1.4 48 volt DC system

1.4.1 A 48 volt direct current (DC) distribution system on the *Monte Stello* was used to power the low voltage control systems for the automation. This equipment included the programmable logic controllers (see Figure 4).

1.4.2 The 48 volt DC distribution system was maintained through one of 2 identical battery charging units located in the emergency switchboard in the emergency generator compartment. Each charging unit rectified a 3-phase 380 volt AC supply into a 48 volt DC which float-charged a battery bank located in an adjacent compartment to the emergency generator room.

1.4.3 One charger was fed from the emergency switchboard and was normally in use and the other charger was fed from the main switchboard and was normally on stand-by.

1.4.4 The battery bank maintained an uninterrupted supply to the 48 volt DC distribution system if the 380 volt AC supply to the charging unit failed.

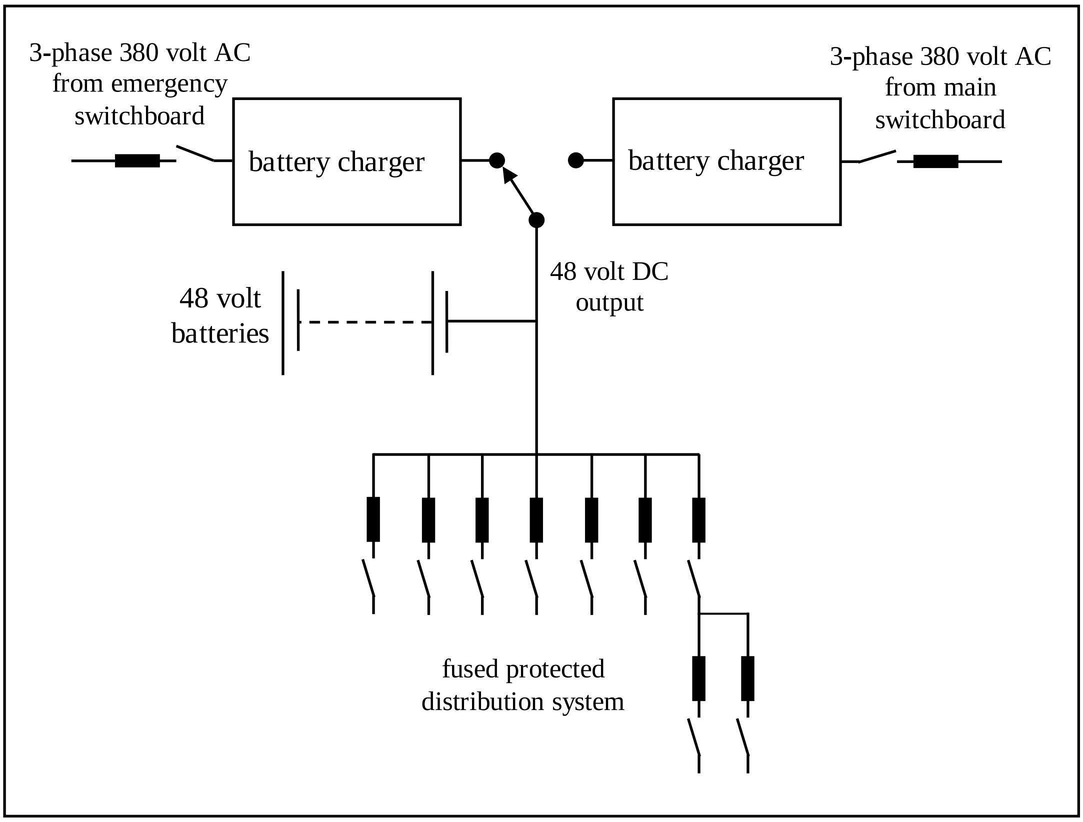

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Figure 4
48 volt DC distribution system (simplified)

1.4.5 Circuit breakers and suitably-rated fuses provided isolation and discrimination in the 48 volt DC distribution system. Circuit breakers and fuses were rated so that a fault condition in a particular circuit would isolate that circuit only, but the remainder of the system would remain operational.

1.5 Generator protection

1.5.1 The 380 volt main circuit breakers which connected the generators to the main bus were arranged so that in the event of certain fault conditions, the breaker would trip isolating the generator from the bus to prevent damage to either the generator or the switchboard.

1.5.2 The generator circuit breakers had an under-voltage coil and a 220 volt AC control voltage which kept the under-voltage coil energised. If either control voltage was not present, or any of the safety string contacts in series with the under-voltage coil opened the generator circuit breaker would trip. The safety string contacts would open if any of the generator parameters were exceeded (see Figure 5).

1.5.3 A separate safety string protecting the diesel engines driving the generators operated a relay which was supplied from the 48 volt DC system. The string included contacts for the protection of the diesel engine in the event of an over-speed, low lube oil pressure or high cooling water temperature. If a fault developed a contact in the safety string would open, de-energising the relay coil. A contact on the relay would then trip the generator engine and a separate contact in the main circuit breaker safety would open, de-energising the under voltage coil and disconnecting the generator from the bus (see Figure 5).

1.5.4 A fault in the 48 volt DC or 220 volt AC control supplies could also potentially trip a generator circuit breaker.

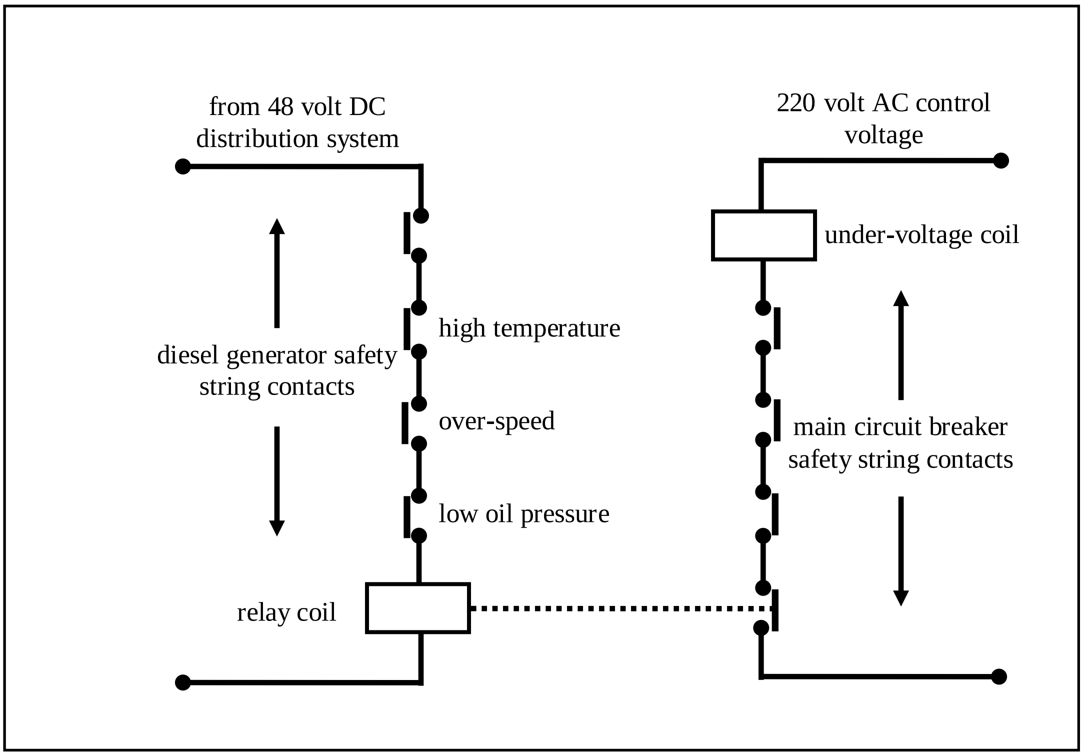

Figure 5
Simplified diagram of part of generator protection system

1.6 Programmable logic controllers and alarm system

1.6.1 A PLC is a computer-based control system commonly used for the automatic control and monitoring of machinery and plant in many industries. A PLC has inputs and outputs that are connected to the controlled process via specific input/output (I/O) cards which are selected for the application. A control program is written to recognise the connected I/O cards as parts of a process and operate the outputs depending upon other conditions being monitored. The operating program is often stored in a battery-backed random access memory (RAM) within a central processing unit and is sometimes (manufacturer dependent) also stored in a back-up memory called an erasable read only memory (EPROM). A PLC is programmed using proprietary software from the manufacturer, often running on a laptop and connected to the PLC via a communications port. Early PLCs used a dedicated programmer about the size of a desktop computer in a ruggedized housing. I/O cards are designed to enable the low voltage PLC microprocessor circuits to interface safely with field voltages at any level. A separate field supply could be connected to the I/O cards field connection terminals.

1.6.2 The PLCs on the *Monte Stello* were the modular type with equipment mounted on one or more racks or chassis and connected via a high speed communications link. Each PLC system had a main rack with CPU, a power supply, communications cards, and a number of 24VDC input and output cards with additional I/O fitted on remote racks. Remote racks could be installed adjacent to the main rack or remote and consisted of a power supply, communications cards and I/O cards as required for the process. The PLCs were used to control machinery, display system information or initiate audio and visual alarms. A schematic diagram of the alarm PLC is shown in Figure 6.

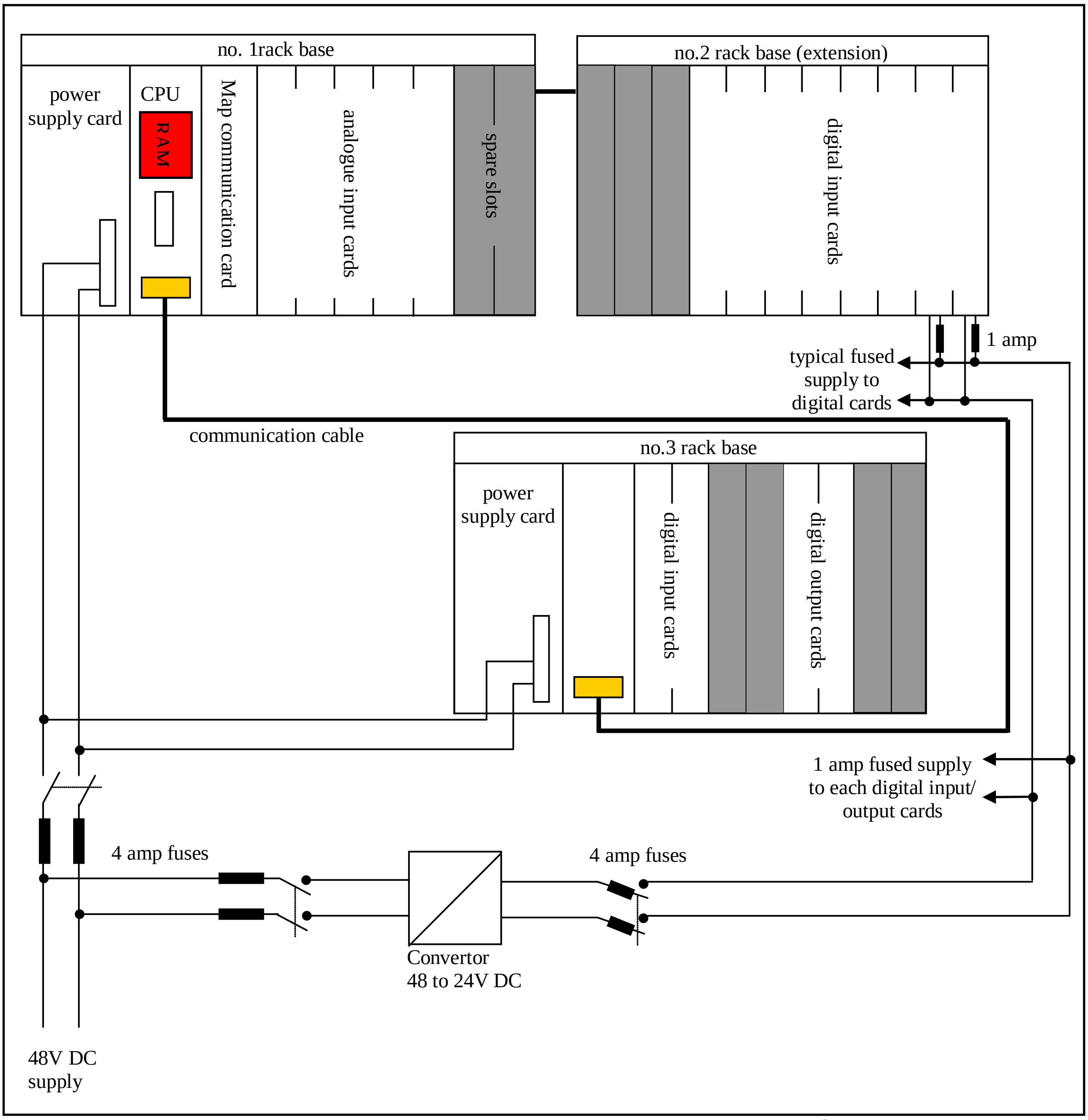

Figure 6
Schematic diagram of modular alarm PLC

1.6.3 On the *Monte Stello* a 48-to-24 volt DC convertor supplied a separate 24 volt DC supply to the field side of the I/O cards and power to any field connected sensors that required power.

1.6.4 There were 4 PLCs in the engine room of the *Monte Stello* which were fitted around 1995 when the ship was refitted after it had run aground (see Figure 7). The functions of these PLCs were:

- alarm PLC
- power management PLC
- auxiliary PLC no. 1
- auxiliary PLC no.2.

1.6.5 The alarm PLC monitored the parameters critical to the safe operation of the ship's machinery and sent signals to the monitoring computers to update the alarm display and print-out. In the event of a parameter being outside preset limits the alarm PLC raised audible and visual alarms in the engine room, on the bridge, and in selected cabins (if the engine room was operating in the unmanned mode).

1.6.6 The 2 auxiliary PLCs were used to control the auto-start and change-over functions of the stand-by pumps for lube oil, fuel oil and cooling water systems etc.

1.6.7 The power management PLC was originally fitted to the ship in 1995 and networked with the auxiliary and alarm PLCs. It was used to control generators and generator circuit breakers automatically from a power management computer (previously this function had been carried out manually). To facilitate automatic operation the existing switchboard logic was used and additional relays fitted either in parallel or series to allow the PLC to work the necessary controls that had previously been operated by push buttons on the switchboard.

1.6.8 The power management PLC was replaced during the 2006 refit in Auckland and was no longer connected to the other PLCs. Each of the original PLCs was still linked by Unitel connection which allowed the direct transfer of information between them for use in their respective control program (see Figure 7).

1.6.9 Each orginal PLC was also linked by a Mapway connection which allowed them to communicate to the man-machine interface on computers located in the control room and on the bridge. These computers had a number of display graphics pages for the operator to easily check the measured running parameters of a particular piece of machinery on a mimic diagram. A separate page listed parameters in the alarm condition and alarms were also recorded on a printer in the engine room.

1.6.10 On the delivery voyage from Europe to New Zealand the power management PLC proved to be unreliable and the operating system was prone to locking up. When the system locked up it was not possible to control the generators and it was necessary to re-boot the computer. This re-boot would take several minutes during which time the power management was not being controlled. On the voyage to New Zealand the analogue PLC cards were also unreliable and prone to failure in the hot and humid conditions of the tropics. The voyage was only able to be completed with the power management PLC disabled and the switchboard in manual operation.

1.6.11 On arrival in New Zealand, Strait Shipping decided that the existing power management system was not reliable enough for the ship's operating environment and tried to replace it with a more up-to-date control system while the ship was being refitted in Auckland prior to entering service.

1.6.12 The manufacturer of the existing system advised it was then obsolete. On the advice of the manufacturer, Strait Shipping then engaged another company to upgrade the power management system with new equipment. The PLC and man-machine interface computer were replaced, but the new supplier was unable to deliver the full scale of the work so Strait Shipping cancelled the contract prematurely.

1.6.13 Strait Shipping decided to return the power management system back to manual operation as it had been prior 1995, which was similar to the system on the company's other Cook Strait ferry, the *Santa Regina*. The ship's electricians modified the switchboard back to manual control and disabled the control functions of the power management PLC.

1.6.14 The new PC and PLC installed were configured with a monitoring function only and did not control the power management of the generators. The trend monitoring provided by this system is discussed in more detail in the analysis section.

1.6.15 The proposed plan to upgrade the ship's 4 PLC systems in stages was put on hold while an alternative solution was sought. Strait Shipping said that it could not source spare parts for the existing PLCs and that they did not have information on the programs written in the processing units of the PLCs, nor did they have the means to communicate with the processor to view or change the control program.

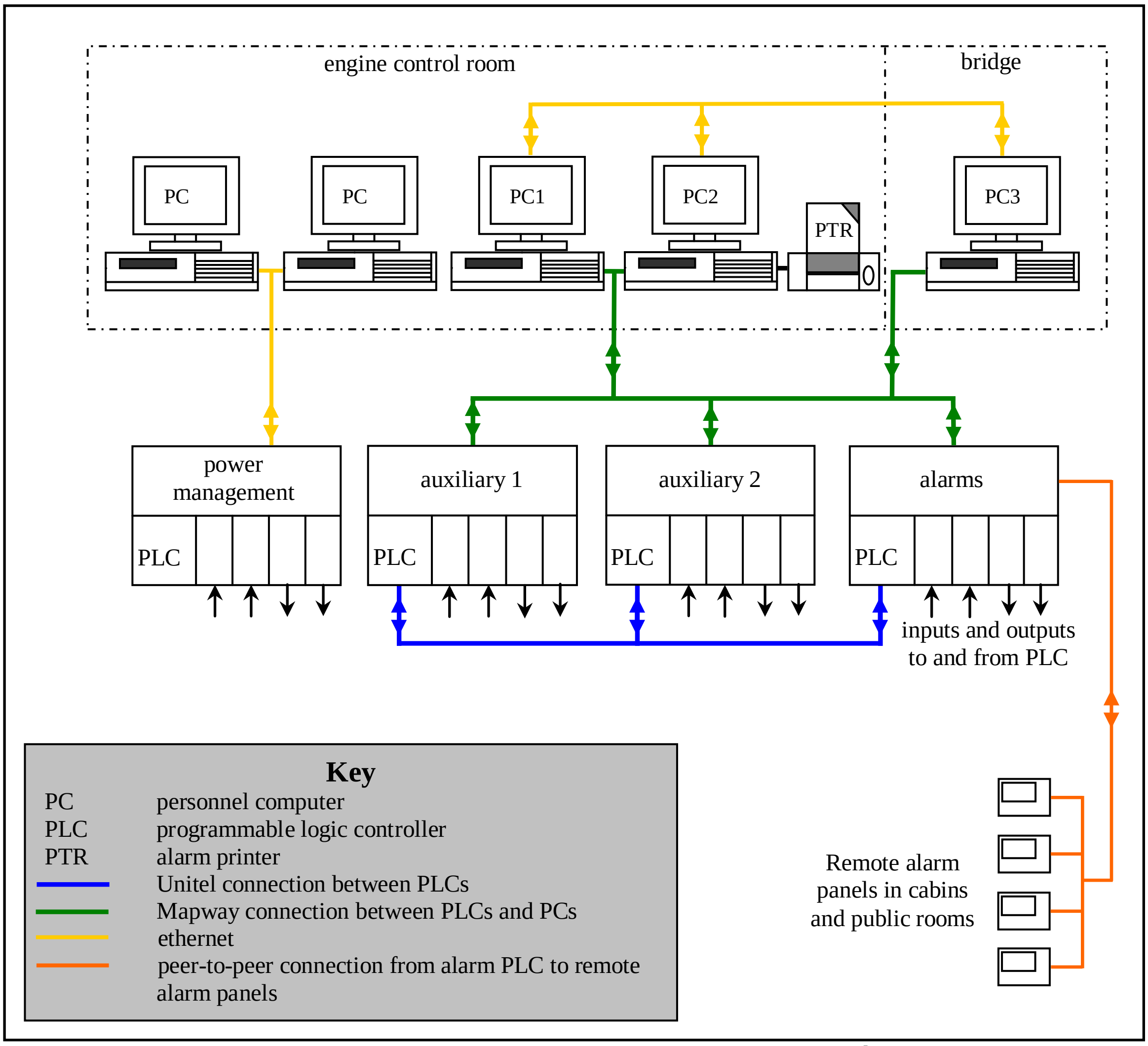

Figure 7
***Monte Stello* PLC system**

1.7 Programmable logic controller maintenance and condition

1.7.1 The main PLCs in the engine control room were not incorporated into the ship's planned maintenance system. Strait Shipping had no information about the control program in any of the 4 original PLCs and no facilities to communicate with the PLCs.

1.7.2 The PLC program was stored in a battery-backed RAM. The battery was a 3.6 volt nickel cadmium rechargeable battery that fitted inside a case in the central processor unit card. It could not be replaced without stopping the PLC (see Figure 8).

1.7.3 The technical staff on-board were concerned that if the PLCs were powered down to carry out maintenance, some or all of the RAM back-up batteries would not support the PLC memories. If the battery could not support the RAM when normal supplies were turned off, the control program would be lost. This situation would have rendered the PLCs inoperable and could have effectively disabled the ship.

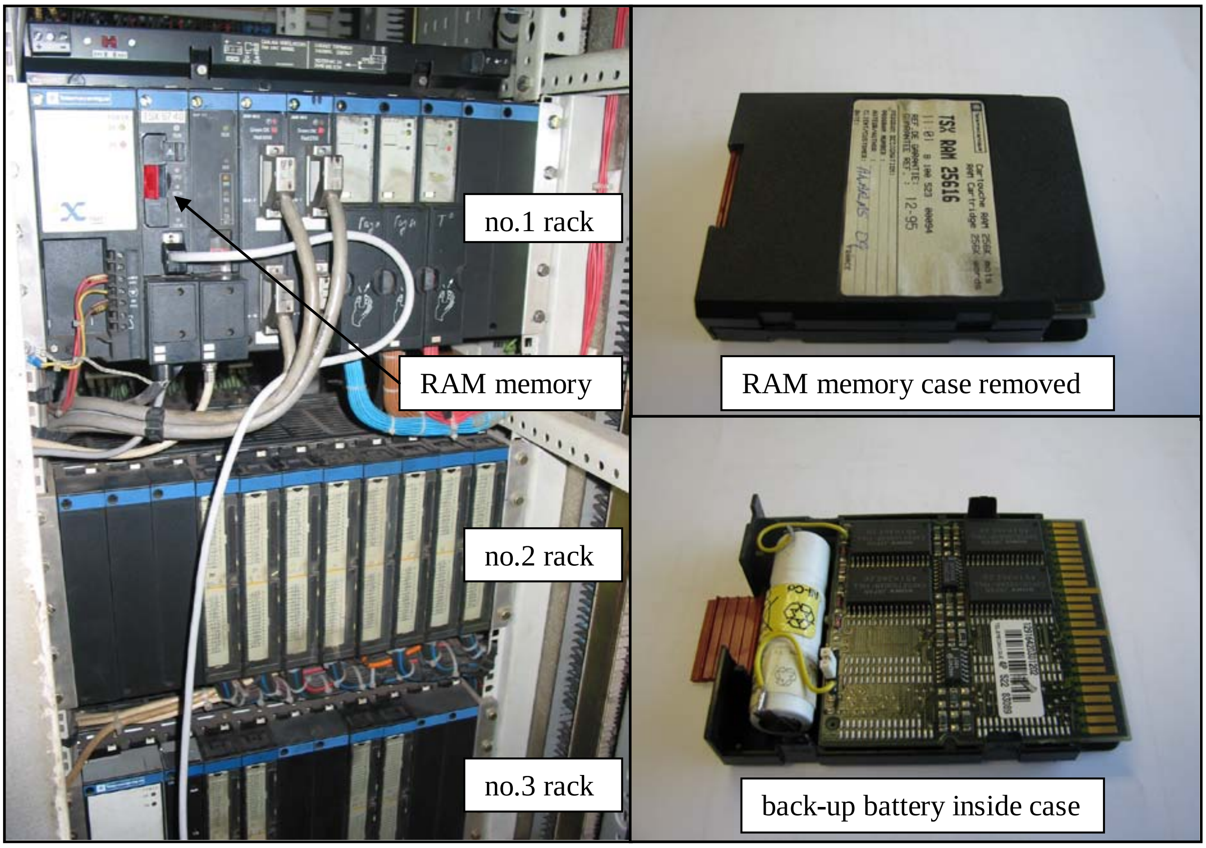

Figure 8
Alarm PLC and processor memory

1.7.4 The engine control room was supplied by ambient unfiltered air from outside the ship ducted from one of the supply fans providing engine room ventilation. An exhaust fan removed air from the control room to the atmosphere and a stand-alone air conditioning unit circulated and cooled air in the control room.

1.7.5 The control room had two entrance doors from the engine room. A number of permanent openings through poorly sealed cable and pipe glands also allowed contaminated air from within the engine room space to enter the control room directly adjacent to electrical equipment (see Figure 9).

1.7.6 The right-hand photograph in Figure 9 shows the carbon residue on the outside of the control room where contaminated air from the engine room had been leaking through a poorly sealed cable entry duct. Strait Shipping said that the carbon deposits had been accrued from large exhaust leaks in the main engines under the previous owner's operation, prior to the ship's arrival in New Zealand. These leaks were fixed by Strait Shipping when the ship arrived in New Zealand.

1.7.7 It is not unusual for the atmosphere in an engine room to be at a higher pressure than that in the control room. This pressure differential can be higher during periods when main engines are running at reduced power, requiring less air than that provided by the ventilators. On the *Monte Stello* contaminated air from the engine room was forced into the control room through the unsealed cable glands and covers. The main switchboard was not completely covered and components were not protected from this atmosphere. This air was also drawn through the unfiltered PLC ventilation fans and blown over the PLC components (Figure 10).

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Figure 9
Control room air supply and atmosphere

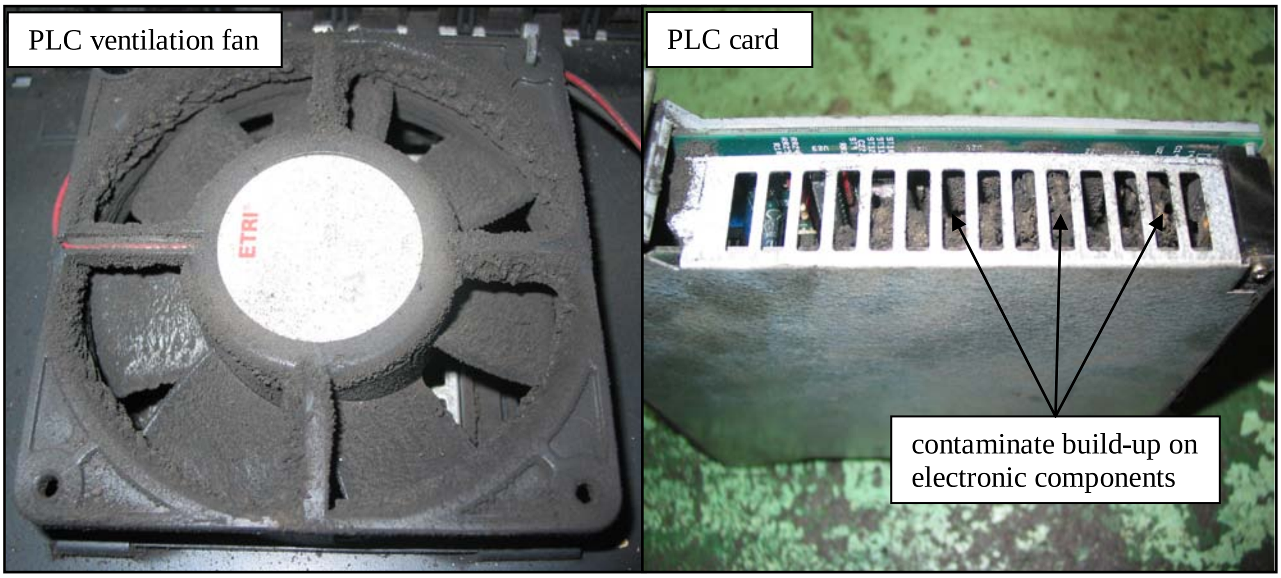

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Figure 10
Greasy carbon deposits on alarm PLC components

1.7.8 All of the 3 remaining original PLCs were covered with a greasy carbon residue and other particulates typically produced by diesel engines running on intermediate fuel. Each of the original PLCs was cooled by two small fans which blew unfiltered air from the control room over the cards in each rack and contaminate was observed inside the PLC card (see Figure 10).

1.8 Post-event inspections

1.8.1 The chief engineer thought that the alarm PLC failed around the time of the loss of mains electrical power just after he heard what he thought was a breaker operating in the switchboard. The times on the PLCs and the bridge were not synchronised so the exact time sequence could not be determined.

1.8.2 The alarm printer recorded the first alarm at about 14:45, which was over 5 minutes later than the time recorded on the power management PLC trend graphs for the diesel generator circuit breakers tripping. At this time all of the engine room alarms monitored by the PLC were initiated. These were displayed on the alarm PC and recorded on the alarm printer. The alarms were basically recorded in consecutive order by their channel numbers over 2 scan cycles of the alarm PLC.

1.8.3 The first 2 alarms recorded were channel number 0001 (high temperature fresh water outlet of the port main engine) and the second alarm was channel number 0002 (low temperature fresh water inlet of the port main engine), rather than related to the diesel generators, so the alarm print-out provided no indication as to the cause of the black-out.

1.8.4 Figure 11 shows the pertinent part of the alarm print-out just prior to the power loss, including the 2 alarms activated when the ship heeled rounding Diffenbach Point. About 215 individual alarms were recorded on the printer in the 2 minutes that followed the initial alarm 001.

time	channel number.	alarm description	alarm activated	alarm cleared
14:29:52	CA1 0307	High level bilge Stb ME **ship rounding Diffenbach Point**	APPEAR	
14:29:57	CA1 0060	Low level oil crankcase DG3 Port	APPEAR	
14:32:22	CA1 0080	Low level oil crankcase DG3 Port		DISAPP.
14:34:05	CA1 0307	High level bilge Stb ME		DISAPP.
14:45:27	CA1 0001	High temp.F.W.output M.E.-Port **(PLC fault)**	APPEAR	
14:45:27	CA1 0002	Low temp.F.W.input M.E.-Port	APPEAR	
14:45:27	CA1 0005	High temp.F.W.injectors-Port	APPEAR	
14:45:27	CA1 0009	Low temp.oil M.P.-Port	APPEAR	
14:45:27	CA1 0012	Duplex oil filter clogged-Port	APPEAR	
14:45:27	CA1 0021	High temperature fuel-Port	APPEAR	
14:45:27	CA1 0022	Low temperature fuel-Port	APPEAR	
14:45:27	CA1 0026	Launching air valve closed Port	APPEAR	
14:45:27	CA1 0030	High temp.reducer oil-Port	APPEAR	
14:45:27	CA1 0032	Reducer oil filter clogged-Port	APPEAR	
14:45:27	CA1 0036	High temp. propeller oil-Port	APPEAR	
14:45:27	CA1 0038	Propeller oil filter-Port	APPEAR	
14:45:27	CA1 0039	Low level oil box 1001 propeller-Port	APPEAR	
14:45:27	CA1 0040	Low level propeller return tank oil-Port	APPEAR	
14:45:27	CA1 0042	Propeller control voltage fault-Port	APPEAR	
14:45:27	CA1 0045	Voltage lack supply 1 safety-Port	APPEAR	
14:45:27	CA1 0046	Voltage lack supply 2 safety-Port	APPEAR	
14:45:27	CA1 0047	Voltage lack 220 V safety-Port	APPEAR	
14:45:27	CA1 0049	High temp.F.W.cylinders-Port		

annotated with red text for emphasis

Figure 11
Part of engine room alarm printer event log

1.8.5 The engine room personnel were unable to silence the alarm sirens and flashing lights or reset the alarms that had been indicated. The light-emitting diodes on the input and output cards of the alarm PLC were noted to be flashing with a constant regularity.

1.8.6 When the ship returned to Picton, the electrician found that all fuses in the 48 and 24 volt DC supplies were intact. The 48-to-24 volt DC convertor which supplied power to the alarm PLC input and output cards and their connected field devices was cycling between 0 and 24 volts DC. This was indicative of a fault either within the 48-to-24 volt DC convertor or one connected to its output which had triggered the internal protection to limit the current output to the fault.

1.8.7 While in Picton an alternative 24 volt supply was rigged to the alarm PLC, but attempts to restart the alarm PLC by switching the power off and on again were not successful. The crew suspected that the RAM back-up battery may have been flat. If that was the case, then switching the PLC off would have cleared the memory. The crew had no means to communicate with the alarm PLC, so that is why Strait Shipping decided to unload the ship and send it back to Wellington for repairs with just the crew on-board.

1.9 International Safety Management Code and maintenance

1.9.1 Under Maritime Rules, Strait Shipping were required to operate the ship within a safe management system complying with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code) as adopted by the IMO.

1.9.2 Statutory inspections of the ship were carried out by the Classification Society Lloyds Register, which was one of a number of such societies recognised by Maritime NZ as being suitable to carry out this function.

1.9.3 Compliance with the ISM system was verified by Maritime NZ which was also responsible for Port State inspections of the ship.

1.9.4 The IMO ISM Code section 10 (International Maritime Organization, 2002) set out the requirements for maintenance of a ship and its equipment:

> 10 Maintenance of the ship and equipment:
>
> 10.1 The Company should establish procedures to ensure that the ship is maintained in conformity with the provisions of the relevant rules and regulations and with any additional requirements which may be established by the Company.
>
> 10.2 In meeting these requirements the Company should ensure that:
> .1 inspections are held at appropriate intervals;
> .2 any non-conformity is reported with its possible cause, if known;
> .3 appropriate corrective action is taken; and
> .4 records of these activities are maintained.
>
> 10.3 The Company should establish procedures in SMS to identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The SMS should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use.
>
> 10.4 The inspections mentioned in 10.2 as well as the measures referred to 10.3 should be integrated in the ship's operational maintenance routine.

1.9.5 When the *Monte Stello* was purchased by Strait Shipping the maintenance records for the ship's machinery were sparse. After the delivery voyage was completed, a sample inspection of the main engine running machinery proved their poor condition and resulted in a major overhaul of both engines. The poor condition of the main engines gave reason for concern over the veracity of the maintenance records that did exist.

1.9.6 Strait Shipping established a computerised planned maintenance system on the *Monte Stello* which set out the maintenance requirements for the ship's equipment and machinery. The system was a copy of that used on the company's other Cook Strait ferry, the *Santa Regina* and so was familiar to technical staff. The system was approved by the Classification Society DNV.

1.9.7 Although the *Monte Stello* was similar to the *Santa Regina*, not all of the job descriptions and maintenance intervals were applicable to the machinery of the *Monte Stello* because there were differences between the 2 ships. Strait Shipping said that this was considered the best option for a starting point and the system would be refined as experience of operating the ship was gained.

1.10 **Personnel information**

1.10.1 The master first went to sea in 1978, gained his second class certificate of competency in 1982, and later gained his master's certificate of competency and was promoted to the rank of master in 2001. Between 1982 and 2004 he had served on a number of ferries and routes around the United Kingdom coast, Scandinavia, France and Holland. In March 2007 the master began service with Strait Shipping, serving about 3 months on another company ship. Having gained his pilot exemptions for the ports of Wellington and Picton he moved to the *Monte Stello* where he had served as master since July 2007.

1.10.2 The second mate held a Class 2 certificate of competency, allowing him to sail up to the rank of mate on a foreign-going ship up to 15 000 t. He had previously sailed as mate and second mate on a variety of ships including cruise, rig supply, anchor handling and seismic vessels worldwide. He had been working for Strait Shipping for about 1 year.

1.10.3 The chief engineer began his sea-going career in 1980 as a motorman and later as an apprentice engineer. He gained his Class 2 certificate of competency in 2002 and his Class 1 certificate in September 2006. In September 2006, he was appointed chief engineer on the Strait Shipping ship, the *Kent*. In March 2007 he moved to the *Monte Stello* where he served as chief engineer working a roster of 2 weeks on and 2 weeks off until the incident.

1.10.4 The third engineer had served in the Royal Navy for 22 years in a similar capacity to that of a third engineer in the Merchant Navy. After he retired he trained and qualified as a third engineer officer in January 2008 and had been employed by Strait Shipping since then.

2 Analysis

2.1 Diagnosis and fault-finding within complex maritime power-management installations can be challenging, and the true reasons why an event occurred cannot always be conclusively identified; this is one of those cases. Fault-finding can be made more difficult on older ships that have been managed by different operators, some of who may have had a minimalistic approach to maintenance. Systems are often modified in response to various events and the systems documentation (electrical diagrams for example) does not always match the actual system. Intimate knowledge of electrical systems is not always passed on from owner to owner, and when problems arise manufacturers' support for the systems is not always available. The *Monte Stello* fell into this category in almost every respect.

2.2 It is a serious safety issue that ship systems do not match the documentation associated with them. Failures can be more difficult to identify and rectify when time is short, and when the ship is navigating in enclosed waters, like this example.

2.3 Strait Shipping recognised some of the short-comings of the electrical systems on-board *Monte Stello* as early as the delivery voyage, and was working systematically through the issues to make the system safe and practicable. Concerns over shutting the PLCs down for maintenance and potentially losing the programs may have been valid; the conundrum being whether to risk components failing in service due to no or poor maintenance, or having them fail as a result of performing that maintenance.

2.4 The replacement of the power management system was not completed when the ship underwent a refit prior to entering service in New Zealand. Unfortunately the supplier was not able to satisfactorily complete the project so the power management system was returned to manual operation for reliability. The manual system was also similar to that used on the sister ship, *Santa Regina*, so this was a reasonable decision at the time.

2.5 In this case it could not be determined whether the black-out was the result of poor maintenance of electrical systems, or for other reasons, or a combination of these. The only facts that could be established were that the circuit breaker for number 3 generator did open and there-by disconnect it from the bus. Number 4 generator absorbed the entire load and settled for some 16 seconds, which it should have been able to, until its circuit breaker opened, also thereby blacking the ship out and causing all propulsion motors to stop.

2.6 The reasons why both diesel generators tripped from the bus is not clear. There was nothing abnormal in the set-up of the power management system, and no unusual internal or external conditions were known to exist. The ship was on its usual path in favourable weather conditions and no unusual manoeuvres were being made at the time.

2.7 The only known unusual conditions were that of the alarm PLC and the 48-to-24 volt DC converter supplying power to its I/O power supply card. As the function of the alarm PLC was only to monitor and sound alarm conditions, rather than control I/Os, this should not have caused the generators to trip off the board. It is possible that the ‘all-alarm’ condition of the alarm PLC and the tripping of the generator breakers were separate and unrelated events, but this would be highly coincidental.

2.8 Tests carried out after the incident on the 48-to-24 volt DC convertor for I/O power supply found that when the load on the input exceeded about 0.5 amps, the convertor internal protection operated causing the same fluctuations and fault condition witnessed at the time of the incident.

2.9 It has not been determined if the alarm PLC was faulty, but it would not run after the event even after an alternative I/O power supply was fitted. There was no equipment available to communicate with the PLC, read the internal software program or check that it was functional. There was very limited documentation on the alarm PLC system and it was not possible to make meaningful analysis based on what was available. The hardware was no longer supported by the original manufacturer and there were no local agents familiar with the system.

2.10 A number of potential theories are discussed below; some have been discounted and others remain a possibility.

Did a mechanical or running fault on the generators cause the black-out?

2.11 The power management PC included a separate trend monitoring display of generator loads, frequency and bus-bar connections against time. The information was updated about every second.

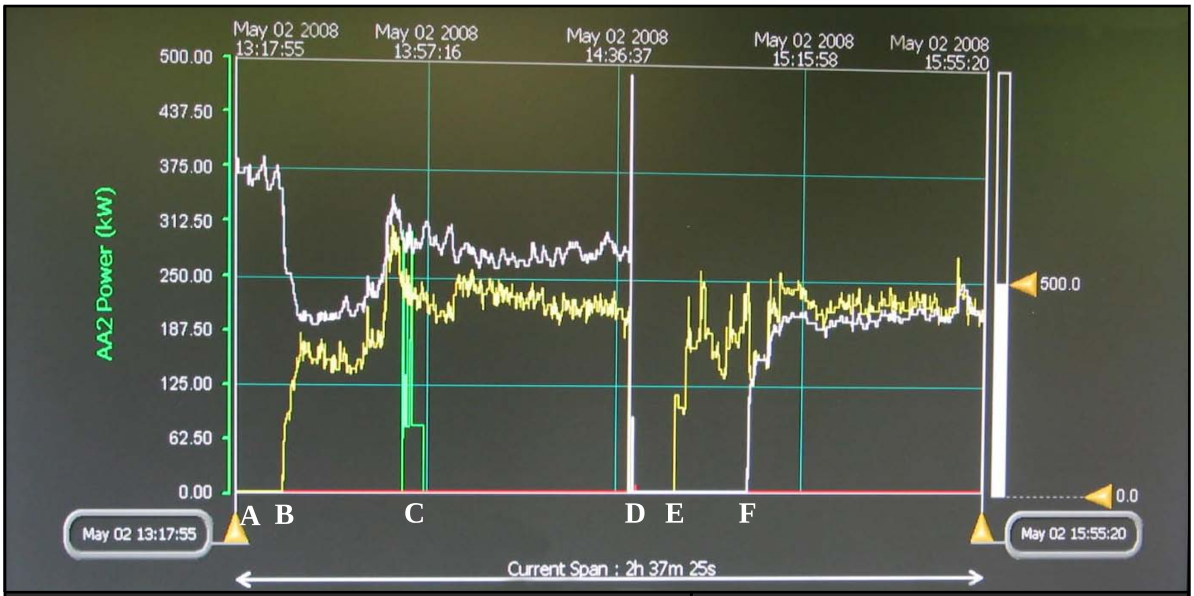
2.12 The trend data was used to identify the exact sequence that the diesel generators tripped and provided information about the nature of the interruption to the power supply.

2.13 Figure 12 shows the load variations on diesel generators shortly before and after the loss of power. The graph covers a time span of 2 hours 37 minutes and key events are highlighted.

2.14 Figure 13 shows the order in which number 3 and number 4 generator circuit breakers opened (“D” in Figure 12) over a smaller time span of 1 minute 32 seconds.

2.15 Figure 13 shows that prior to the power interruption number 3 and number 4 diesel generators were supplying a combined load of about 488 kW. At 14:39:28, number 3 diesel generator instantaneously shed its load. At the same time the load shed by number 3 generator was taken up by number 4 diesel generator. The resultant total load on number 4 generator was less than its design rating, meaning that it should not have been overloaded.

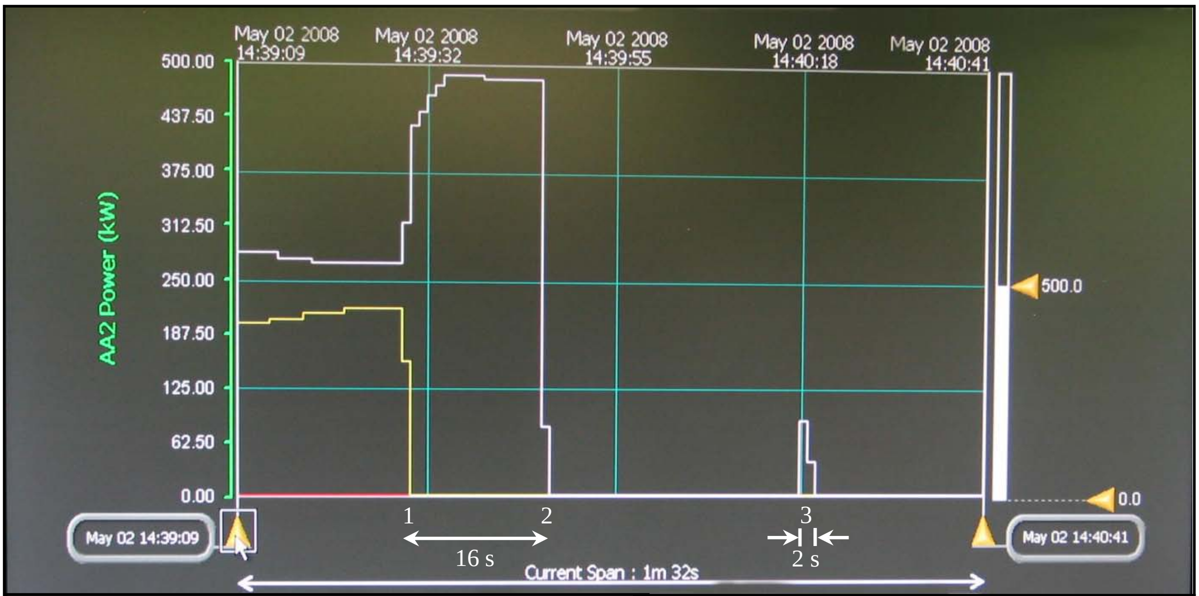
2.16 After several seconds the load on number 4 diesel generator stabilised for about 16 seconds before its circuit breaker opened also. There was then no power supply to either number 1 or 2 bus-bars, after which the main engines protection devices operated shutting the main engines down.



	Event log
A	no. 4 diesel generator on load alongside in Picton
B	no. 3 diesel generator started prior to departure Picton
C	no. 2 shaft generator on load bow thruster in use
D	no. 3 and 4 diesel generators circuit breakers trip
E	no. 3 diesel generator back on load
F	no. 4 diesel generator back on load

Key	
	no. 1 shaft generator
	no. 2 shaft generator
	no. 3 diesel generator
	no. 4 diesel generator
h	time in hours
m	time in minutes
s	time in seconds

Figure 12
Load trend graph



	Event log power trend graph
1	no. 3 diesel generator circuit breaker open
2	no. 4 diesel generator circuit breaker open
3	no. 4 diesel generator circuit breaker closed/ open

Key	
	no. 1 shaft generator
	no. 2 shaft generator
	no. 3 diesel generator
	no. 4 diesel generator
s	time in seconds
m	time in minutes

Figure 13
Load trend graph at time of power loss

2.17 Figure 14 shows the generator frequency trend over the initial period of the black-out. It shows that prior to either generator circuit breaker opening there were no large fluctuations in frequency on the bus-bars. A conclusion can be drawn that both diesel generators stopped supplying load due to their respective circuit breakers opening rather than due to a fault on either generator. Supporting this conclusion was that a mechanical or running fault on either diesel engine (e.g. fuel starvation) would be expected to show some fluctuations in the bus-bar frequency as the generator automatic voltage regulator (avr) responded to changes in the engine speed, which was not the case. The frequency was steady until the instantaneous trip occurred.

Event log frequency trend graph		Key	
1	no. 4 diesel generator circuit breaker open	(green line)	no. 1 bus-bar frequency
2	no. 2 shaft generator circuit breaker open	(red line)	no. 2 bus-bar frequency
3	no. 4 diesel generator circuit breaker closed/ open	(yellow line)	no. 3 bus-bar frequency
		m	time in minutes
		s	time in seconds

Figure 14
Frequency trend graph at time of power loss

2.18 After number 3 generator tripped, the load on number 4 generator stabilised at about the same level as the total load beforehand. If number 3 generator had a problem with its diesel engine and was still connected to the board then the generator would act as a motor and would start to take load from the switchboard until its reverse power trip operated. This would be seen as an increase in the total load and would be seen as an increase in load on number 4 generator above what had been the total load prior to number 3 tripping. This was not the case and the reverse power trip for either machine did not need to be reset.

2.19 The frequency trend graph shows the frequency dropping to zero immediately on numbers 1 and 2 bus-bars (interconnected) when number 4 generator tripped. The frequency on number 3 bus-bar dropped to zero about 4 seconds later, which coincided with when the port main engine and the shaft generator it was driving stopped following the black-out.

2.20 Figures 13 and 14 show that after the initial loss of power, number 4 diesel generator circuit breaker was closed again to number 1 and 2 bus-bars, but after about 2 seconds it opened again. This matched the chief engineer's description of noticing that number 4 diesel generator was still running and trying to connect it to the bus-bars again. In the absence of any mechanical fault with the generator, it should have connected. Why it did not could not be determined, but could possibly be related to the reason why it tripped off in the first place.

2.21 Finally, both numbers 3 and 4 generators were subsequently connected successfully to the bus when the chief engineer applied the black-out recovery check sheet, and both ran normally after that. In view of the above it is unlikely that a problem with either or both diesel generators caused the black-out.

Did the alarm PLC or the 48-to-24 volt DC convertor power supply fail?

2.22 The possibility that a voltage dip in the 48volt DC power supply may have caused the black-out was considered. Also considered was if there was a voltage dip, was it caused by the fault on the alarm PLC I/O power supply (48-to-24 volt DC convertor). A potential link back to the generators was that the 48 volt DC supply was the power supply common to the 4 engine room PLCs and a protection safety string (series connected set of contacts) in the diesel generator bus-bar connection circuit-breaker trip circuitry (see Figures 4 and 5). The argument was that if the 48 volt DC voltage dipped sufficiently; the 48 volt DC trip relay would not have sufficient energy to hold energised and the contacts would change-over. This would immediately trip the under-voltage trip coil and open the generator circuit breaker, removing that generator from service.

2.23 While a voltage dip is a possible scenario that might create a black-out, it would be highly unlikely to have been caused by the failure of the alarm PLC I/O power supply. Such a voltage dip would require a substantial fault current that would have left obvious clues to its existence. The 48 volt DC system had a high fault current capacity, but no evidence of high fault current was observed near the I/O power supply location, and also the 4 amp upstream and downstream fuses were still intact. The 48 volt DC power supply system was operational before, during and after the black-out and no fault was found within it.

2.24 The observed failure mode of the I/O power supply was that the output voltage was cycling between zero and 24 volts DC. The cause was that the power supply had a standard type of internal protection called voltage fold-back. That is, as the power supply load increased above its rated capacity, the output current would be limited and the output voltage automatically reduced (folded back) to limit the output power to protect the unit. Assuming that the alarm PLC I/O circuitry had some sort of cyclic fault on it, the output voltage of the I/O power supply would follow as this supply protected itself whenever the fault was connected. The electrical systems on the ship were checked extensively after the event and the alarm PLC removed and replaced with a new PLC. No evidence of such a fault was found external to the alarm PLC, but if one was in existence it could have been removed with the replacement of components or checking of the system post incident or during the delivery voyage back from Picton to Wellington.

2.25 The physical condition of the PLC was not ideal, with greasy carbon deposits from years of unfiltered cooling air built-up within the case and across the cards within the unit. Switching the unit on and off again in an attempt to re-boot the system did not work, even when an alternative power supply was connected to it. The nickel cadmium battery backing up the RAM was later tested and found okay, so re-booting the system should have restored it. The fact that it did not supports the theory that there was a fault within the alarm PLC. However, as mentioned above, this alone should not have disabled the generators because the alarm PLC performed a monitoring function only.

2.26 The possibility of another fault on the 48 volt DC system was considered but there was no maintenance carried out on this system and no fault was reported post-incident by the ship's technical staff in the subsequent operation of the ship, including the emergency batteries.

2.27 The possibility that some kind of software or hardware link between the alarm PLC power management PLC and switchboard was examined. If such a link existed it may have been possible for a fault in the alarm PLC to cause the generators to trip from the bus. When the power management system was returned to manual, the switchboard was modified to disable the automatic control functions of the power management PLC. The design drawings did not reflect the actual installation and were not updated with the changes made to the power management system over the years. Additionally the software control program documentation for all 4 PLCs had been lost. Post-incident investigation however did not reveal any links, but for the reasons given above this scenario is still considered possible.

Other possible explanations

2.28 Given that the alarm PLC should not have been capable of blacking the ship out, the possibility of other unrelated events causing the generators to trip off the bus must be considered. Having essentially ruled out a mechanical or running problem with the diesel generators the possibility of human intervention has been considered.

2.29 Staff had difficulty recounting the exact sequence of events during the black-out sequence. There was a lot of activity happening in a space of about 25 seconds – two generators tripped off the board, numerous and continuous alarms were generated by the alarm PLC (that the staff could not silence), and the black-out – all with the staff's knowledge that the ship was in restricted waters inside Tory Channel.

2.30 The chief engineer's recollection of the sequence of events was different from other evidence. For example he recollected starting number 4 generator first using the black-out procedure, when in fact the power management trend data showed that number 3 generator was started and connected to the bus first, followed by number 4.

2.31 The crew recollections on whether the diesel engine for number 3 generator remained running after its breaker disconnected from the bus were collectively vague. The chief engineer thought it had, but crew in the engine room described it as having stopped, or run down, or not really sure.

2.32 Other evidence points to the engine having stopped. For example the chief engineer described looking for and not finding a red light on the switchboard indicating the breaker had disconnected, which he would have seen had the engine still been running. Also, had number 3 breaker tried to automatically connect to the bus again, as described by the chief engineer, this would have shown momentarily on the load trend graph if the engine was still running, but it did not. The evidence shows that from the time number 3 generator disconnected from the bus, it remained disconnected until the chief engineer followed the black-out procedure to restore power, after which it started, connected to the bus, and remained running without any further problem throughout the return trip to Picton and then back to Wellington. The balance of probability indicates that number 3 diesel generator disconnected from the bus and shut down.

2.33 The proximity of the third engineer to number 3 generator when it tripped from the bus raises the possibility that during his checks he disturbed the generator and inadvertently caused it to stop, which would automatically trip the breaker. He was the only person in the generator room, but his account of events did not indicate that his actions would contribute to number 3 generator stopping. If he had inadvertently stopped the diesel generator, then in normal circumstances this would trigger alarms in the engine control room. The chief engineer said that no alarms were evident when he heard what he thought was the number 3 breaker trip, which if it was the case would shift weight towards a link with the failed alarm PLC being the cause instead.

2.34 It is possible that the alarm PLC went into its all-alarm state before the actual total black-out. The reset buttons would indicate to the chief engineer that there was either a mechanical or electrical fault with that generator, when in fact there might not have been. He recalled pushing the illuminated reset buttons and that action failing to clear whatever fault was causing it to illuminate. Pushing the illuminated reset button for the running generator would not have caused its breaker to open; this was tested after the incident. Why number 4 generator shut down and disconnected from the bus when it had already absorbed the load shed by number 3 generator and steadied at a level below its maximum rating requires some explanation. It could possibly have been caused by whatever caused number 3 generator to shut down, or it could have been inadvertently shut down in haste as the ergonomics of the switchboard meant it would have been easy to push the wrong button. The chief engineer's recollection of events does not support this theory.

2.35 These scenarios are possibilities only and should not be read as criticisms of the possible crew actions at a time of heavy workload. They would be viewed as typical reactions of people who are faced with an unusual and rapidly developing situation, for which in the heat of the moment, there was no rational explanation.

Response to the emergency

2.36 When the black-out occurred, the back-up systems came on-line as designed. Critical equipment had power fed to it from the emergency switchboard, including the steering gear.

2.37 The ship was fortunately in a relatively straight section of Tory Channel at the time, so the forward momentum did not pose a significant immediate risk to grounding. The risk however would have been even less had steering control been maintained, but through a miscommunication between the master, the officer-of-the-watch and the helmsman, steering control was not maintained, which allowed the ship to drift off its intended course prematurely. Had the black-out occurred at a more inopportune location, in a turn or at Tory channel entrance for example, this omission could have been critical to the outcome.

2.38 The miscommunication highlights the importance of good crew resource management during responses to emergencies.

2.39 Once the risk of grounding was realised, the response was well thought out, measured and successfully averted a grounding.

3 Findings

Findings are listed in order of development, not in order of priority.

3.1 The *Monte Stello* suffered a loss of electrical power when first number 3, and then number 4 diesel generators tripped from the bus. Number 4 generator should have been able to carry the total electrical load being drawn from the bus.

3.2 The *Monte Stello* lost all propulsion due to the total loss of electrical power, which was consistent with the design of the power management and distribution system.

3.3 The back-up emergency power supply system started automatically and supplied power to critical systems as it was designed to do.

3.4 The alarm PLC adopted an all-alarm status that might have been caused by an internal fault. The alarm PLC was impregnated with greasy carbon deposits built-up over time from unfiltered cooling air, which would have made it susceptible to failing.

3.5 The alarm PLC condition should not have caused the generators to trip from the bus, because it was supposed to provide a monitoring and reporting function only. However, the possibility that some undetected connection to the power management system remained following successive repairs and modifications made throughout the life of the vessel.

3.6 The reason for the diesel generators tripping from the bus could not be conclusively identified. The generator trend data shows that the reason was unlikely to be related to a fault in the diesel generators, and there was no evidence of a fault in the 48 volt DC system supplying power to the generator control circuitry.

3.7 The possibility exists that the diesel generator trips were inadvertently activated by personnel, contributed to by haste in resolving a developing situation, and the poor ergonomics of the switchboard layout. The alarm PLC fault could have been initiated by alarms associated with the first generator tripping, but this would be highly coincidental.

3.8 It is a serious safety issue when detailed knowledge of the actual configuration and relationship between the various components in the system were not available because records had not been maintained and passed on by various ship owners over the years, as was the case with the *Monte Stello*.

3.9 There was some confusion on the bridge over the status of the steering system under emergency power mode, which resulted in a premature loss of directional control, but otherwise the actions of the bridge team in bringing the vessel to anchor were measured and well controlled and prevented the ship grounding.

4 Safety Actions

Since the incident Strait Shipping Limited has carried out the following safety actions:

PLC systems

4.1 The faulty alarm PLC was replaced before the ship was returned to service. The PLC was replaced and the new system configured with new software.

4.2 The 2 auxiliary PLCs have been replaced with new PLCs compatible with the alarm and power monitoring PLCs.

4.3 Information pertaining to the operation and maintenance of new PLC and operating system has been documented into a manual.

4.4 Technical support is available from a local contractor who provided the new PLCs if required.

Control room air supply

4.5 Filters have been fitted in the ambient air supply for the control room to prevent debris and dust being blown into the control room.

4.6 Glands and seals at the penetrations in the control room bulkheads and floor have been overhauled.

4.7 The new alarm PLC has been housed in a perspex case and fitted with a forced fan ventilation unit fitted with a fine filter.

Switchboard ergonomics

4.8 The generator circuit breaker pre-select buttons on the generator switchboard controls have been re-positioned and labelled to make them clearer to the operator.

5 Safety Recommendation

5.1 On 25 February 2010, it was recommended to the Director of Maritime NZ that she:

> forward this report to the International Maritime Organization bringing to its attention the safety issue where there is no mandatory requirement for continuity of ships' maintenance records and system diagrams when ships' change ownership, and inviting it to refer this report on to the appropriate committee for its consideration (005/10).

5.2 On 22 December 2009, the Director of Maritime NZ replied in response to the preliminary safety recommendation in the draft preliminary report, worded as above. That reply, in part, was:

> MNZ supports the recommendation to forward this report to IMO once published.
> In light of the information provided in the report, with particular emphasis of the safety risks associated with the lack of available records relating to ships components, MNZ intends to
>
> 1. Undertake a Flag State inspection of the ***Monte Stello*** to satisfy itself that the safety actions mentioned in paragraph 4 of the draft report have in fact been undertaken.
>
> 2. Write to all Classification Societies drawing attention to ISM Code section 10 — with a view to pointing out that a safety bulletin will be issued identifying the risks associated with the lack of proper documentation for components such as the wiring diagrams and the need to address such matters.
>
> 3. Issue a safety bulletin drawing attention to the risks identified in this report to owners and operators.

Approved on 25 February 2010 for publication

Hon.W P Jeffries
Chief Commissioner

Works Cited

International Maritime Organisation. (2002). *ISM Code- text*. Retrieved January 2009, from International Maritime Organisation: http://www.imo.org/