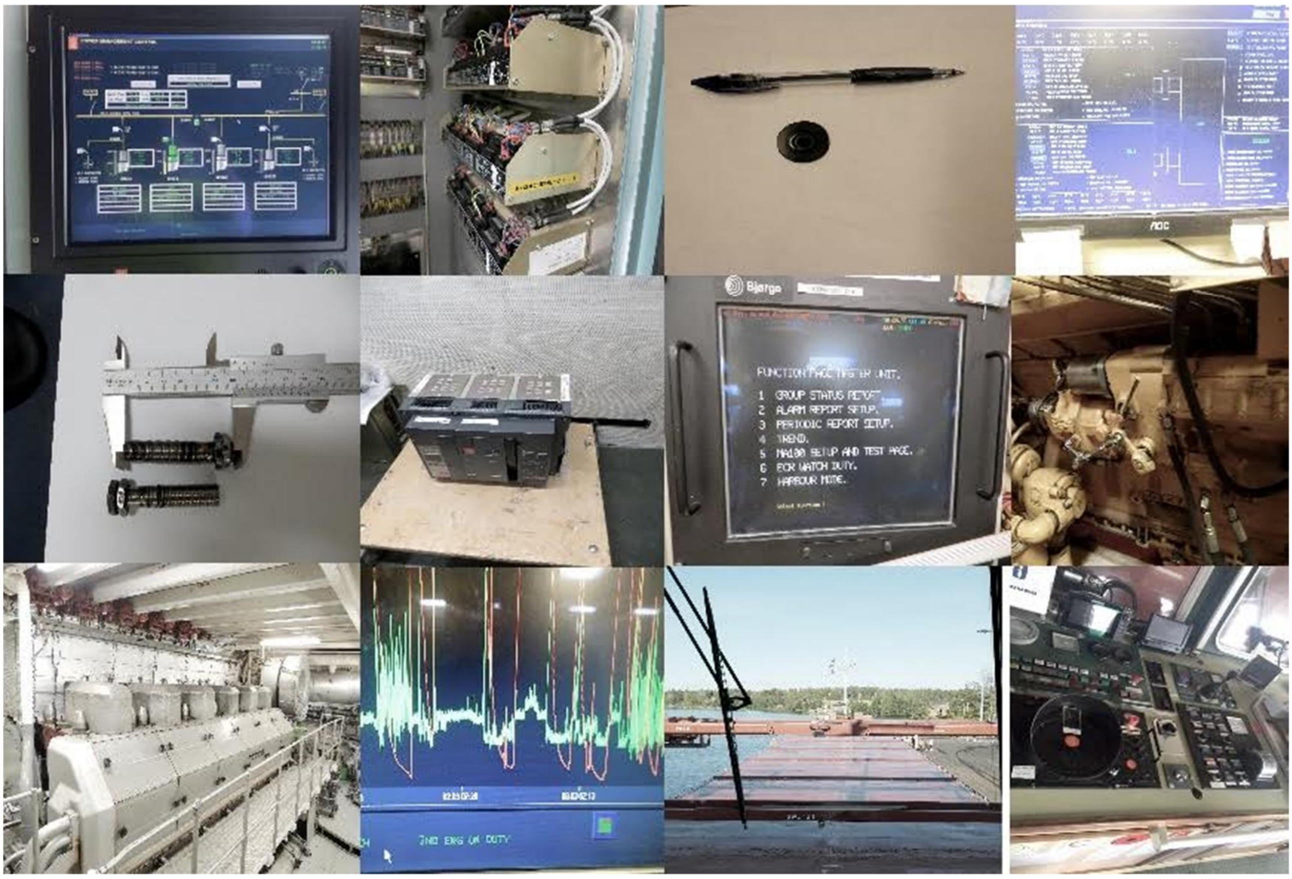
Power Failures on Ships

Safety study



Investigation number: M2016-S1

FOREWORD

On the basis of section 2 of the Safety Investigation Act (525/2011), the Safety Investigation Authority decided to initiate a safety study on power failures on ships. Senior researcher Sirpa Kannos led the investigation team until 24 February 2017, after which Lieutenant Senior Grade (retired) Jari Alanen took over as investigation team leader. As members of the joint investigation team were appointed Captain (Master of Maritime Management) Teemu Leppälä, Chief Engineer Tuomo Leppälä and Captain (Master of Maritime Management) Johanna Vahtera. In addition, on site investigations were conducted by Captain Bengt Malmberg, Captain Mikko Rausti and Naval Architect Niklas Rönnberg. Chief Engineer and Electrical Engineer Pekka Ilmiö was appointed expert on power failures. Chief Marine Safety Investigator Risto Haimila was Investigation Leader.

This safety study report describes the investigation process, gives general information about power failures on ships and presents acts and regulations concerning power failures on ships. The reports on specific cases as well as a joint analysis on them are included. At the end of this report safety recommendations are presented. By implementing them, similar accidents and incidents can be avoided in the future, or their consequences can be mitigated.

The purpose of safety investigation is increasing public safety, preventing accidents and incidents as well as mitigating damages caused by accidents. Safety investigations do not consider possible liabilities or obligations to compensate for damages. The use of investigation reports for any purpose other than to improve safety must be avoided.

Power failures in narrow fairways and in areas with dense traffic can cause very serious sea- and environmental accidents. These risks are pronounced in the Finnish narrow and rocky fairways in both sea areas and in inland waterways. The safety study strived to identify causes for power failures on ships. An evaluation concerning factors that decreased or increased safety was also conducted. These are presented in the incident reports included in this safety study, section 2.3.

Information about the power failure cases included in this safety study was received from the Finnish Transport Safety Agency, the Finnish Transport Agency, Finnpilot Pilotage Ltd. and shipping companies. It was decided that 12 cases of power failures, or incidents with similar consequences, would be investigated. The shipping companies were informed about the commencement of the investigations. The on site investigations were conducted by 2-3 experts. The scope of the investigation of individual cases was limited to the component-, system- and operational- levels. None of the investigated cases did result in a very serious sea accident or environmental accident. Reports were prepared on the results of the on site investigations. The reports have been included in this safety study. After a one-year monitoring period, the investigated incidents were analysed using the Bow Tie method of analysis.

The incident reports were sent to the concerned shipping companies for review. The draft report was sent for review to the Finnish Transport Safety Agency, the Finnish Transport Agency and to Finnpilot Pilotage Ltd. A summary of the reviews has been included in this report. Statements or reviews by private persons are not published.

Senior Lecturer Peter Björkroth has translated the investigation report to Swedish and English. The investigation report, as well as a summary, is published on the Safety Investigation Authority's website, www.turvallisuustutkinta.fi

GLOSSARY AND ABBREVIATIONS

DWT	Deadweight tonnage, the ship's weight carrying capacity
GMDSS	Global Maritime Distress and Safety System
GT	Gross tonnage, the ship's internal volume
IMO	The International Maritime Organisation, a United Nations agency
IMO number	A unique number assigned to all merchant vessels of 100 GT or above. The number remains the same for the whole lifetime of the vessel
ISM Code	International Safety Management Code Code An international safety management system
NT	Net Tonnage The volume of the ship's cargo spaces
SMS	Safety Management System Safety Management System used by shipping companies and ships
SOLAS	International Convention for the Safety of Life at Sea
STCW	Standards of Training, Certification and Watchkeeping for Seafarers An IMO adopted convention
Trafi	The Finnish Transport Safety Agency
UPS	Uninterruptible Power Source
VTS	Vessel Traffic Service
SAR	Search And Rescue (SAR) services provided by the government and volunteers.
Generator backfeeding	The electricity flows to the generator because of malfunction in the power plant. The generator then begins to work as a motor, supplied by the power grid.
Propulsion	Vessel thrust
Stand by	Status where a unit or machine is ready to be started
Power Failure	Situation in which power generation or distribution is temporarily interrupted or is disturbed.

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1 ENSURING THE ELECTRICITY PRODUCTION AND DISTRIBUTION ON SHIPS

1.1 Definition of Power Failures and Investigated Cases

A power failure is a situation in which power generation or distribution is temporarily interrupted or disturbed. Failure or overload in the ship's electricity distribution system can result in a partial or complete loss of electrical power, i.e. a blackout. The scope and severity of the disturbance depends on how the system is built, its back up systems and where the distribution system failure occurs. The diversity of electricity distribution systems and the large number of components in them, make it difficult to anticipate faults.

Ship accidents and incidents related to failures in the distribution of electricity were followed for a period of 12 months, beginning 1 February 2016. In the end 12 cases were included in this investigation. Ten of them concerned distribution of electricity and two of them main engine failures. The consequences of the main engine failures were similar to the consequences of power failures.

1.2 Electricity Generation and Distribution System

Ships have own electrical networks, production, distribution and connected consumers of electricity. The ship's electrical network enables the ship to operate as an independent entity at sea and often also in port. The latter if the ship is not connected to shore power to ensure availability of electricity onboard.

A vessel's electrical network can be implemented in a variety of ways. The intended use of the vessel, its type, as well as specific features in the vessel design determine how the electric network is implemented. In the International Convention for the Safety of Life at Sea (SOLAS) it is required, that on vessels in international traffic, electricity can be produced by two independent sources, both of which alone has the capacity to produce electrical power enough to maintain the ship's seaworthiness.

The power needed onboard is produced by the ship's own generators. They are rotating at constant speed, usually powered by diesel engines. From the diesel generators, electricity is transferred to the main electrical grid, which in turn distributes electricity to the consumer points. There can be one or more diesel-powered generators on a ship. The number and size of generators will depend on the ship's need for electrical power.

It is also possible to use a shaft generator or a generator connected to the main engine, for producing the electricity needed on a ship. A shaft generator is a generator that can be connected directly to the propeller shaft that is rotated by the main engine. Another possible arrangement is to have the main engine rotate the propeller shaft and a generator connected to it by a reduction gear.

A shaft generator can often generate all the electrical power needed for the ship. Usually the shaft generator is used when the ship is *en route*. Upon arrival in ports or in narrow fairways, the needed electrical energy can be produced with generators powered by auxiliary engines in order to ensure safety.

The ship must be fitted with an emergency power source, which may be an emergency generator or a set of batteries. The electrical energy produced by the emergency source is transferred to the emergency electric panel from where it is transferred to the safety-critical equipment such as the steering system. The required emergency power depends on the power demands of the equipment that has been defined as critical. This power demand, in turn, will determine the choice of emergency power source. Most ships have a diesel generator as emergency power source.

1.3 Ships' Power Distribution Systems, Power Sources and the Requirements of the SOLAS Convention

1.3.1 Power Distribution System

The power distribution systems are implemented on vessels following the instructions issued by classification societies. The intended use of the vessel, its type as well as special features in the vessel design, determine how the power distribution is realised. In its simplest form there can be one lone diesel generator onboard. A technically more demanding arrangement is a power distribution system realised with several diesel generators. This arrangement is common on vessels with a high demand for electric power. These include, for example, vessels with electric propulsion or vessels with a large consumption of electricity due to a large number of passengers. Electricity can be produced also with a generator connected to the main engine or the propeller shaft.

1.3.2 Main Source of Electrical Energy

At present the most common main source of electrical energy on ships is diesel generator sets, producing alternating current for the ship's electrical grid. There can be several installed diesel generator sets and they are controlled with the machine automation system. Other electricity sources are, e.g., generators connected directly to the main engine and shaft generators. Shaft generators are connected to the same shaft line as the main engine. They are connected to the shaft either directly or through a reduction gear.

If a cargo- or passenger ship in international traffic has auxiliary- systems or equipment running on electrical power, it must be fitted with a minimum of two generator systems. One of the generator units must be dimensioned in such a way that it on its own is capable to meet the electricity requirement of the ship's machinery and equipment. Ships, constructed after 1 July 1998, on which the availability of main power is essential for operating the ship's main propulsion plant and steering system, must note the following: the power generating system must be built and equipped in such a way that – in the event of failure of one generator – the supply of electricity for the equipment necessary for the operation of the propulsion plant and steering system immediately is restored.[1] This requirement can be met by fitting several diesel generators in parallell and with automatic transfer switches for the critical equipment.[2]

The distribution of the load between generators must be arranged in a way preventing an overload of a generator.[3] This can be achieved by adjusting the start-up limits of the generators so that when a generator or generators reach, for example, an 85% load, the next generator starts up and is synchronised into the network to produce the necessary additional energy.

1.3.3 Emergency Source of Power

The ship must be fitted with an emergency power source, which may be an emergency generator or a set of batteries. The demand for emergency electrical power determines the choice between the options. Nowadays most ships have diesel generator units as emergency power source. They produce AC to the ship's electrical grid. A diesel generator is a compact solution

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[1] SOLAS 2009: 84
[2] SOLAS 2009: 83
[3] SOLAS 2009: 89-97

compared with batteries. Greater demand for emergency electrical power, results, in practice, in choosing a diesel generator for emergency source of power.

Batteries as a source of emergency power are used on small vessels. Batteries are used to secure radio equipment, navigation equipment as well as machine automation. In ships where electrical power is necessary for restoring the operation of the main propulsion plant after a power failure, the capacity of the emergency power system has to be dimensioned as follows: electricity feed for the propulsion plant and the necessary equipment related to it, has to be restored within 45 seconds after the beginning of a power failure if the emergency power source is a generator. If the emergency power source is a set of batteries electricity feed has to be restored immediately.[4]

1.4 SOLAS Requirements on Other Critical Systems for the Emergence and Consequences of Power Failures on Ships

1.4.1 Propulsion System

In case of disturbances and fault situations, the safety of the ship is set to take precedence over the protection of the machineries and equipment against damage. In fault situations the propulsion system should remain in operation as long as possible. It must also be possible to restart it even if an auxiliary essential for the propulsion system has malfunctioned. Auto-stop is only allowed in cases that can lead to serious damage of the propulsion system.[5]

When designing machinery systems on ships, the aim is to duplicate all critical functions. Classification societies do however accept that ships only have one propeller, one shaft line and one main engine.

1.4.2 Steering System

It must be possible to maintain the ship's manoeuvrability when the propulsion engine is running and even after it has stopped e.g. due to a hardware failure. Because of this, components in the ship's steering system, e.g. equipment conveying steering commands and units producing power for steering, e.g. hydraulic pumps, are among the most important elements of the ship's electrical network. Ships must be fitted with a main steering system and an auxiliary steering system that can be taken into use quickly. The main steering gear and the auxiliary steering gear must be constructed and installed so that a failure in one system does not affect the performance of the other. [6]

Power units in the steering gear, such as electrically operated hydraulic pumps, must start automatically after a power failure. It must also be possible to take them in use from the navigating bridge. Failure of a power unit, or automatic startup failure, can result in decreased or loss of power for turning the rudder. Disturbances in the power units of the steering gear must activate an alarm on the navigating bridge.[7]

1.4.3 GMDSS Equipment

Sea areas are divided into four GMDSS areas, according to which the requirement on the composition of the radio equipment on board is determined. [8]

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[4] SOLAS 2009: 89- 97
[5] SOLAS 2009: 89- 97
[6] SOLAS 2009: 71- 72
[7] SOLAS 2009: 233- 234
[8] SOLAS 2009: 233- 234

The functioning of the radio equipment in the event of disturbances in the power distribution onboard, is secured with a separate emergency power supply, i.e. with a set of batteries for the radio equipment. The batteries must not be dependent on the propulsion plant or the electrical network. The batteries must supply the ship's radio equipment, composed according to the requirements of the GMDSS-area, with power for at least six hours. If the ship is equipped with an emergency generator, the radio equipment must function for at least one hour with power from batteries.

1.4.4 Machine Automation System

The machine automation system must be able to distribute the load on the power grid (the generators). In the event of a generator failure, the machine automation manages the start-up of the stand by generators as well as their synchronising to the network. The machine automation also restarts the auxiliaries necessary for the propulsion plant and steering gear. [9]

When the electricity supply has been realised using more than one generator, the machine automation system must - in the event of a generator failure - be able to ensure that other generators connected to the network remain in the network without getting overloaded. The machine automation must further be able to ensure that the propulsion plant and steering gear are able to function normally. [10]

In case of disturbances in a system, the machine automation must take care of switching connections to the stand-by units that have been defined by the user.[11]

If the machine automation system fails, so that it cannot perform the required functions relating to electricity distribution, the system can cause interference in the power distribution. Such a situation may arise, for example, if the power plant is not adjusted properly e.g. concerning generators used in parallel. If the ship's power control does not work as planned, a rapid variation of the power control from the control room may result in greater load on a diesel generator connected to the network and to the subsequent opening of a generator circuit breaker.

1.4.5 Requirements in the ISM Code

According to the ISM Code, vessels in international traffic must have a safety management system.

The safety management system must include instructions for recruitment and familiarisation of the crew, as well as instructions for various emergencies such as disturbances in the power distribution.

According to the ISM Code, critical equipment and components must be noted in the ship's preventive maintenance system. On request, the shipowner must be able to present critical equipment and components to the classification society or to the flag state authority. Failure of that equipment or those components may result in hazardous situations. The list of critical equipment must include at least the critical equipment and components of the propulsion plant, steering gear and power distribution system. [12]

The shipping company must define the criticality of on board systems in accordance with their own activities and thereby develop the functionality of the preventive maintenance system and the safety management system.

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[9] SOLAS 2009: 97

[10] ISM Code: 16

[11] ISM Code: 16

[12] ISM Code: 16

1.4.6 Requirements in the STCW

The STCW convention is a set of international regulations for training, certification (competencies), and watchkeeping for seafarers. The STCW convention contains a code, the STCW Code, which sets minimum standards for the training and competence of seafarers.

Competencies and training of the crew on cargo and passenger ships in international traffic must be in compliance with the STCW Code.

1.4.7 Flag State Requirements

Flag states monitor ships' compliance with regulations through port state controls and inspection procedures.

In Finland, the Finnish Transport Safety Agency's Decree on Electrical Installations on Ships[13] sets requirements for main and emergency power systems for ships operating in domestic traffic areas.

2 INVESTIGATED POWER FAILURES

2.1 Access to Information on Power Disruptions

At the beginning of this safety study, the authorities and shipping companies were sent a request to notify the Safety Investigation Authority about power failures on ships. There is no obligation to notify about them in present legislation. A change in the maritime law concerning the reporting of hazardous situations is under preparation. The change relates to notifying the Finnish Transport Safety Agency about accidents and incidents in connection with the use of the vessel. When it enters into force, the law also facilitates access to information on power supply disruptions, which often are so called near misses.

In Finland information on ships' power failures is collected by, among others, The Finnish Transport Safety Agency, the Finnish Transport Agency, Finnpilot Pilotage Ltd and the shipping companies. They reported, in accordance with the request they received, on the incidents that had come to their knowledge, to the Safety Investigation Authority, which decided to investigate 12 cases.

In addition to these 12, the Safety Investigation Authority was informed about eight cases of power failures or other disturbances with similar effects as power failures. Those cases were not investigated. Based on the statistics collected by the Finnish Transport Agency and Finnpilot Pilotage Ltd, there have apparently been another 10 power failures during the monitoring period, for which no information was received.

2.2 The Investigation Process

Based on the data first received, the Safety Investigation Authority decided on whether the case would be included in the safety study or not. The on-site investigation was carried out by groups of 2-3 people and the intention was to investigate as soon as possible after the incident.

In the on-site investigations the course of events was clarified by hearing the crew and by collecting necessary recordings on the vessel. If possible, the following information about the incidents was collected:

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[13] TRAFI/10743/03.04.01.00/2014 Electrical Installations on Ships

- Time and duration of the incident
- Place of incident
- Weather conditions at the time of the incident
- Traffic situation in the incident area
- Manning at the time of the incident, navigating bridge/engine room
- Pilot or line pilot on board? Pilot exemption?
- Description of incident
- Reasons for the power failure
- Immediate effects of the power failure on board
- Emergency and back-up systems and their operation
- Measures taken during the power failure situation and restoring the system to normal mode
- Measures taken by external stakeholders, including possible rescue operations
- Consequences of the incident
- The essential points in the vessel's safety management system and their implementation in practice
- Contact information: vessel, shipping company, classification society and agent
- and all necessary records and recordings to support the investigation and to establish the basic vessel information.

In addition, the on-site investigators wanted to know whether there before the beginning of the incident had been any service, maintenance or other work in progress that might have affected the case, or whether there had occured any alarms related to the incident. The preventive maintenance system and the service history of components related to the incident in systems that substantially affected the incident were examined.

The experts involved in the on-site investigations compiled an incident report after finishing an investigation. In addition to the information obtained in the on-site investigation, safety findings of the investigators concerning the incident were added in the report. The safety observations were divided into positive and negative findings, since one of the objectives with the safety study was to pin down best practices and other factors that saved the situation and prevented an accident.

2.3 Incident Reports

The safety study strived to identify causes for power failures on ships. An evaluation concerning factors that decreased or increased safety was also conducted. These factors are presented as safety observations in the incident reports below. The observations are often covered by §already existing legislation. Safety could be improved by complying with present legislation as well as by committing to the spirit of the legislation.

2.3.1 M/S Polaris VG, a Series of Power Failures, February 2016

General information

Time and place of incident	2.2.2016 Rostock, 6.2.2016 Rauma, 8.2.2016 Rostock, and 12.2.2016 Rauma
Vessel name, call sign and IMO number	Polaris VG, OJQX, 8716100
Type of vessel	Ro-ro vessel
Flag state	Finland
Place of build and time	J.J. Sietas, Germany, 1988
Main dimensions	LOA 123.47 m; beam 20.20 m; maximum draught 6.16 m
NT, GT, DWT	2700, 7950, 6494
Owner	VG Shipping Ltd
Ship manager	VG Shipping Ltd
Classification society	Bureau Veritas
Main engine, power	Wärtsilä 6R46, 5100 kW
Auxiliary engine, power	2 x KDH F5L 912, 342 kW, total 684 kW
Propulsion	Adjustable pitch propeller
Cargo	Many different cases, not known
Crew	9
Meteorological conditions	Many different cases, not known

Overview of Incident

In February 2016, several power failures took place on M/V Polaris VG, during which the power supply was lost completely. The vessel was in port, moored, during all cases of power failures, and they caused no dangerous situations.

Because information about the power failures was not received until considerably later, accurate information about the situation in each individual case was no longer possible to get. The vessel's engine crew had changed, and the situations had not been documented in detail. Thus the investigation focused on the causes of the failures and on the solutions that had been used.

Description of the power failures and their reasons

The vessel has one main engine, equipped with a shaft generator, and two auxiliary engines, which have their own generators. When at sea, the vessel uses only the shaft generator to produce electric energy, while the auxiliary engines are in standby mode. In fairways and ports, the auxiliary engines are used to produce electricity, and the shaft generator is not in use.

In the incidents in question, the control system of the auxiliary engines stopped, depending on the case, the auxiliary engine, or engines, without a clear reason. In the incidents involving several running auxiliary engines, the generator of the faulty auxiliary engine was not disconnected from the network, but remained connected. The operational auxiliary engine then became overloaded and stopped. Some of the incidents took place when only one auxiliary engine was running while the other was undergoing maintenance.

Troubleshooting was difficult. At first, it was done mainly on a trial-and-error basis. The vessel had been purchased second-hand from Germany about a year earlier, and lists over equipment and documents, manuals and maintenance records, were incomplete.

To begin with, the vessel's crew replaced the RPM measurement sensors in the auxiliary engines because they suspected that the engine control automation incorrectly conveyed too low RPM data. Replacing the sensors did not, however, solve the problem.

Next an engine control automation expert was called for to the vessel. He was able to locate the fault to the auxiliary engines' control system, which was from the year 1988. The electronic cards in the system had lost their efficiency with time, and were no longer able to process information properly. After replacing the electronic cards, the problem disappeared.

Effects onboard of the power failure

The failures did not have any significant or long-lasting effects, because the vessel was in port at the time of the incidents, and usually one auxiliary engine could be started and connected to the network quickly.

The emergency- and backup-systems and their operation

The vessel's emergency generator started automatically in all cases.

Onboard activities during the power failure

Since the automation of the vessel's emergency generator worked as planned, the crew basically only had to restore the system to normal mode.

Restoring the system to normal mode

The engine crew started an auxiliary engine, or engines, and connected them to the network. The alarms were acknowledged and equipment that had stopped and required a manual start-up was restarted. Most of the equipment restarted automatically when the electricity supply had returned to normal.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

The shipping company has a quality- and safety management system (ISO 9001:2008 and ISM), which includes the company's safety and quality manuals, general and vessel specific guidelines for their ships. However, in practice, there were no vessel specific instructions. Instead the vessels followed the shipping company's general instructions for the vessels.

In the vessels' general instructions for emergencies, there were no instructions specifically for power failures. The issue was touched upon in the instructions for incidents involving vessel not under command situations. After this case, the shipping company has planned to develop instructions for power failures as a step in developing the SMS. The list of critical equipment was found in the general instructions for the vessels, but there was no vessel specific list.

Deviation reports were later compiled onboard, on the shipping company's request, but they contained very little information about the incidents. In practice, the vessel was in the habit of taking care of things with the shipping company by phone, and to make the mandatory reports for serious incidents after the matter had been resolved. Reporting smaller incidents was not considered necessary.

Factors that reduced safety

- The vessel's crew had not internalised the deviation reporting practice and did not understand its importance. Deviation reports were only compiled on serious incidents or at the request of the shipping company, and the reporting of smaller incidents was not considered necessary.
- The vessel did not have any vessel specific instructions onboard. Vessel specific instructions are mandatory according to the quality and safety management system. The shipping company had delegated the responsibility for developing the vessel specific instructions to the vessel, and had not ensured that the request had been carried out.
- High turnover of crew made solving the problem more difficult and it complicated the flow of information.
- The electronic cards in the system had lost their efficiency with time, and they were no longer able to process information properly. The preventive service system does not support following up the condition of the electronic cards. The only option to manage the risk would be to change the electronic cards at specific intervals.
- The vessel had been purchased second-hand from Germany about a year earlier, and the lists over equipment and documents, manuals and maintenance records, were incomplete. Further on, it was not possible to get user support for the old automation system.

External factor that influenced positively on the occasion

- The vessel was in port, moored, during all power failure cases.

2.3.2 M/S Coral Carbonic, Power Failure, 3.3.2016

General information

Time and place of incident	3.3.2016 at 18.34 - 18.49, Sköldvik fairway
Vessel name, call sign and IMO number	Coral Carbonic, PCFW, 9201906
Type of vessel	Gas carrier
Flag state	The Netherlands
Place of build and time	Frisia's Shipyard, the Netherlands 1999
Main dimensions	LOA 79.55 metres; beam 13.73 m; maximum draught 6.50 m
NT, GT, DWT	547, 1825, 1786
Owner	Anthony Veder Rederij B.V.
Ship manager	Anthony Veder Rederij B.V.
Classification society	Bureau Veritas
Main engine, power	M.A.K 6A25, 1800 kW
Auxiliary engine, power	2 x Catepillar 3306, 175 kW, tot. 350kw
Propulsion	Controllable pitch propeller, Becker rudder
Cargo	In ballast
Crew	9 + pilot
Meteorological conditions	Wind E, 8 m/s, clear

Overview of Incident

In the afternoon on the 3rd of March 2016, the gas tanker Coral Carbonic was anchored in Sköldvik, outer anchorage F. The pilot came on board, the anchor was heaved up and the vessel set off towards Sköldvik oil port following the nine-meter fairway. About an hour after departure, the vessel suffered a complete power failure when approaching light buoy Sköldvik 2. The vessel then began to drift.

The pilot informed Helsinki VTS and vessels in the vicinity about the situation over the VHF-radio. The vessel prepared for anchoring. Visibility, weather conditions and the position of the vessel, however, were such that the vessel could be let drifting in the fairway. After ten minutes the engines could be restarted, and the vessel was able to continue its voyage to port.

Description of the power failure and its reasons

Shortly before the power failure the vessel's radio equipment, sonar and the speed log began to flash. The chief engineer informed from the engine room, that there were problems with the frequencies. Soon after this, the vessel suffered a total black out, i.e. all equipment dependent on electricity, stopped working.

The regulator in auxiliary engine 1 stopped working and caused strong oscillation in the engine's rotation speed. Because both auxiliary engines were connected to the main switchboard at the time of the incident, the strong voltage and frequency oscillation affected the whole power distribution system and neither of the engine's circuit breakers opened. After the auxiliary engine stoppage, the circuit breaker of the faulty engine could be opened, and the operational engine was restarted.

The load on the auxiliary engines was about 60 kW at the time of the incident, and the voltage oscillation between 400 and 440 V.

Effects onboard of the power failure

As the vessel's 24V DC power system is dependent on the vessel's main electrical system's transformer feed, the malfunction in the main system caused a great voltage oscillation in the DC power system. The alarm- and control-systems of the main engine were disturbed by the oscillation, the main engine oil pressure sensor stopped working, and the main engine stopped due to the low oil pressure signal.

When the main engine stopped, the vessel lost its ability to manoeuvre. Most of the navigation devices, for example the radars, stopped working. On the navigating bridge, however, one of the VHF radios and the internal telephone remained operational and enabled communication.

The emergency- and backup-systems and their operation

The vessel's emergency generator failed to start because its starter relay did not work. All the vessel's 24V-dependent equipment was powered by one 24V DC power system. Normally the equipment got its power feed from the main switchboard, through the transformer and rectifier, or, in the event of disturbances, from the emergency switchboard. In addition, the DC system has a battery supply (UPS) for emergency situations, as well as individual batteries for a few devices. As the emergency generator failed to start, the electrical system did not get power from the main switchboard, or from the emergency switchboard. The battery supply capacity was not sufficient on its own. This resulted in that the voltage of the DC system decreased very quickly, and only the devices with own batteries remained operational.

Onboard activities during the power failure

At the time of the incident the master of the vessel, a watchman and the pilot were on the navigating bridge. The vessel's chief engineer and third engineer were in the engine room. The master turned on the navigation lights for vessels not under command and took over the hand steering. The chief mate and the watchman were sent to the bow to be prepared to anchor. The pilot informed the VTS and vessels in the vicinity about the incident. The pilot had a navigation application on a tablet. That made it possible for the bridge team to follow the direction the vessel drifted in.

The vessel's chief engineer stopped the auxiliary engines, opened the circuit breaker of auxiliary engine 1 and restarted auxiliary engine 2.

Restoring the system to normal mode

It took 5-10 minutes to restart and reconnect auxiliary engine 2 to the main switchboard. After this the systems dependent on electricity were largely operational again. After the alarms had been acknowledged, the main engine was restarted and the vessel was able to continue the voyage towards port.

The following week, an external service man, commissioned by the shipping company, came to the vessel to try to clarify the reasons for the power failure and for the oscillation of the voltage in the auxiliary engine. The regulator in auxiliary engine 1 was found to be defective and was replaced with a new.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

The company has issued clear instructions for power failure situations. The master followed them consistently.

There were instructions for power failure situations also in the vessel's engine room. The chief engineer deviated from the instructions on purpose, once he observed that the emergency generator failed to start. He focused on restarting the auxiliary engines rather than on trying to start the emergency generator manually.

Factors that reduced safety

- The vessel was not under command during the power failure.
- The vessel's 24V DC power system was common for all devices dependent on electricity, including navigation devices and alarm systems.
- The backup for the DC system was primarily based on the functioning of the emergency generator. The battery bank, intended to be a secondary backup in case of an emergency generator failure, was not alone sufficient to maintain the power supply to all devices connected to the system.
- The emergency generator did not work.

Factors that increased safety

- The pilot had a navigation application on a tablet that was not dependent on the vessel's devices. That made it possible for the bridge team to monitor the vessel's position and the direction it drifted.

- There was a pilot with knowledge about the local circumstances, onboard. He took care of the communication with the VTS and vessels in the vicinity. The vessel's crew could thus focus on ensuring the safety of the vessel.
- The instructions for measures to be taken on the navigating bridge in case of a power failure are clear, and the crew followed them consistently.

External factors that influenced positively on the occasion

- The vessel was drifting slowly in good weather conditions.
- The water depth in the surrounding area was large enough to allow for safe drifting of the vessel.

2.3.3 M/S Missouriborg, Main Engine Failure 16.3.2016

General information

Time and place of incident	16.3.2016 at 07.13 – 07.22, off Pori
Vessel name, call sign and IMO number	Missouriborg, PFBI, 9228978
Type of vessel	Dry cargo carrier
Flag state	The Netherlands
Place of build and time	Bijlsma Shipyard, Netherlands, 2000
Main dimensions	LOA 134.55 m; beam 16.5 m; maximum draught 7.30 m
NT, GT, DWT	3493, 6585, 9119
Owner	Wagenborg Shipping B.V
Ship manager	Wagenborg Shipping B.V
Classification society	Bureau Veritas
Main engine, power	Wärtsilä 8L38, 5280 KW
Propulsion	Adjustable pitch propeller
Cargo information:	Coal
Crew:	9+1 apprentice, pilot
Meteorological conditions	Wind NW 6.6 m/s, temperature -2 °C, sky clear

Overview of Incident

M/V Missouriborg unberthed in Tahkoluoto, Pori, in the morning of 16.3.2016. The vessel began reversing towards the Kissanhauta turning basin within the port area. About 15 minutes after departure, the main engine suddenly stopped. The pilot reported the incident to the VTS. The vessel prepared for anchoring and evaluated the need for requesting tug assistance. The vessel continued its astern movement to the north side of Kissanhauta and then drifted slowly in open water. It was not necessary to anchor the vessel. There was sufficient depth of water to drift freely, and the vessel could be maneuvered using the bow thruster. Weather conditions at the time of the incident were good and the port was almost completely free of ice. There was no other vessel traffic in the area at the time of the incident. The crew succeeded in restarting the main engine after about 10 minutes, and the voyage was continued out to sea.

NB. This incident concerns a main engine failure, not a power failure. When the vessel's main engine failed, the propeller no longer rotated and thus did not produce kinetic energy for the ship. However, the vessel had two auxiliary engines running, which produced electricity onboard during the main engine failure.

This incident was comparable to a power failure to its effects, and that is why it is included in this safety study.

Description and causes for the main engine failure

The rotation speed of the main engine is monitored in its control system by two magnetic sensors. The sensors are located on the side of the main engine, in the measuring point of the camshaft's gear wheel. The sensors have LED indicators that flash when they are in working order. One of the sensors is the main sensor and the other is a backup. The backup sensor will be activated automatically if the main sensor fails or is broken. Both sensors operate independently and send rotation speed information to the main engine controller. If the controller does not receive rotation speed information from either one of the sensors, it will stop the main engine.

The main engine stopped because both sensors were damaged. The plastic insulation of both the sensors were very worn. It is possible that the worn insulation caused an earth fault, preventing correct information on speed of rotation from reaching the controller. When the controller did not get the main engine rotation speed information, the control system gave the alarm "ME both pick ups failed" because of the failing sensors. The main engine then immediately stopped.

Effects onboard of the main engine failure

When the main engine stopped, the propeller stopped, and the vessel began to drift. When the speed decreased, the effect of the rudder decreased due to the missing slipstream.

The vessel’s electrical system was working normally, so, for example, all the navigating bridge equipment remained operational.

The emergency- and backup-systems and their operation

In case the sensor for providing the main engine control system with rotation speed information fails, the backup sensor is activated. In this case, both sensors failed at the same time, i.e. the backup system failed.

Onboard activities during the main engine failure

The master and the pilot were on the navigating bridge at the time of the incident. The master, who also operated the bow thruster, did manual steering. The chief officer and the bosun were in the bow of the ship, ready to anchor if necessary.

As soon as the main engine stopped, the pilot informed the VTS about the incident. The master continued maneuvering the vessel with the rudder and the bow thruster as long as the vessel had any speed. Considering the position of the vessel and the weather conditions, it was judged that tug assistance was not necessary. It would have lasted approximately two hours for the tug to arrive. The bridge equipment was operating normally and it was possible to monitor the position of the vessel continuously during the incident.

The chief engineer was in the engine control room and the engineer in the engine room when the engine alarm system alerted about failure in the rotation speed sensors. The automation stopped the main engine immediately. Based on the engine alarm, the chief engineer judged that faulty speed sensors caused the main engine failure. He immediately began to sort out whether there were spare parts onboard, so that the damaged sensors could be replaced with new ones.

Restoring the system to normal mode

The necessary spare parts were found onboard, and both the magnetic sensors were replaced. The main engine was restarted and the vessel was maneuverable again.

Entries in the vessel's Safety Management System (SMS) concerning main engine failure and their implementation

In connection with this incident it did not become clear whether the company had issued any instructions for situations with main engine failures.

Factors that reduced safety

- Obtaining tugboat assistance in the port of Pori would have taken two hours.
- The preventive maintenance system was insufficient, because the simultaneous wear of the main- and backup-sensor was not detected.

Factors that increased safety

- The auxiliary engines remained operational, so limited maneuvering of the vessel, using the bow thruster and rudder, was possible.
- The bridge equipment was operational and it was possible to monitor the position of the vessel continuously during the incident.
- The crew was able to identify and rectify the fault quickly.
- There was a pilot with knowledge about the local circumstances onboard. He took care of the communication with the VTS and vessels in the vicinity. Thus, the vessel’s crew could focus on ensuring the safety of the ship.
- There were necessary spare parts onboard.

External factors that influenced positively on the occasion

The vessel was drifting slowly in good weather conditions.

The water depth in the surrounding area was large enough to allow for safe drifting for the vessel.

There was no other traffic in the fairway that would have had to be taken into account during the incident.

2.3.4 M/V Alppila, Power Failure, 4.4.2016

General information

Time and place of incident	4.4.2016 at 8.08 – 8.12, Ust-Luga anchorage, Russia
Vessel name, call sign and IMO number	Alppila, OJOF, 9381706
Type of vessel	Bulk carrier
Flag state	Finland
Place of build and time	ABG Ship Yard, India, 2011
Main dimensions	LOA 155.4 m; beam 25.2 m; maximum draught 9.59 m
NT, GT, DWT	6420, 14841, 20499
Owner	ESL Shipping Ltd
Ship manager	ESL Shipping Ltd
Classification society	Lloyd's Register
Main engine, power	Man B&W 6550MC-C, 8580 kW
Auxiliary engine, power	3 x Wärtsilä 6L20, 860 kW, total 2580kW
Propulsion	Adjustable pitch propeller
Cargo information	In ballast
Crew	14 + 2 cadets
Meteorological conditions	Wind NE 3 m/s, temperature + 1 °C, rain

Overview of Incident

4.4.2016 in the morning, M/S Alppila was at anchor in the Ust-Luga anchorage when an AB wanted to start one of the vessel's deck cranes. He intended to move some fenders. After the AB had checked with the engine room that the main switchboard was in automatic mode, something that starting the crane requires, he turned the switch requesting adequate power for starting the crane.

The auxiliary engine in operation stopped almost immediately, and the vessel's power supply was cut off. The backup auxiliary engine next in line started about one minute later, and the vessel's power supply was normalized in a matter of minutes.

The incident did not cause any danger, because the vessel was at anchor and no critical operations were in progress.

Description of the power failure and its reasons

The vessel's deck cranes have a switch for requesting adequate power and for getting permission from the main switchboard to start the crane. If the load on the auxiliary engine in use is such that it does not allow for an increase of the load, the automation does not give permission to start the cranes before the backup auxiliary engine next in line has started and is connected to the network. There is a separate start button for the crane. The crane can only be started when the automation has approved the power request.

The vessel has three auxiliary engines. At the time of the power failure, auxiliary engine number 3 was in use. The voltage of auxiliary engine 3 had already earlier been noticed to constantly vary between approximately 376 - 405 V. The reason for the variation had not been found, but the variation had been noted in the first engineer's end of shift report.

When the crane's power allocation request switch was turned, the voltage and possibly also the frequency of auxiliary engine 3 simultaneously dropped below the alert limit. The drop in voltage and frequency most likely caused the power failure. The automation then stopped auxiliary engine 3 to protect the technology. The start button of the crane was not pushed at any point. The connection between the crane's power allocation request and the stopping of the auxiliary engine, could however not be definitely established.

Effects onboard of the power failure

The vessel's power supply was interrupted for four minutes. The power failure had no significant effects onboard.

The emergency- and backup-systems and their operation

The backup auxiliary engine next in line started automatically.

It was not possible to establish with certainty, from the engine control system's alarm lists, whether the emergency generator had started, as it should have.

Onboard activities during the power failure

As the automation of the vessel's auxiliary engines worked as planned, the crew only had to restore the system to normal mode.

Restoring the system to normal mode

After the power failure, a control round, consistent with the company's instructions for this type of incidents, was made. During the round, alarms were acknowledged and devices that had stopped were restarted.

Due to the uncertain operation of auxiliary engine 3, the starting order of the auxiliary engines was changed, so that auxiliary engines 1 and 2 would start before number 3.

Later the voltage regulators and potentiometers of auxiliary engine 3 were replaced with new ones. After replacing the parts, the voltage fluctuations stopped and the auxiliary engine ran normally.

The shipping company plans yet to have the potentiometers fine-tuned in accordance with the manufacturer's instructions.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

- The company has issued instructions for measures to be taken on the navigating bridge and in the engine room in case of a power failure. The vessel's crew followed the instructions.
- A deviation report on the incident, consistent with the requirements in the safety management system, was prepared. The vessel's proposal for corrective measures was to call for a technician specialised in voltage control and to have him check and possibly adjust the voltage regulators of all three generators.
- No changes were made in the SMS or in the preventive maintenance system as a result of the incident.

Factors that reduced safety

- The voltage fluctuations in auxiliary engine 3 had already earlier been noticed, but no active measures had been taken to clarify the problem. No attempts had been made to control the risk caused by the fluctuations in the voltage, not by changing the starting order of the auxiliary engines or by other means.

2.3.5 M/V Lianne, Power Failure, 23.6.2016

General information

Time and place of incident	23.6.2016 at 11.10 - 11.13, Lake Saimaa, Taipale lock
Vessel name, call sign and IMO number	Lianne, V2CP4, 9422275
Type of vessel	Dry cargo carrier
Flag state	Antigua and Barbuda
Place of build and time	Ustamehmetoglu Shipyard, Turkey 2005
Main dimensions	LOA 79.94 m, beam 12.50 m, maximum draught 4.75 m
NT, GT, DWT	958, 1903, 3024
Owner	Scheepvaartbedrijf van Dam B.V.
Ship manager	Scheepvaartbedrijf van Dam B.V.
Classification society	Registro Italiano Navale,
Main engine, power	MAK 6M20, 1140 kW
Auxiliary engine, power	2 x Volvo Penta TAMD 74, 135 kW, total. 270 kW
Propulsion	Controllable pitch propeller, Becker rudder
Cargo	In ballast
Crew	7 + pilot
Meteorological conditions	Wind SE 2 m/s, temperature +22 °C, sky clear

Overview of Incident

M/V Lianne was en route, under pilot, to Siilinjärvi, north Saimaa. When entering the lock in Taipale canal, the vessel suffered a power failure. The vessel was already halfway into the lock at the time of the incident and had a speed of about 1 to 2 knots. The lock walls kept the vessel parallel with the lock while it slowly glided forward until the electricity supply was back to normal. The power failure lasted for about 2-3 minutes. Neither the vessel nor the lock structures suffered any damage.

Description of the power failure and its reasons

The vessel has two main engines and two auxiliary engines. Normally the shaft generator, connected to the main engine, produces electricity for all devices of the vessel while at sea. When in fairways, the shaft generator is used for producing electricity for the thruster while the auxiliary engine generators produce electricity for the other devices of the ship.

In the lock the master began using the bow thruster by pressing the power button. Immediately after this, the circuit breakers of the shaft generator and the auxiliary engine generators opened, causing a complete power failure. The use of the bow thruster should not have put an unusual load on the electricity network; this was normal operation of the bow thruster. Moments earlier the bow thruster was operating normally. The main engine and auxiliary engines remained running, despite the opening of the circuit breakers.

Since all generator circuit breakers feeding the electricity network opened at the same time, it can be assumed that both auxiliary engine generators and shaft generator were connected in parallel.

This differed from what above is said about what was the normal electricity distribution arrangement while in fairways. Because of this, the disturbance in the electric network could propagate through the whole electric network, causing all the circuit breakers to open.

It was not possible to establish a definite reason for the opening of the generator circuit breakers based on the available information.

One possible reason may be a network overload due to the simultaneous power need of high power consumers, such as the starting air compressor and bow thruster. The load variation on the main engine may have caused the voltage and frequency of the shaft generator output to fluctuate, causing circuit breakers to open. Other possible causes may have been a disturbance in the automation of the shaft generator and auxiliary engine generators, or in the operation of the circuit breakers themselves.

Effects onboard of the power failure

Neither the vessel's bow thruster nor the rudder, worked during the power failure, and the vessel was thus not under command.

The emergency- and backup-systems and their operation

The vessel has no emergency generator. The vessel has an emergency battery system (UPS), which, during a power failure, produces power for emergency lighting, the GMDSS radio station, as well as for the engine automation. The operation of the emergency battery system during the incident could not be verified afterwards.

Onboard activities during the power failure

The master and a pilot were on the navigating bridge at the time of the incident. They observed the movements of the ship.

The chief engineer was in his cabin when the engine alarm caused by the power failure was activated. He went to the engine control room and began restoring the system to normal after noticing that the generator circuit breakers had opened.

Restoring the system to normal mode

The chief engineer reset the protection relays of the generator circuit breakers, and reconnected the generators to the main electricity network. He acknowledged the alarms that the control system had registered and verified the operation of the engine room equipment.

Entries in the vessel’s Safety Management System (SMS) concerning power failures and their implementation

The shipping company had general instructions for power failure situations, but the technical details in the instructions had not been modified to be compatible with this specific vessel.

Also the list of critical equipment was general, intended for the whole shipping company, and not vessel specific. Equipment maintenance was monitored with the electronic preventive maintenance system.

No deviation report on the incident was made, even if the shipping company SMS requires reporting of incidents.

Factors that reduced safety

- Neither the vessel's bow thruster nor the rudder, worked during the power failure, and the vessel was thus not under command.

- The master and chief engineer were not aware of that the shipping company had instructions for power failure situations. Actions onboard were based on situation-specific solutions.
- The vessel's personnel did not have sufficient understanding of the vessel's systems and the different modes used when operating at open sea and in fairways.
- The shipping company's general instructions for power failure situations, and the technical details in them, had not been modified to fit this specific vessel.

External factor that influenced positively on the occasion

- The failure occurred in a situation when the vessel's speed was low and the lock prevented drifting.

2.3.6 M/S Finnsun, Power Failure, 30.6.2016

General information

Time and place of incident	30.6.2016 at 14.03 – 15.18, Vuosaari fairway
Vessel name, call sign and IMO number	Finnsun, OJPA, 9468918
Type of vessel	Ro-ro cargo ship
Flag state	Finland
Place of build and time	Jinling Shipyard, China, 2012
Main dimensions	LOA 188.4 m; beam 26.5 m; maximum draught 6.9 m
NT, GT, DWT	8401, 28002, 10370
Owner	Finnlines Ltd
Ship manager	Finnlines Ltd
Classification society	RI, Registro Italiano Navale
Main engine, power	2 x Wärtsilä 8L46F, 10 000 kW, tot. 20 000 kW
Auxiliary engine, power	2 x Mitsubishi S 12R, 1100 kW, tot. 2200 kW
Propulsion	2 controllable pitch propellers
Cargo	Ro-ro cargo
Crew	16 + 1 trainee
Meteorological conditions	Wind ESE 2 m/s, temperature + 18 °C, clear

Overview of Incident

M/V Finnsun was en route to Vuosaari port 30.6.2016, in the afternoon. Before the beginning of the Vuosaari port channel, the vessel's auxiliary engines and main engines stopped. The vessel suffered a complete power failure, and lost its manoeuvrability. A few minutes before the power failure, the vessel had shifted from shaft generator power feed, used at open sea, to auxiliary engine feed, used when in fairways.

The vessel informed the VTS about the situation. Visibility, weather conditions, traffic and the position of the vessel were all such that the vessel safely could be let drifting in the fairway. It took about an hour and 10 minutes before the main- and auxiliary-engines could be restarted and the vessel was able to continue its voyage to port.

Description of the power failure and its reasons

The shifting of the power feed from the shaft generators to the auxiliary engines went as normal: the automation system started the auxiliary engines, connected them to the main switchboard and disconnected the shaft generators from the same.

4-5 minutes after the shifting, the engine control system gave a frequency alarm from the electricity network. After a few seconds both auxiliary engines stopped, and the power feed to the main switchboard was interrupted. At the same time, the main engines stopped, because the electric pumps, connected to the main switchboard, stopped working.

It was found that the auxiliary engines stopped because of a fuel supply disruption, caused by water in the fuel. The fuel supply lines to the auxiliary engines, and the fuel in the day tank were contaminated with water. Initially it was thought that the water in the day tank had leaked there from a steam pipe in the tank's heating system. The day tank heating was not in operation, but the valve in the heating system's return side was open.

The steam line was pressure tested after the incident and was found to be intact. In a more detailed inspection, it was found that the fuel had been contaminated by steam and condensed water from another fuel separator's heat exchanger. This is a maintenance-free heat exchanger that cannot be opened, so the leakage could not be observed from the outside.

Effects onboard of the power failure

When the main engine stopped, the speed of the vessel decreased to zero. The vessel was thus not under command, even though the rudder, because of the power feed from the emergency generator, remained operational throughout the incident. The bridge equipment and the engine room automation remained operational due to power feed from the UPS-system batteries and the emergency generator.

The vessel's power supply was interrupted for about one hour. The vessel arrived in port about one and a half hours later than scheduled.

The emergency- and backup-systems and their operation

The vessel's emergency battery power system (UPS) and emergency generator operated normally and produced electricity for the devices connected to the emergency switchboard. It took 20 seconds for the emergency generator to start, and about a minute for it to connect to the emergency switchboard.

Onboard activities during the power failure

The engine office, close to the engine control room, was manned at the time of the incident. When the auxiliary engines stopped, the chief engineer quickly went to the control room and tried to restart the auxiliary engines, but without success. The engine crew began acknowledging the alarms that had come from the engine control system. When the emergency generator had started, it was possible to use lighting normally again. Thereafter the chief engineer proceeded to the auxiliary engine room and tried to start the engines manually from there, but that did not succeed either. Engines and auxiliary systems were inspected visually, but no defects were detected. Next, the fuel feed was investigated, and water was found in the fuel system. It took about 10 minutes to determine the cause of the incident.

The OOW and a watchman were on the navigating bridge at the time of the incident. The master and chief mate came to the bridge soon after. All the bridge equipment remained operational, since the backup systems functioned normally. The crew on the bridge was thus able to focus on controlling the vessel’s position. The vessel informed the VTS about the incident, and the day signals for vessel not under command were hoisted. There was no need to anchor, but it would have been easily done, if necessary, because the anchor chain stoppers were open and the anchors could have been let go from the navigating bridge.

Restoring the system to normal mode

The crew began removing the water from the day tank, immediately after discovering it. Approximately 20-30 litres of water was removed from the day tank, and the fuel lines to the auxiliary engines were drained of water. All fuel filters in the auxiliary engines were replaced and the crew then began to bleed out the air from the fuel system. About an hour after the failure, the vessel's auxiliary engines could be started and the electricity supply returned to normal.

Day tank water retention was monitored, and some more water still had to be removed. The day tank's steam pipe valve on the return side was closed, because it was suspected that the steam pipe inside the tank was leaking.

Lastly the boilers and main engines were started, and the vessel continued its voyage to the port of Vuosaari.

It could later be established that the origin of the water in the fuel was a broken heat exchanger in the fuel separator. The broken heat exchanger was replaced. After the incident, the shipping company has instructed also the sister-ships to drain the fuel tanks of water more often, so that similar instances can be detected in a timely fashion.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

The vessel had instructions, issued by the shipping company, for measures to be taken on the navigating bridge and in the engine room, in case of a power failure. The vessel's personnel acted in accordance with the instructions.

A deviation report on the incident, consistent with the requirements in the safety management system, was prepared.

Factors that reduced safety

- When the main engine stopped, the speed of the vessel decreased to zero. The vessel was thus not under command, even though the rudder, with power feed from the emergency generator, remained operational throughout the incident.
- Both auxiliary engines have a common day tank and a common fuel supply line. There is no possibility to use an alternative fuel supply in case of an emergency.

Factor that increased safety

- The vessel has instructions to change the power supply from shaft generator to auxiliary engines 45 minutes before arriving to pilot boarding area, or to beginning of port entrance fairways.

External factors that influenced positively on the occasion

- The vessel was drifting slowly in good weather conditions.
- The water depth in the surrounding area was large enough to allow for safe drifting for the vessel.
- There was no other traffic in the fairway that would have had to be taken into account during the incident.

2.3.7 RMS Neudorf, Power Failure, 11.7.2016

General information

Time and place of incident	11.7.2016 at 16.20 - 19.10, Kissaluoto S, Lappeenranta
Vessel name, call sign and IMO number	RMS Neudorf, V2A15, 8920256
Type of vessel	Dry cargo carrier
Flag state	Antigua and Barbuda
Place of build and time	Damen Shipyards, the Netherlands, 1990
Main dimensions	LOA 82.46 m; beam 12.50 m; maximum draught 4.37 m
NT, GT, DWT	969, 1985, 2631
Owner	Rhenus Maritime Services GmbH
Ship manager	Rhenus Maritime Services GmbH
Classification society	DNV-GL
Main engine, power	MAK 6M322, 1 200 kW
Auxiliary engine, power	Caterpillar 3304, 110 kW
Propulsion	Adjustable pitch propeller
Cargo	In ballast
Crew	6 + 1 persons
Meteorological conditions	Wind SW 5 m/s, temperature + 19 °C, clear

Overview of Incident

Cargo vesselRMS Neudorf left Mälkiä lock in Saimaa Canal, under pilotage, towards Port of Puhos in Lake Saimaa. Having left the lock, the vessel slowly increased speed. Approximately 10 minutes after leaving the lock, when the fairway curved slightly to starboard, the vessel suffered a short power failure. At the time of the incident, the rudder was turned to starboard. The rudder remained in position 15 degrees to starboard, and the vessel continued its turn out of the fairway area.

An attempt was made to prevent the vessel running aground by using the main engine full astern. The vessel did not respond to this quickly enough, so it touched ground off the fairway area with a speed of approximately two knots. The bow thruster could not be used during the power failure.

The vessel's auxiliary engine restarted automatically after the failure, and the vessel's manoeuvring ability was restored quickly. The vessel was able to get away from the shallow by its own efforts, and subsequently to move on to anchor on a nearby bay. After an inspection of the damage, it was found that the vessel had no leaks and the vessel got permission to continue its voyage to the port of destination for further inspections.

The grounding was reported promptly to Saimaa VTS and other authorities.

Description of the power failure and its reasons

The vessel’s main engine was running and the shaft generator was connected to the main switchboard. The auxiliary engine was in standby mode. The vessel's estimated need for electric power at the time of the incident was between 50 and 70 kW when the effect of the shaft generator was 600 kW.

The cause for the power failure was that the shaft generator disconnected from the main switchboard for an unknown reason. Before the power failure, the engine control system gave a "miscellaneous" alarm, which cause or connection to the failure is not known. In retrospect, it was not possible to find an explanation for the disconnecting in the vessel's control systems. The failure had an estimated duration of a few minutes.

A possible cause for the shaft generator's electric switch to open can be a breaker malfunction. Initially it was considered onboard that an overload of the shaft generator would have caused the failure, but the low power consumption at the time of the incident does not support this theory.

Effects onboard of the power failure

When the power feed from the main switchboard was interrupted, all the connected devices, including the steering gear hydraulic pumps, stopped working. The rudder remained in the position it was in when the failure occurred. The standby auxiliary engine started automatically less than a minute after the shaft generator's circuit breaker had opened.

The failure did not affect the operation of the main engine.

The emergency- and backup-systems and their operation

The main navigation equipment of the vessel and the engine automation were secured by a 24V battery supply (UPS) system, and they worked normally during the power failure.

The vessel has an emergency generator, but it did not have time to start before the auxiliary engine in standby mode already started.

Onboard activities during the power failure

The first mate and the pilot were on the bridge at the time of the incident. After detecting that the rudder did not work, they tried to start the bow thruster. That was, however, not possible without the shaft generator. At the same time an attempt was made to re-start the rudder pumps, without success. They tried to stop the vessel by using the engine hard astern.

Also the master came to the bridge, having noticed that the vessel’s motion changed. At this point, the vessel’s rudder started to work again. The vessel was, however, already so close to the shallow, that the grounding no longer could be prevented.

The chief engineer was in the engine room at the time of the incident. After having realised that the shaft generator had disconnected from the main switchboard and that the auxiliary engine had started, he immediately began to restore the system to normal mode.

After the grounding, the vessel reversed back to the fairway area and anchored on the nearby Riutanselkä-bay, where the crew began inspecting tanks for leaks.

Restoring the system to normal mode

After the auxiliary engine had started, the power supply returned to normal. The chief engineer was able to synchronise and connect the shaft generator to the main switchboard without any problems.

Because of the incident, the classification society required the vessel to have a service provider check the connections and alarm systems of the shaft generator. No defects were found in the control.

Entries in the vessel’s Safety Management System (SMS) concerning power failures and their implementation

There were no separate instructions for power failures in the vessel's SMS manual. Steering malfunctions and groundings were dealt with in separate check lists. There were informal instructions in the engine room for restoring the systems to normal operation.

The incident was reported to the shipping company by telephone, but a deviation report was not immediately compiled.

Factors that reduced safety

- The steering gear hydraulic pumps stopped working and the rudder remained in the position where it was when the failure occurred.
- The wear and condition of the electric circuit breakers are not monitored regularly. To manage this risk, electric circuit breakers should be checked or replaced periodically.
- In RMS Neudorf's electric system, only one power supply at a time can be connected to the main switchboard. In case of disturbances, switching power source will always cause an interruption in the electricity supply. In a narrow fairway even a short interruption can be critical.
- The vessel’s bow thruster receives its electricity supply only from the shaft generator. The power produced by the auxiliary engine is not sufficient for using the bow thruster.

External factor that influenced negatively on the occasion

- Saimaa fairways are very narrow and even small deviations from the route easily result in accidents.

2.3.8 M/S Amorella, Power Failure, 18.7.2016

General information

Time and place of incident	18.7.2016 at 09.31 - 09.40, Airisto
Vessel name, call sign and IMO number	Amorella, OIWS, 8601915
Type of vessel	Ro-ro passenger ship
Flag state	Finland
Place of build and time	Brodosplit, Croatia, 1988
Main dimensions	LOA 157.97 m; beam 27.6 m; maximum draft 6.35 m
NT, GT, DWT	19689, 34384, 3690
Owner	Viking Line Ltd
Ship manager	Viking Line Ltd
Classification society	DNV-GL
Main engine, power	4 x Wärtsilä Pielstick 12PC 2-6, 5940 kW, total 23760 kW
Auxiliary engine, power	4 x Wärtsilä 32R8, 2430 kW total 9720kW
Propulsion	2 controllable pitch propellers
Cargo	2088 passengers + cars
Crew	181 + 14 artists or service personnel
Meteorological conditions	Wind ESE 1m/s, temperature 18 °C, clear

Overview of Incident

M/V Amorella departed 17.07.2016 at 08.50 for its scheduled voyage from Turku to Stockholm via Mariehamn. About 40 minutes after departure the generator breaker in auxiliary engine number 3 opened, and, as a result, the vessel suffered a partial power failure. One of the main engines and one auxiliary engine remained running, so the vessel maintained limited manoeuvring capability and was able to continue its voyage along the fairway at slow speed.

The pilot informed about the situation to the VTS and vessels in the vicinity. The backup auxiliary engines started within a few minutes. The engine crew got the main engines that had stopped re-started and the situation returned to normal in about ten minutes.

The incident did not cause any danger onboard or for nearby traffic.

Description of the power failure and its reasons

When the vessel left Turku main engines 2 and 4, and auxiliary engines 1 and 3 were running. Auxiliary engines 2 and 4 were at standstill. About half an hour after departure main engines 1 and 3 were started, after which all four main engines were running. When all main engines were running, the load on the power grid increased.

The opening of the generator breaker in auxiliary engine 3, and the simultaneous short circuit alarm in the power grid, caused the power failure. As a result of the short circuit alarm, the power grid's disconnect switch opened, and the vessel suffered a partial power failure. The auxiliary engine that remained running was overloaded, but continued to run. The opening of the generator breaker in auxiliary engine 3 and the short circuit alarm were most likely caused by a failure of the generator breaker.

Main engine 3 and auxiliary engine 1 remained running, because the power supply for their operating pumps was on the port side of the network to which auxiliary engine 1's generator was connected.

According to the alarm history, main engines 1 and 4 stopped due to low lubricating oil pressure. The lubricating oil pumps connected to the starboard side of the network stopped because they did not have any electric power. The stand-by lubricating oil pumps, connected to the port side of the network, did not start because of an error in the logic of the automation system of the machinery.

Main engine 2 stopped, because the cooling water pumps for the cylinders did not have electric power. The primary as well as the stand-by cooling water pump was wrongly connected to the starboard side of the network, which was de-energized due to the power failure. The primary pump should have been connected to the port side network.

Effects onboard of the power failure

Some of the propulsion machinery operating pumps and three main engines stopped.

Secondary electricity consumers disconnected from the network. The air conditioning, including ventilation units, for example, stopped.

The vessel's manoeuvring ability was limited, because only the controllable pitch propeller and rudder connected to the main engine that remained running were in use.

The incident did not cause any observable harm to the vessel's passengers.

The emergency- and backup-systems and their operation

The vessel's emergency generator failed to start because the power grid remained energised.

Onboard activities during the power failure

At the time of the power failure the master, the line pilot, the watch officer and the chief officer were on the navigating bridge. The power failure was detected when a "panic alarm", signifying a serious engine failure, started flashing. When that alarm had been acknowledged, a lot of other alarms were activated. The engine room also informed the bridge about the partial power failure.

The pilot informed the VTS and vessels in the vicinity about the situation. An AB was sent to the forecastle to prepare for anchoring, in case that would prove necessary. The vessel has a traffic-light symbol describing the state of the power distribution system. Green indicates normal mode; yellow – emergency generator input; and red – battery input. According to the observations of the bridge personnel, the traffic-light remained green throughout the incident. This information was important for the bridge personnel when they made decisions concerning manoeuvring.

The vessel's engine room is always manned. At the time of the incident the engineer on watch and an engineer on day work, were in the engine room. Soon afterwards, the chief engineer and the electrical engineer came there. Together they began to sort out the reasons for the failure, acknowledged the alarms, and began restoring the system to normal mode.

Restoring the system to normal mode

Having detected a disturbance in the electrical network, the auxiliary engine automation started the auxiliaries next in line, i.e. auxiliaries 2 and 4. When they were connected to the network, the engine crew started the pumps and other supportive equipment of the main engines. After that, the main engines were started, one at a time. The disconnect switch of the power grid that was opened by the short circuit alarm was closed when the machinery was considered stable.

After the incident the faulty circuit breaker in auxiliary engine 3's generator was replaced with a new, and its operation was tested. In addition, auxiliary engine number 3 was put last in running order until it could be verified whether the faulty circuit breaker indeed was the reason for the power failure.

A manufacturer's serviceman was sent for to the vessel to check the faulty circuit breaker. The serviceman's report was received on board a few days after the incident, and it was recommended that the circuit breaker would be sent to France for more detailed inspection

The shipping company and the manufacturer have together tried to sort out the error in the logic of the machinery's automation system that caused main engines 1 and 4 to stop. The automation system was not able to identify the situation as a power failure, since one of the auxiliary engines was running and the electric grid remained energised. The device manufacturer is planning to modify the automation system so that it in the future would recognise also a partial power failure.

The shipping company also looked into the incorrect connecting of the cooling water pump. The pump had been incorrectly connected since the building of the vessel, but now it has been corrected.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

The shipping company SMS system included vessel specific instructions for measures to be taken on the navigating bridge and in the engine room in case of a power failure. The bridge crew followed the instructions, something that supported their operation during the incident. The engine room instructions were mainly aimed for situations with total power failures, but also they were followed, to suitable parts.

A deviation report on the incident, consistent with the requirements in the safety management system, was prepared.

Factors that reduced safety

- The back up of critical systems did not work as planned.
- The stand-by lubricating oil pumps connected to the port side of the network did not start because of an error in the logic of the automation system of the machinery.
- The cooling water pumps of main engine 2's cylinders did not have power supply because they were incorrectly connected.
- One of the main engine's cooling water pumps had been incorrectly connected since completion of the vessel.

Factors that increased safety

- One main engine, one auxiliary engine and one rudder remained operational, so the vessel maintained limited manoeuvrability.
- The bridge equipment was operational and it was possible to monitor the position of the vessel continuously during the incident.
- The vessel has a traffic light symbol describing the state of the power distribution system. It assists the bridge crew in assessing the severity of the disturbance in the electricity distribution and in choosing the necessary measures to be taken.
- The instructions for power failures supported the crew's operation in a real situation.

External factor that influenced positively on the occasion

- The incident took place on a straight and a wide part of the fairway, where a vast safe water area surrounded the vessel.

2.3.9 M/S Egon W – Main Engine Failure and Grounding, 13.9.2016

General information

The time and place of incident	09.13.2016 at 08.35, the Saimaa deep route fairway, Härkinsalo
Vessel name, call sign and IMO number	Egon W, V2CE5, 9279018
Type of vessel	Dry cargo carrier
Flag state	Antigua and Barbuda
Place of build and time	Leda Shipyard, Croatia / Peders Yard, Netherlands, 2004
Main dimensions	LOA 82.5 m; beam 12.52 m; draft of 4.85 m
NT, GT, DWT	959, 2409, 3500
Owner	Andre Wieczorek GmbH & Co.KG
Ship manager	Andre Wieczorek GmbH & Co.KG
Classification society	Bureau Veritas
Main engine, power	Caterpillar 3512 DI-TA, 1249 kW
Auxiliary engine, power	Sisu 634DSG, 130kW
Propulsion	Adjustable pitch propeller
Cargo information:	Cellulose
Crew:	6 + pilot
Meteorological conditions	Wind SSW 6.6 m/s, temperature +10 ° C, sky clear

Overview of Incident

M/V Egon W departed, under pilot, fully loaded with cellulose, from Joensuu deep-water harbour towards Germany, in the evening of 12.09.2016.

The next morning, at 08.32, while the vessel was turning to starboard in the fairway south of Savonlinna, the main engine failed. Despite counter helm, the vessel continued to turn and drifted into the shallows east of Härkinsalo at 08.35. At the time of the incident there was no other vessel traffic in the area.

The pilot reported the incident to the VTS, the police and the rescue department. After the grounding the crew conducted a damage survey and inspected the tanks. No leaks were detected. There were no injured persons and no environmental damage was caused.

While the main engine was stopped, the vessel was leaning on rocks. The vessel's main engine could not be started again while aground, because of the risk for damaging the propeller. A salvage tug towed the vessel back to the fairway where the main engine was started. The vessel was then transferred to the other side of the fairway where it anchored. While the vessel was at anchor a diver inspected the hull, after which the vessel sailed to Savonlinna for further inspections.

In Savonlinna a diver representing the classification society found scratches and small dents on the vessel's hull as well as a 2-3 mm tear in the forepeak's welding seam. The vessel got permission from the Finnish Transport Safety Agency to continue its voyage to Germany and to repair the damage to the due date.

Note that this incident concerns a main engine failure, not a power failure. The vessel's auxiliary engine was running throughout the incident and produced electricity for the vessel. This incident was however comparable to a power failure to its effects and it is therefore included in this safety study.

Description of the main engine failure and its reasons

The vessel was turning to the south, NE of Härkinsalo, when the main engine failed. The vessel's speed was about ten knots, which corresponds to approximately 77% power.

The engine control automation gave runaway- and overload-alarms for the main engine. The automation also stopped the main engine after giving the alarms, to protect it from being damaged. The engine automation follows the main engine's rotation sensor information about the main engine's rotation speed. If the rotation speed exceeds the set upper limit, it triggers the automation to perform a controlled stopping of the main engine. The main engine is also shut down, if the automation does not get any information from the rotation sensors.

The reason for the main engine failure is considered to be that the engine automation received incorrect rotation speed information. It was first thought that dirty speed sensors in the main engine were the reason for the incorrect information.

In later, more detailed, inspections, wiring in poor condition was found in the main engine's power control unit. The wiring was most likely the reason for the incorrect rotation speed information.

Effects onboard of the main engine failure

When the vessel's main engine stopped, the propeller did not rotate and thus did not produce a slipstream for the rudder, resulting in loss of manoeuvrability.

The vessel's bow thruster gets its electric power from the shaft generator. The shaft generator is directly, without switches, connected to the main engine. The power produced by the auxiliary engine is not sufficient for using the bow thruster. After the main engine stopped, it was thus not possible to use the bow thruster for manoeuvring support.

The electric power produced by the auxiliary engine, ensured smooth operation for all the vessel's devices, apart from the bow thruster.

The emergency- and backup-systems and their operation

The vessel has only one main engine, so there is no backup system.

The vessel's emergency generator failed to start because the auxiliary engine was running and the power grid remained energized.

Onboard activities during the main engine stop

During the vessel's main engine stop, the master of the vessel and the pilot were on the bridge. The vessel was turning to starboard when the master noticed that the main engine had stopped completely unexpectedly.

The pilot had the con at the time of the incident, and he tried to stop the turn by applying opposite rudder, hard a port. The vessel, however, continued to turn towards the eastern shore of Härkinsalo. At the same time the master tried to start the main engine from the bridge, but without success.

The chief engineer had breakfast in the mess hall when he heard the main engine revolutions rise very quickly for a few seconds, before the main engine stopped. The chief engineer immediately went to the engine room and saw the received alarms on the engine control automation screen. He then began to clarify the situation.

Restoring the system to normal mode

The chief engineer tried to start the main engine three times, but without success. After having been to the bridge to discuss the situation with the master, he returned to the engine room and reset all main engine systems. No attempt was made at this stage to start the engine, since the vessel was in shallow water and there was risk of damaging the propeller and the propeller shaft. The main engine was started when the vessel had been towed back into the fairway.

It was not possible to get a qualified service technician to inspect the main engine to Savonlinna within reasonable time. The chief engineer cleansed the main engine speed sensors himself, as instructed by the classification society, before departure from Savonlinna.

Later, in connection with the hull repair docking in Delfzijl in the Netherlands, a service technician, representing the engine manufacturer, visited the vessel. He discovered that the insulation of a lot of the power control unit wiring had been chafed and was punctured. All damaged wiring was replaced and the system was tested.

Entries in the vessel's Safety Management System (SMS) concerning main engine failure, and their implementation

The company has instructions in the SMS for main engine failures and they were available onboard, as required.

The master reported about both the main engine failure and the grounding to the company, and compiled the required deviation report after the incident.

Factors that reduced safety

- When the vessel's main engine stopped, the propeller did not rotate and thus did not produce a slipstream for the rudder, resulting in loss of manoeuvrability.
- After the main engine stopped, it was not possible to use the bow thruster for manoeuvring support.
- In preventive maintenance work, the wear of the insulation in the power control unit and the soiling of the main engine speed sensors were not detected.
- The vessel's bow thruster gets its electric power only from the shaft generator. The shaft generator is directly, without any switches, connected to the main engine. There is no backup system to ensure power supply.

2.3.10 M/S Prima Ballerina, Power Failure, 20.10.2016

General information

Time and place of incident	20.10.2016 at 0520, Gedser TSS - Danish straits
Vessel name, call sign and IMO number	Prima Ballerina, OJPR, 8609618
Type of vessel	Dry cargo carrier
Flag state	Finland
Place of build and time	J.J. Sietas, Germany, 1986
Main dimensions	LOA 87.88 m; beam 12.8 m; maximum draught 5.20 m
NT, GT, DWT	1240, 2673, 3004
Owner	Prima Shipping Ltd
Ship manager	Prima Shipping Ltd
Classification society	RI, Registro Italiano Navale
Main engine, power	Wärtsilä 6R32 BC, 1975, kW
Auxiliary engine, power	3 x Deutz BF6L513 R, 118 kW
Propulsion	Adjustable pitch propeller
Cargo	In ballast
Crew	8
Meteorological conditions	Wind SE 3 m/s, temperature + 9 C, good visibility

Overview of Incident

M/S Prima Ballerina suffered an about 10 seconds long power failure when her shaft generator disconnected from the electricity grid. She was en route to Rostock, in the Gedser traffic separation scheme in the Danish straits. It was early morning.

The vessel's main engine remained running during the power failure. The vessel's propulsion was working normally and she was manoeuvrable.

There was other vessel traffic in the vicinity at the time of the incident, but it was not endangered by the incident.

Description of the power failure and its reasons

Before the power failure, the vessel's main engine was running. The shaft generator was in use and produced power to the electricity grid. One auxiliary engine was in standby mode.

About half a minute before the failure, the engine control system gave an alarm on low control-air pressure in the main engine.

When the power failure occurred, the main engine control-air pressure dropped below the alarm limit. When the control-air pressure dropped, the shaft generator's RPM speed was reduced and the frequency of the electricity network fell below the specified limit. This development activated the automation to disconnect the shaft generator from the vessel's electricity network. The auxiliary engine in standby mode started, and connected to the network.

The reason for the control-air pressure drop was the breaking of a round rubber membrane (ø2cm) in the alarm sensor of the air pressure system. The compressed air could uncontrollably escape out of the control-air pressure system.

Effects onboard of the power failure

The vessel's navigation equipment went out momentarily, with the exception of the GMDSS equipment. The vessel's only gyrocompass switched to failure mode, which is why it no longer provided information to the autopilot. It was thus necessary to switch to hand rudder. When comparing gyro data with the magnetic compass data, it was found that the direction data the gyro gave, was correct. This was the case, regardless that the gyrocompass was in failure mode. [14]

The vessel's main engine remained running, but control of the engine switched down to the engine control room.

The emergency- and backup-systems and their operation

When the shaft generator disconnected, the auxiliary engine that was in standby mode started in less than 10 seconds. There was no time for the vessel's emergency generator to start.

Onboard activities during the power failure

The chief officer and a watchman were on the navigating bridge at the time of the incident. The master was in his cabin, on off-duty, but woke up because of the incident, and came to the bridge soon after the power supply was restored.

The chief officer switched to hand rudder. On the navigating bridge, when the power supply was restored, the radar was restarted, the vessel's position and the traffic situation were checked, and the control over the propulsion power was returned to the bridge. The watchman was sent to check the situation in the engine room. Realizing that it was not possible to re-activate the autopilot, the master and chief officer took turns hand steering.

The engine room was unmanned. The chief engineer woke up to the engine alarm in his cabin and went to the engine room. He discovered that the control-air pressure had decreased and began troubleshooting the problem. The auxiliary engine in standby mode had already started, and the vessel's power supply had been restored.

Restoring the system to normal mode

When the power supply was restored, all navigation equipment, except for the autopilot and the gyrocompass, operated normally. It took about four hours for the gyro to determine its direction data and for the state of the system to stabilise. After that, direction data was once again available for the autopilot.

[14] (Global Maritime Distress and Safety System), a global distress and safety system

The chief engineer made a membrane for temporary use, and replaced the broken rubber membrane in the alarm sensor with it. After this, the control-air pressure system worked normally, and it was again possible to use the shaft generator.

In the next Finnish port the vessel called at, a service man came on board to check the gyrocompass. He moved the gyrocompass's electric power feed to the distribution board, an electric panel, for critical equipment on the navigating bridge. That distribution board has a battery backup system.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

There were separate instructions, in the shipping company's SMS (Safety Management System, Security Management System), for measures to be taken on the navigating bridge, in case of a power failure. The main engine and propulsion remained operational, and thus the instructions were not fully applicable. After the incident the master and the chief officer checked the instructions as well as other related possible functions and tasks.

There is a list on the navigating bridge over all equipment onboard that will remain operational during power failures.

There were instructions, divided into different phases, in the engine room, for measures to be taken in case of power failure. In this incident, the automation carried out all necessary measures and there was no need to use the instructions.

After the power failure the actions taken during the incident were compared with the shipping company's instructions. The master compiled a deviation report in accordance with the instructions of the shipping company.

The company has issued instructions for measures to be taken on the navigating bridge and in the engine room in case of a power failure. The vessel's crew followed the instructions.

Factors that reduced safety

- The wear and condition of the membrane in the alarm sensor of the main engine's control-air system is not monitored in the preventive maintenance system.
- The vessel does not have two independent compasses, displaying true directions.

Factors that increased safety

- The vessel's main engine was running all the time.
- The vessel was manoeuvrable with hand rudder, in spite of the gyrocompass failure.

2.3.11 M/S Mariella, Power Failure, 5.11.2016

General information

Time and place of incident	5.11.2016 at 17.14, Stadsgårdskajen, Stockholm
Vessel name, call sign and IMO number	Mariella, OITI, 8320573
Type of vessel	Ro-ro passenger ship
Flag state	Finland
Place of build and time	Wärtsilä shipyard Turku, Finland, 1985
Main dimensions	LOA 175.70 m; beam 28.40 m; maximum draught 6.78
NT, GT, DWT	24421, 37860, 3524
Owner	Viking Line Ltd
Ship manager	Viking Line Ltd
Classification society	DNV-GL
Main engine, power	4xWärtsilä Pielstick 12PC2-6V-400, tot. 23 000 kW
Auxiliary engine, power	3x Wärtsilä Vasa 6R32, tot. 5400 kW
Propulsion	2 controllable pitch propellers
Cargo	1823 passenger + cars
Crew	198
Meteorological conditions	Wind N 4 m/s, temperature +1 °C, sky clear

Overview of Incident

The vessel was preparing for departure from Stockholm and had just changed from shorepower to its own power generation. A few minutes after starting the auxiliary engines, one of the auxiliary engines failed and caused a disturbance in the power distribution.

The vessel was berthed at the time of the event, and the main engines had not yet been started. The vessel's power generation was restored to normal in about five minutes. The vessel set off towards Mariehamn as scheduled.

The failure did not cause any danger onboard.

Description of the power failure and its reasons

The vessel has four main engines and three auxiliary engines. As a general rule, the vessel's auxiliary engines produce the electricity. The main engines have shaft generators, which can be used, if necessary, to produce the electricity required for the vessel.

The vessel's auxiliary engines 1 and 2 were running and connected to the power grid. When auxiliary engine 3 was started, it connected to the network and surprisingly shouldered the total load of the power grid. The power grid frequency rose and a reverse power situation followed. The reverse power situation caused auxiliary engines 1 and 2 to disconnect from the network. Auxiliary engine 3's RPM continued to rise until the engine's mechanical overspeed protection stopped the engine. Auxiliary engines 1 and 2 remained running, but did not supply the electricity network with power - thus the power failure onboard.

The power failure was caused by the faulty signal that the regulator in auxiliary engine 3 received from the servomotor's automation system. As a result of this, the regulator increased the engine's fuel supply more than necessary. The cause of the faulty signal was a stuck relay switch in the automation system's DPU - processing unit (Distributed Processing Unit).

The vessel's changing from shorepower to its own electricity generation, was not connected with the power failure.

Effects onboard of the power failure

All the vessel's electrical equipment that was connected to the main switchboard and not secured with a battery supply system (UPS), was without electricity for about 10 seconds.

The incident did not cause any observable harm to the vessel's passengers.

The emergency- and backup-systems and their operation

The vessel's emergency generator started automatically and the other backup systems worked as planned.

Automation-, alarm- and navigation-systems were either secured with batteries (UPS), or received power from the emergency generator.

Onboard activities during the power failure

The navigating bridge was manned for departure at the time of the incident. The master noticed the power failure mainly from flashing lights and alarms on the bridge. More detailed information about the disturbance was acquired by telephone from the engine control room.

The engine crew was in the control room preparing for departure when the disturbance occurred. After the frequency alarm, the automation system disconnected auxiliary engines 1 and 2 from the net, stopped auxiliary engine 3, and started the emergency generator.

Auxiliary engines 1 and 2 remained running, and the crew in the engine control room quickly reconnected them to the network. They acknowledged the alarms and restarted the systems that had stopped.

The vessel informed the shipping company about the incident, which, in turn, informed The Finnish Transport Safety Agency.

Restoring the system to normal mode

The engine crew immediately began investigating the reason for the overspeeding of auxiliary engine 3. The engine was restarted without connecting it to the network. The same fault reoccurred and the cause was suspected to be malfunction of the auxiliary engine regulator.

All three auxiliary engines were not necessary for the safe operation of the vessel, so it was decided that troubleshooting would continue after departure. The defective auxiliary engine was not used during the voyage.

After departure the vessel's crew replaced the regulator on auxiliary engine 3. The auxiliary engine was tested in Helsinki the following day and it was found that the fault was not caused by the regulator. The fault was eventually located to a relay in the processing unit of the automation system. The circuit board in the processing unit was replaced with a spare that had been stored onboard, and the malfunctioning ended. An inspector from The Finnish Transport Safety Agency also visited the vessel, and stated that the vessel can continue normal operation.

As a preventative measure, it was decided that the circuit cards also in the other auxiliary engines' processing units would be replaced with new ones, as soon as possible.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

There were instructions for power failure situations on the navigating bridge. The instructions were, however, mainly intended for situations in which the vessel is at sea. In the engine room, there were brief instructions for actions to be taken by the engine crew in the event of power failures. In addition, the vessel had instructions for situations with automation system malfunctions.

The instructions were limited, however, and there were some shortcomings in the awareness of their existence. The management of the situation leaned on the professional skills and long experience onboard, and neither instructions nor checklists were used.

A deviation report on the incident, consistent with the requirements in the safety management system, was prepared.

Factors that reduced safety

- The circuit cards in the automation system were not monitored in the preventive service system.
- The instructions were limited, however, and there were some shortcomings in the awareness of their existence.

Factor that increased safety

- The crew's professional skills and long experience on the vessel, contributed to the normalisation of the situation and to detecting the cause of the failure.

External factors that influenced positively on the occasion

- The vessel was moored at the time of the incident.

2.3.12 M/S Viggen, Power Failure, 10.01.2017

General information

Time and place of incident	10.01.2017 at 0726, at the arrival to Åva, Åland Islands
Vessel name, call sign and IMO number	Viggen, OJIQ, 9173719
Type of vessel	Ro-ro passenger ferry
Flag state	(Finland) The Åland Islands
Place of build and time	Uudenkaupungin työvene Ltd, Uusikaupunki - Finland, 1998
Main dimensions	LOA 53.50 m; beam 12.25 m; maximum draught 4.0 m
NT, GT, DWT	513, 1512, 300
Owner	The Government of Åland
Ship manager	Nordic Jetline Finland Ltd / Nordic Coast Line
Classification society	Lloyd's Register
Main engine, power	2 x Wärtsilä BL20, 1320 kW, tot. 2640 kW
Auxiliary engine, power	2 x Sisu Valmet 612 DSJGM, 136 kW, tot. 272 kW
Propulsion	Adjustable pitch propeller
Cargo	7 passengers, 1 full trailer, 1 truck, 3 cars
Crew	4
Meteorological conditions	Wind SW 9 m/s, temperature + 3 °C, clears

A short description of the incident

On the 10th of January 2017, M/V Viggen, doing scheduled ferry service, departed at 0700 for the first voyage of the day, from Vuosnainen to Åva. When approaching the port of Åva the vessel suffered a power failure, approximately 100 meters before the wharf. As a result, the vessel's propeller stopped rotating and thus did not produce kinetic energy for the ship. The vessel glided about 50 meters, turning slightly to port, and ended up on a shoal with a speed of about 2-3 knots. The vessel's bow was stuck on the bottom.

The vessel's electricity supply was normalised after maybe 2 minutes, when the other auxiliary engine started.

The crew inspected the vessel for external as well as internal damage. No leaks were detected. The vessel then pulled away from the shoal and moved to the wharf at 0746.

The vessel then transferred from Åva to Vuosnainen. There divers inspected the underwater parts of the vessel. The damage was only surface scratches. The vessel got permission to continue normal operation by a joint decision of the classification society, the Finnish Transport Safety Agency and the shipping company.

Description of the power failure and its reasons

Before the power failure both main engines and auxiliary engine 2 were running. The auxiliary engine produced the vessel's electrical power. Auxiliary engine 1 was in standby mode.

The engine control system alarmed for low seawater pressure and for high cooling water temperature. As a result of the alarms, the automation of the engine control system shut down auxiliary engine 2. This resulted in the power failure.

A faulty cooling water temperature sensor, which relayed incorrect information to the automation of the engine control system, stopped auxiliary engine 2. There are pre-set limits for the engine control automation. The automation gives advance warning for starting the backup auxiliary engine based on the pre-set values.

Effects onboard of the power failure

The vessel's main engines disconnected from the propeller axis. The propeller stopped rotating and did not produce kinetic energy for the vessel. As a result, the vessel lost its manoeuvring ability and glided into the shoal. The rudder, as well as the bow and stern thrusters, was not operational during the failure.

The emergency- and backup-systems and their operation

The engine control automation started the emergency generator about 10 seconds after the power failure. It then produced electricity for all critical equipment. The standby auxiliary engine 1 started and connected to the vessel's electricity grid after about 2 minutes.

Onboard activities during the power failure

The master and a deck hand were on the navigating bridge at the time of the incident. The master was at the conning station on the port side bridge wing, when the vessel approached the wharf. When the power failure began, the master turned the vessel to starboard, but since there was no propeller thrust, the vessel did not respond to steering and instead turned slowly to port, ending up at the shoal.

The master lowered the anchor about one meter using the remote control on the bridge. This was of no use in practice, since the vessel already was on the shoal. The deck hand was just leaving the navigating bridge to go out on deck to prepare for mooring, but returned to the bridge after having noticed the power failure. The vessel did not contact the VTS.

The chief engineer, who was in the engine room, began clarifying the reason for auxiliary engine 2's stopping. After this, he went to the engine control room to acknowledge alarms.

The deck hand that had been preparing for mooring on deck, checked for possible external damage and for possible tank leakages. The heavy vehicles on deck were moved to the stern, to lighten the bow, and thus to facilitate refloating of the vessel and manoeuvring away from the shoal.

When the power supply had returned to normal, the master ordered engine control to the bridge, reversed the vessel away from the shoal, and berthed at the wharf.

Restoring the system to normal mode

The chief engineer acknowledged the alarms and the master reset the manoeuvring system, in accordance with the chief engineer's advice. Auxiliary engine 1, which had been in standby mode, started. After that, the main engines were connected to the propeller shaft.

On the 13th of January 2017, a service man, commissioned by the shipping company, came to inspect the problem that had occurred in the engine control automation. The service man overhauled the defective cooling water temperature sensor that had caused the power failure, and checked the engine control automation.

In connection with the service man's visit, also an overall ageing of the components in the electrical system and a need for maintenance were noticed.

Entries in the vessel's Safety Management System (SMS) concerning power failures and their implementation

There are instructions available on the navigating bridge for measures to be taken in case of power failures and emergency anchoring-situations. The master checked the instructions after the power failure to see whether their actions had been in line with them. In the engine control room, there were no instructions for actions to be taken in case of power failures, but there is a list of the equipment that must be restarted.

The master informed the shipping company's operative manager. This was in accordance with the instructions of the shipping company. After the incident, a deviation report was compiled and distributed to other concerned parties. The vessel got permission to continue operating.

The vessel uses a browser based maintenance and monitoring system, which is administered by the government of Åland. All routine maintenance tasks will be reported to the administration, which then, based on the reports, will decide on necessary maintenance and ordering of spare parts. The vessel does not have maintenance plans concerning components.

Factors that reduced safety

- Ageing and wear of components in the engine control automation had not been monitored sufficiently. Service and overhaul in connection with power failures require specialised expertise. Shipping companies often depend on external operators in these situations.
- The maintenance and monitoring system does not meet the maintenance needs of the vessel. The service plan for components is inadequate.
- The power failure caused the vessel's main engine to disconnect from the propeller shaft. The propeller then stopped rotating and thus did not produce a slipstream for the rudder, resulting in loss of manoeuvrability.
- The vessel did not contact the VTS about the incident.

3 ANALYSIS

The analysis in this investigation was done using the Bow Tie method. The Bow Tie diagram illustrates the risks included in an incident as relations between hazards, top event, threats and consequences. In addition to these four factors the model includes preventive barriers, barriers mitigating consequences as well as escalation factors, which can prevent barriers from working.

The starting point for the Bow Tie method is the top event, which in this investigation was a power failure (continuity of operations and the electricity supply to critical systems). In the analysis causes and background factors for the power failures were established. Also the consequences of the power failures were established. The analysis also listed preventive barriers that influence in the background of the causes and that have an effect on the formation of them. The factors that mitigated the consequences of the incidents were also clarified. These factors prevented the incidents from escalating into more serious accidents. Also the escalating factors that made the situations worse were clarified.

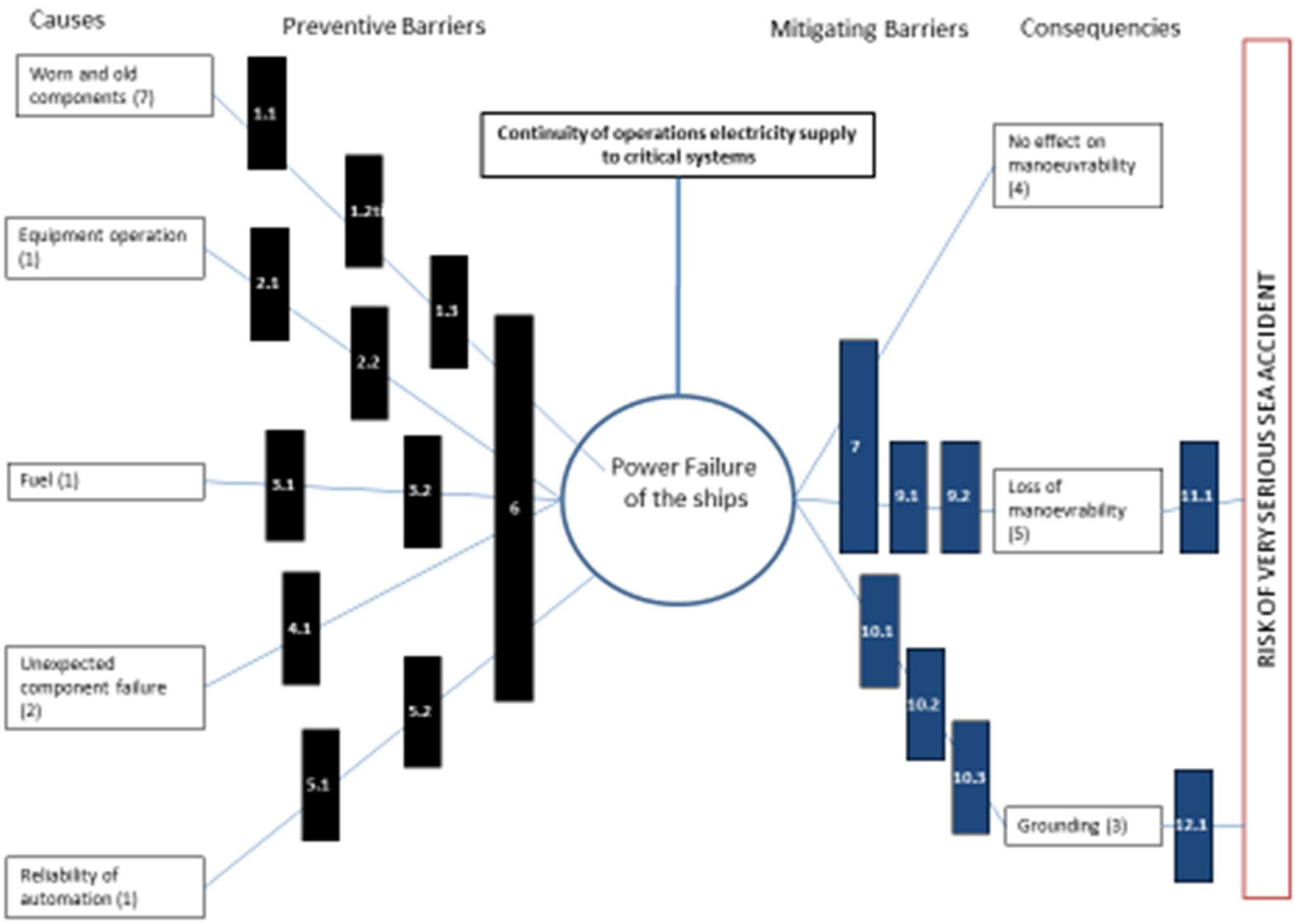

Figure 1: Bow Tie Diagram

3.1 Causes for Power Failures and Related Observations

The causes for the investigated power failures were grouped on the left-hand side in the Bow Tie diagram.

The cause for most of the investigated power failures (7) was a worn or old component, e.g. a sensor or an electronic card. In one of the investigated cases the cause was probably a user error. One power failure was caused by water in the fuel. An unexpected failure of a component (in these cases, a controller or a relay) caused two power failures. One case was caused by unreliable machine automation. For each cause of a power failure the analysis sought to identify the preventive barriers and background factors that would have prevented the emergence of a power failure, had they operated properly.

3.1.1 Worn and Old Components

Maintenance System (1.1)

Deficiencies in the maintenance system were found to be in the background of many cases caused by worn or old components. It was found that wear of components is not always noticed during inspections. This is because components are not always inspected due to the structure of the systems. Electrical systems require special expertise, something which is not always sufficiently available.

Duplication of Critical Systems (1.2)

International and national maritime legislation emphasise the importance of safe operation of vessels. This includes, *inter alia,* duplication of critical systems.

The duplication, or ensuring, related to fuel- and emergency power systems, was not adequately taken into account in two cases. According to chapter 10.3 of the ISM Code, a shipping company shall - in the safety management system - identify the technical systems and equipment of which a sudden failure may lead to an incident.

Deviations and Responding to them (1.3.)

The crew did not always know how to detect deviations and how to respond to them. The ISM Code requires that shipping companies have a deviation reporting system included in the safety management system. Chapter 10 of the ISM Code deals with service and maintenance of the vessel. Based on this, each deviation must be reported, corrective actions must be performed and documented. A prompt and competent response to deviations is an essential part of securing the functionality of critical systems.

3.1.2 Equipment Operation

Knowledge of Systems (2.1)

In crew changes ship-specific knowledge and experience in the use of systems do not always transfer from one crew to the next. In one of the investigated cases, inadequate familiarisation resulted in the emergence of a power failure. Shortcomings in ship-specific documentation also posed problems. According to section 6.2 of the ISM Code, a shipping company must ensure that the ship is manned by personnel who can manage the ship's maintenance tasks. According to chapter 6.3 of the code, the shipping company must have methods for familiarising new staff with their duties. Knowledge of systems is a very important part of the crew's know-how. It is also important to consider how to ensure the transfer of tacit knowledge in crew changes.

User Interface Clarity and Instructions (2.2)

Control and operating systems for automation systems, machinery and equipment were often complicated and their manuals were incomplete or completely missing. According to section 6.5 of the ISM Code, a shipping company must establish procedures to maintain the proficiency level of the ship's crew. According to section 6.6 of the ISM Code, the shipping company must ensure that the ship's crew receives the necessary information on the ship's safety systems in the ship's working language.

3.1.3 Fuel

Full Duplication of the Fuel System (3.1)

In one of the investigated cases the fuel system was not fully duplicated. The fuel system should be duplicated in such a way that the system consists of two independent entities.

Fuel Quality Monitoring and Maintenance of the System (3.2)

In the above mentioned case there were also shortcomings in the monitoring of the quality of the fuel. As a result of this, the water that had gotten into the fuel system eventually caused a power failure. The quality of the fuel is not monitored enough onboard. Regular maintenance of the fuel system reduces the fuel related risk, which, if realised, can result in similar situations as power failures.

3.1.4 Unexpected Component Failure

Choosing Components During Construction or when Renewing Systems (4.1)

The quality of the components and their suitability for use at sea is of decisive importance. This should be taken into account during the construction phase of the ship as well as when renewing systems onboard. In one case an almost new electrical component malfunctioned unexpectedly.

3.1.5 Reliability of Automation

Design (5.1)

There were deficiencies in the design and documentation of the automation systems. When assessing the reliability of the automation, it is important that the documentation of it is up to date, clear and understandable. It is important to emphasise the ease of maintenance of the system already at the design stage.

Testing and Maintenance of the Automation System (5.2)

The different functions of the automation system had not always been tested in accordance with regulations. Tests are done to detect deficiencies. It is of outmost importance to carefully test automation systems and all their functions, already when taking them into use. According to chapter 10.3 in the ISM Code, also systems that are not in continuous use must be tested in accordance with system-instructions and on a regular basis. Automation systems’ fast ageing is a problem. System upgrades, support and spare parts may not be available for the whole lifetime of a system.

Functioning of Backup- and Emergency Systems (6)

Deficiencies in the backup- and emergency systems were found in all investigated cases. Failure situations, like serious power failures, are not always tested due to the risk of damaging the systems. According to chapter 10.3 of the ISM Code, a shipping company must design measures to ensure the reliability of systems whose failure may cause hazardous situations. According to the ISM Code, the measures must include testing of backup- and emergency systems as well as of systems in non-continuous use. The testing must be done in accordance with the instructions for the test.

3.2 Consequences of Power Failures and Managing them

The consequences of the investigated power failures were grouped on the right-hand side in the Bow Tie diagram. None of the investigated cases did result in a very serious sea accident or in serious environmental damage.

In four cases the power failure had neither any effect on the vessel's manoeuvrability nor other significant or long-lasting effects on the operation of the vessel.

In four cases the power failure, or main engine stoppage with similar effects, caused a total loss of manoeuvrability and, in one case, a partial loss.

In three cases the vessel grounded either because of a power failure or of a main engine stoppage. After inspections the vessels got permission to continue their voyages and instructions for the repairs.

3.2.1 No Substantial or Long-term Effects

No Risk of Collision or Grounding due to Conditions (7)

In four cases the operations of the vessels were not significantly compromised since they were anchored, berthed or in safe waters at the time of the power failure. In addition, the weather conditions and the traffic situation were favourable at the time of the incident.

Quick Startup of Backup- and Emergency Systems (8.1)

In the above-mentioned cases the quick startup and functionality of backup- and emergency systems, as well as the crew's correct actions, prevented more serious consequences.

3.2.2 Loss of Manoeuvrability

Safe Procedures (9.1)

In four cases the power failure, or the to the effects equivalent main engine stoppage, caused a total loss of manoeuvrability and the vessel began to drift. In one case manoeuvrability was partially lost, but the vessel remained in the fairway. The loss of manoeuvrability lasted, depending on the case, from a few minutes to more than an hour. Safe procedures for the onboard operations and favourable conditions prevented the incidents from developing into more serious accidents.

Good Local Knowledge and Situational Awareness (9.2)

The watch keeping crew's know-how as well as good situational awareness and overview of the situation reduced the risk of an accident. In two cases involving loss of manoeuvrability the local knowledge of the pilot and - in one case - the line pilot, contributed to the positive outcome of the incident.

3.2.3 Loss of Manoeuvrability and Grounding

Narrow Part of Fairway, Shoals and Rocks Nearby (10.1 and 10.2)

In three of the groundings, the power failure or main engine stoppage occurred in a narrow part of the fairway. The limited area with sufficient depth for safe navigation and the short response time due to the speed of the vessel were not sufficient to prevent a grounding. In two cases, the loss of manoeuvring capacity took place when the vessel was turning in a narrow fairway. One case occurred when the vessel was approaching port.

Inadequate Power in Backup- and Emergency Systems (10.3)

In one case an error message from the machine automation stopped the main engine and, at the same time, the shaft generator. The vessel lost its manoeuvring capability because the effect of the auxiliary engine was not enough to run the bow thruster, which required the effect of the shaft generator.

In another case it took about two minutes to start the backup system. During that time the ship drifted into a shoal after having lost its ability to manoeuvre.

In a third case the backup system that had started was not enough to prevent a grounding in a turn, in a narrow part of the fairway. An attempt was made to stop the movement of the vessel by operating the main engine full astern.

3.2.4 Avoiding Very Serious Sea Accidents

Favourable Traffic Situation (11.1 and 12.1)

In eight cases the conditions, a favourable traffic situation or low speed, prevented a more serious accident. None of the cases involved dangerous cargo and the risk of the environmental damage associated with them. The conditions and the cargo are relevant when assessing the risk caused by power failures. A power failure is a serious deviation.

3.3 Analysis of Rescue Operations

External help for rescuing the ship was needed in only one case. After the grounding, the pilot reported the incident to the VTS, the police and the rescue department.

When the main engine was stopped, the ship was leaning on the rocks. The ship's main engine could not be started again while aground, because of the risk for damaging the propeller. A salvage tug towed the ship back to the fairway where the main engine was started. The ship was then transferred to the other side of the fairway where it anchored. While the ship was at anchor a diver inspected the hull, after which the ship sailed to Savonlinna for additional inspections.

A rescue vessel arrived quickly to the scene and the flow of information among the involved parties concerning the incident was smooth. The pilot onboard the casualty communicated with all parties, which facilitated the rescue operations.

3.4 The Activities of the Authorities

The VTS centre was contacted in almost all investigated cases. The VTS centre monitored the situation and assessed the need for additional help together with the vessel. The centre also assessed the risks for other traffic and to the environment. VTS-centres do not always receive adequate information about type, cause and consequences of vessels' technical problems.

In Finnpilot Pilotage Ltd's deviation report form there is no separate section for power failures. They are reported simply as technical defects. On the basis of reports received from Finnpilot it is therefore difficult to identify the type of the technical failure and to assess whether or not it included a partial or complete power failure or a main engine stoppage.

It is difficult to get accurate data on power failures. Different parties record power failures in different ways. There is no common practice of reporting power failures. The definitions of power failures should also be harmonised.

This investigation involved two cases in which the inspector of the Finnish Transport Safety Authority inspected the vessel after its grounding and gave it permission to continue to operate. After the grounding, the inspector, together with representatives for the classification society and the shipping company, assessed the vessel's seaworthiness and decided to allow continuing its operating.

4 CONCLUSIONS

Based on the investigation, it can be generally stated that obtaining accurate information on power failures is difficult. Different parties record power failures in different ways. There is no common practice of reporting power failures and there is no definition for power failures.

When looking at the findings in the analysis, it can be concluded that good quality of components, reliability of systems, sufficient skills of the crew and favourable conditions are factors central for preventing power failures. The quality of the components, the reliability of the systems and the competence of the crew can be influenced and the impact of the conditions can be anticipated.

4.1 Component Quality

It was found that wear of components is not always noticed in inspections. This happens because the component level is not always inspected due to the structure of the systems. In addition, maintenance of electrical systems requires special expertise and that is not always sufficiently available onboard. According to chapter 10.3 of the ISM Code, a shipping company shall - in the safety management system - identify the technical systems and equipment of which a sudden failure may lead to an incident.

Users must identify the critical components of the electrical systems and plan for ensuring their functionality.

The lifespan, replacing intervals and maintenance needs of electrical components are usually not planned with sufficient precision and long-term perspective. The electronic cards are replaced only when they stop working or when the reliability of the data they provide has diminished. Professional monitoring and functionality testing of sensors are important parts of the maintenance system. When replacing components in systems their compatibility and functionality must be assured.

Unexpected failures can be avoided by selecting high quality and marine compliant components both during the ship's construction phase and when components are renewed. In addition, good and up-to-date documentation of used and stored components is needed.

4.2 Sufficient Know-How

Deficiencies in ship-specific documentation, lack of knowledge and experience as a result of crew changes caused problems in the operation and maintenance of systems. Knowledge about systems is a very important part of the crew's know-how. The shipping company must ensure that the ship is manned with a crew with the skills required to carry out the technical service and maintenance tasks of the ship.

The operating systems of different equipment are often too complicated in relation both to how often they are needed and to the crew's skills.

A new crew arriving at a vessel does not always have time to carefully familiarise themselves with their duties. In order to guarantee safe operation of the vessel when carrying out crew changes, *shipping companies must take into account the skills required for the position as well as the qualifications and work experience from similar positions of the person selected for the job.*

For the purposes of familiarisation, it is important for the vessels to have clear operating instructions for all systems, at least in the working language of the ship. The vessel must have safe procedures that have been implemented in the safety management system, that are based on risk assessment and that have been trained and drilled. When this is realised, everyone is aware of, and knows, their role in situations involving disturbances and emergencies.

The shipping company and the crew must be familiar with the deviation reporting procedures. They must be able to compile reports and they must also report on noted deviations. The shipping company's management and the ship's crew must demonstrate their commitment to the reporting system required in the ISM Code, by ensuring both that they can manage it and that it works.

4.3 Reliability of Systems

There were deficiencies in the design and documentation of the automation systems. The different functions of the automation system had not always been tested in accordance with regulations. Tests are done to detect deficiencies. The fast ageing of automation systems is a problem. System upgrades, support and spare parts may not be available for the whole lifetime of a system.

Duplicating critical systems and sufficient, functioning backup- and emergency systems are central when trying to either prevent power failures in the systems, or to mitigate the consequences of them.

Systems must be tested when in use and when doing maintenance work on them. The vessel must have suitable equipment for testing and the necessary backup files for the automation system onboard. In addition, maintenance work on systems must, from the point of view of the user, be as easy as possible. Complex fault situations, such as complete power failures, are usually not tested because of the risk of damaging systems.

Testing backup systems as well as disturbances and fault situations before arriving to the narrow fairways in the archipelago or in inland waterways, or to the pilot boarding place, would improve safety.

Availability and quality control of fuel needed for producing electricity is important. Water that had entered the fuel system caused a power failure since the quality of the fuel had not been sufficiently monitored onboard.

The production of electrical energy requires a robust and reliable technical solution.

Regular maintenance of vessels' fuel systems reduces the fuel related risk, which, if realised, can result in similar situations as power failures.

4.4 Conditions

The conditions and the cargos are of importance in terms of the risks in connection with power failures. A power failure is a serious deviation. Monitoring changes in the operating conditions must be active and proactive, so that there is ample time to react to them.

Loss of manoeuvrability in narrow fairways in the archipelago and in inland waterways, or at open sea in dense traffic areas, can result in serious sea or environmental accidents. The risk of an accident is greater in situations where the back-up and emergency systems are not available for immediate startup, do not work, or are of inadequate power.

Pilot's and ship crew's common view and situational awareness on the operation of the ship's systems are important. This is highlighted in the narrow waters of the archipelago, where the briefest of power failures can lead to a serious sea accident or environmental accident.

5 SAFETY RECOMMENDATIONS

5.1 Procedures for Reporting Power Failures

According to the ISM Code, shipping companies must, in the safety management system, identify the vessel's critical systems and equipment that, in case of a sudden failure or incorrect use, can result in a hazardous situation or accident. A power failure is a serious deviation. There is no aggregated or comparable information available on deviations in connection with power failures. The Safety Investigation Authority recommends, that

> *The Finnish Transport Safety Agency together with the shipping companies, develop procedures to obtain detailed information about power failures for analysing purposes. [2017-S60]*

The reform of the Finnish Maritime Code, if implemented, creates the conditions for the implementation of this recommendation. Reporting of incidents is required in the draft of the new code.

It is important that the new procedures for reporting to be developed, allow for concrete measures to be taken in order to address the identified problem. It is also important that the definitions needed in the reporting are clear and understood in the same way by various parties.

This recommendation, if implemented, would also contribute to pinpointing risks connected with the emerging transport system and to preparing for them.

5.2 Assessing the Need for Developing the Legislation Concerning Safe Conduct of Vessels

The conditions and the vessel's cargo are of importance for the graveness and extent of the consequences of a power failure. This is emphasised in the narrow fairways in the archipelago and in inland waterways, where safety margins for navigation often are very small. A sea accident in these circumstances can also cause a serious environmental accident. The reliability and sufficiency of the backup- and emergency systems are, for this reason, of utmost importance. The Safety Investigation Authority recommends, that

> *The Finnish Transport Safety Agency together with the Finnish Environment Institute, assess the adequacy of and the need for the development of the legislation concerning the safe conduct of vessels in the archipelago and in inland waterway areas. [2017-S61]*

Procedures e.g. relying solely on the use of a shaft generator in narrow fairways in the archipelago and in inland waterways increase the risk for accidents.

Helsinki, 4 December 2017

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SUMMARY OF STATEMENTS RECEIVED ON THE DRAFT INVESTIGATION REPORT

The draft incident reports were sent for statements in July 2017. Statements were received from four shipping companies.

Based on Viking Line Ltd's statement, the number of main engines on M/S Mariella was corrected in the report.

ESL Shipping Ltd stated that the paragraph "Negative safety aspects" did not fully correspond with their view, as the voltage problem of auxiliary No. 3 had been under scrutiny already for a longer period of time.

The two remaining shipping companies stated that the incident reports were clear and in line with the events.

The draft investigation report was sent for statements in October 2017. Statements were received from the Finnish Transport Safety Agency and the Finnish Environment Institute. The statements supported the investigation and were positive to the recommendations.

According to the statement of the Finnish Environment Institute, the investigation report pointed out - in a praiseworthy way - that in addition to the investigated incidents there had been other incidents that had not been investigated or on which no data had been obtained. Based on this, the Finnish Environment Institute wished, that the maritime reporting system would be developed so that as many disturbances and deviations as possible would come to light. The Finnish Environment Institute also stated that they support the recommendation that the need to revise the regulations concerning safe conduct of vessels in the archipelago and in inland waterways must be evaluated.

The Finnish Transport Safety Agency said in their statement that the recommendation in the investigation to develop procedures together with the shipping companies for obtaining information concerning power failures already has been realised. As part of the new reporting scheme shipping companies are obliged to report accidents as well as incidents to the Finnish Transport Safety Agency. The Finnish Transport Safety Agency also stated that they will be in contact with the Finnish Environment Institute concerning the second recommendation in the report.