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Swiss Transportation Safety investigation Board STSB

Aviation Division

Final Report No. 2232 by the Swiss Transportation Safety Investigation Board (STSB)

concerning the serious incident involving the commercial aircraft A319-112, registration HB-IPX

on 11 December 2012

on scheduled flight LX 1250 from Zurich (LSZH) to Stockholm (ESSA)

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Ursachen

Der schwere Vorfall ist auf wiederholte Spannungseinbrüche und Störungen in der Stromzufuhr verschiedener Verteilschienen zurückzuführen.

Die genaue Ursache konnte nicht eruiert werden.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Article 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident/incident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

Unless otherwise indicated, all information in this report refers to the time of the serious incident.

Unless otherwise indicated, all times in this report are stated in coordinated universal time (UTC). At the time of the serious incident, Central European Time (CET) applied as local time (LT) in Switzerland. The relationship between LT, CET and UTC is: LT = CET = UTC + 1 h.

Events which relate to a point in time are indicated to the second and events which extend over a period of time are indicated to the minute.

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Final report

Synopsis

Owner	Clariden aircraft leasing Inc. 8058 Zurich, Switzerland
Operator	Swiss International Air Lines Ltd. Postfach, 4002 Basel, Switzerland
Manufacturer	Airbus Industrie, Toulouse, France
Aircraft type	A319-112
Country of registration	Switzerland
Registration	HB-IPX
Location	Scheduled flight LX 1250, from Zurich (LSZH) to Stockholm (ESSA), at flight level 390, in the vicinity of Hamburg
Date and time	11 December 2012, 13:11:56 UTC

Investigation

The serious incident occurred on 11 December 2012 at 13:11:56 UTC. The notification arrived on 13 December 2012 at the Swiss Accident Investigation Board (SAIB). In a letter dated 21 December 2012, the Swedish investigation authority (SHK) delegated the investigation of the serious incident to the SAIB-AD. The investigation was opened on 4 January 2013 by the SAIB-AD. The SAIB-AD informed France and the Kingdom of Sweden about the serious incident on the appropriate communication channels. The two countries each designated an authorized representative who assisted with the investigation.

This final report is published by the SAIB.

Summary

On 11 December 2012 at 12:31 UTC, an A319-112 aircraft, registration HB-IPX, took off from runway 28 in Zurich (LSZH) on a scheduled flight to Stockholm (ESSA) under the radio call sign *swiss two five zero kilo* and flight number LX 1250. At 13:11:56 UTC the “DC BUS 1 FAULT” alert together with multiple intermittent system warnings appeared on the electronic centralized aircraft monitor (ECAM). At 13:34:18 UTC the transformer rectifier (TR) 1 automatically shut down. Between 13:34:20 UTC and 13:55:42 UTC the DC BUS 1 and DC BAT BUS experienced several short voltage lowering events, even though they were now being powered by TR 2. During this period, further ECAM messages were displayed.

After an analysis of the situation, the crew decided to continue the flight to Stockholm.

At 13:57:41 UTC, while descending to flight level 350, circuit breaker AB11 tripped automatically. This resulted in the permanent loss of various systems. At 14:20 UTC the power supply to the SUB BUS 131XP was interrupted once and between 14:22 UTC and 14:25 UTC the power supply to the AC ESS BUS was interrupted briefly several times; among other things this resulted in the temporary blanking of the commander's primary flight display (PFD) and the navigation display (ND), as well as the upper ECAM display unit (DU). The crew then transmitted an urgency message (*Pan Pan, Pan Pan, Pan Pan*).

Flight LX 1250 then received landing priority from air traffic control and was vectored with heading and altitude instructions for an approach on the instrument landing system for runway 01L.

After the landing at 14:40 UTC the left engine's thrust reverser did not function.

The passengers were able to vacate the aircraft normally.

Causes

The serious incident is attributable to repeated voltage lowering events and faults in the power supply to various busses.

The exact cause could not be determined.

Safety recommendations

In the context of the investigation, no safety recommendation was issued.

1 Factual information

1.1 Pre-history and history of the flight

1.1.1 General

The recordings of the radio communications, the flight data recorder (FDR) and the direct access recording (DAR), as well as the statements of the crew members, were used for the following description of the pre-history and history of the flight. The relevant maintenance documentation was also available.

During the flight and for the approach and landing the co-pilot was pilot flying (PF) and the commander was pilot not flying (PNF).

This was a scheduled flight under instrument flight rules (IFR).

This report contains many technical terms and abbreviations relating to the aircraft's electrical system. Annex 9 contains a glossary with the full text and explanations.

1.1.2 Pre-history

According to the technical documentation there were no restrictions in relation to the electrical system of HB-IPX.

1.1.3 History of the flight

At 12:31 UTC on 11 December 2012, the A319-112 aircraft, registration HB-IPX, took off from runway 28 in Zurich (LSZH) on a scheduled flight to Stockholm (ESSA) under radio call sign *swiss two five zero kilo* and flight number LX 1250. The take-off was uneventful. During the climb to flight level (FL) 200, DC BUS 1 of the DC network experienced a voltage lowering event for a short time[1]; this meant that from this point onwards the DC ESS BUS was supplied with direct current by the essential transformer rectifier (ESS TR) and no longer by the TR 1 (cf. chapter 1.6.2.2). This change in the configuration of the power supply took place at 12:39:20 UTC and was indicated on the lower display unit (DU) of the electronic centralized aircraft monitor (ECAM) (cf. chapter 1.6.2.3). It was not mentioned by the crew in the air safety report (ASR).

According to the statement of the crew, the message “DC BUS 1 FAULT” appeared on the ECAM approximately one hour after take-off. In addition, the following cautions were displayed: “BRAKE SYST 1 FAULT”, “BLOWER FAULT” and “EXTRACT FAN FAULT”. These indications were intermittent. The aircraft was at that time in the Hamburg area at FL 390. The recordings show that the “DC BUS 1 FAULT” alert was generated at 13:11:56 UTC for the first time and that between 13:13 UTC and 13:30 UTC the DC BAT BUS was supplied several times by the TR 2 and again by the TR 1. At 13:34:18 UTC the TR 1 automatically shut down[2] and the DC BUS 1 as well as the DC BAT BUS were supplied by the TR2 for the rest of the flight. This configuration change was also indicated on the lower ECAM display unit and was perceived by the crew.

As a precautionary measure the commander now discussed the situation with the co-pilot and the head of the cabin crew (*maître de cabine* - MC), in order to prepare them for a possible emergency descent if smoke were to occur. The smoke removal procedure was also discussed. In the event of a further deterioration of the

[1] Greater than 100 milliseconds (> 100 ms).

[2] This event (TR 1 FAULT) was transmitted via the aircraft communications addressing and reporting system (ACARS) to the maintenance provider on the ground. The "FAULT" status of a transformer rectifier (TR) can only be reset on the ground by the maintenance personnel.

situation, a premature landing in Copenhagen was considered. Further landing options in case of an emergency were considered as well.

The commander then contacted the maintenance centre in Zurich via satellite phone and informed them of the situation. After a lengthy discussion, the crew were advised to pull circuit breaker (CB) AB10, to interrupt the power supply to TR 1.

Between 13:34:20 UTC and 13:55:42 UTC the DC BUS 1 and the DC BAT BUS experienced several short-duration voltage lowering events, even though both were now being powered by TR 2. During this period, further ECAM messages were displayed, including the messages “APU FIRE DET FAULT”, “APU FIRE LOOP A FAULT” and on the overhead panel the “CARGO DISCH” lights illuminated. According to the crew, the side stick solenoid on the co-pilot’s side was several times audibly activated[3]. The side stick itself, however, remained inactive. The voltage at the above-mentioned distribution busses normalised at 13:56 UTC and remained constant for the remainder of the flight of less than an hour.[4]

After an analysis of the situation, taking into account systems availability and the weather situation, the crew decided to continue the flight to Stockholm (ESSA). During this time, according to the flight crew, the MC was either in the cockpit or in its immediate vicinity. The jump seat was in the stowed position.

At 13:57:41 UTC, during the descent to FL 350, circuit breaker AB11 tripped automatically without any associated warning; this was heard by the MC, who stayed behind the commander's seat.[5] As a result, the SUB BUS 103 XP was de-energized. This resulted in the loss of various systems (cf. Annex 1). Among other things, the temperature regulation system for the cockpit failed and the cockpit temperature fell below freezing point. According to the crew, the temperature was in the range from -4 to -6 °C, when +30 °C was selected. The integral lighting of various control panels also failed.

During the descent, the crew switched on the engines' anti-ice system. Thereby, on the anti-ice panel only the ENG 2 “ON” light illuminated.

At 14:21:54 UTC the crew of flight LX 1250 made contact with Stockholm approach control and immediately received clearance to descend to FL 90. A short time later, at 14:22:14 UTC, the Stockholm approach control air traffic control officer (ATCO) reported to the crew of HB-IPX: *“Swiss two five zero kilo, we gonna sweep the runway shortly, you will be number two in sequence after that, expect to be on ground time four three.”*

At 14:20 UTC the power supply to SUB BUS 131XP was briefly interrupted once. Between 14:22 UTC and 14:25 UTC power to the AC ESS BUS was briefly interrupted several times. This resulted in the temporary loss of various systems. Among other things, during this time the commander's primary flight display (PFD) and navigation display (ND), as well as the upper ECAM display unit blanked.

At 14:24:05 UTC, the crew of flight LX 1250 transmitted the following urgency message: *“aaah… declaring Pan Pan, Pan Pan, Pan Pan due to electrical problem, request straight-in approach to ILS[6] zero one left”*. The ATCO immediately asked: *“aaah... you mean you want a straight-in approach right now?”* to which the crew

[3] The solenoid ensures that when the autopilot (AP) is engaged the side stick can be operated only by applying a defined force (pitch 5 daN, roll 3.5 daN), which simultaneously disengages the AP.

[4] Annex 4 shows the configuration of the electrical power supply on the ECAM ELEC page after 13:56 UTC.

[5] Circuit breaker AB11 is located in the immediate vicinity of the jump seat; physical contact with the circuit breaker is not possible if the jump seat is in the stowed position.

[6] Instrument landing system (ILS).

confirmed as follows: *“charlie charlie, we like…. vectoring direct zero one left, swiss two five zero kilo”*.

The ATCO then enquired whether the crew wanted to declare an emergency situation: *“eeh... do you declare emergency?”*, whereupon the crew repeated at 14:24:24 UTC: “*declaring Pan Pan, Pan Pan, Pan Pan, swiss two five zero kilo*”. Then flight LX 1250 was guided by heading and altitude instructions onto an ILS approach for runway 01 L. In the process, the ATCO informed the crew that they could select a speed at their own discretion.

At 14:25:47 UTC the crew reported to the ATCO that because of problems with the electrical system some instruments were failing intermittently. At 14:27:05 UTC the ATCO asked about the number of people on board, to which the crew replied “*one zero niner*”. At 14:30:46 UTC the ATCO informed the crew that they were number one and that before their landing the braking action would be measured again. At 14:33:29 UTC the crew asked if they were cleared for approach: *“swiss two five zero kilo, confirm cleared for approach runway zero one left”* to which the ATCO immediately replied: *“that is correct, you are cleared approach, number one”* The crew then confirmed: *“cleared for approach zero one left, swiss two five zero kilo”*. At 14:35:29 UTC the ATCO informed the crew about the braking action measurement: *“swiss two five zero kilo, braking action is point two eight, two eight, two four”,* which the crew acknowledged.

At 14:35:36 UTC flight LX 1250 received clearance to land: “*swiss two five zero kilo, you are cleared to land runway zero one left”,* and this was acknowledged by the crew. A few seconds later, at 14:35:60 UTC, the ATCO gave the following information to the crew: *“swiss two five zero kilo, wind is three six zero one six knots, you have thirty percent high intensity lights on*”. The crew acknowledged this: *“that is copied, cleared to land zero one left, swiss two five zero kilo”*.

At 14:36:58 UTC the ATCO instructed the crew of HB-IPX to independently change to the ground control frequency after landing; this was immediately confirmed by the crew. At 14:39:57 UTC the ATCO repeated the landing clearance: *“swiss two five zero kilo, wind three six zero, one five knots, you are cleared to land zero one left”* which the crew immediately confirmed.

After landing at 14:40 UTC, the left engine's thrust reverser did not function. According to their statement, the crew was surprised by this fact and stated that they had always assumed that the information about the non-available systems (INOP SYST) on the ECAM status page was reliable.

The passengers were able to vacate the aircraft normally.

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	5	104	109	N/A
Total	5	104	109	0

1.2.2 Nationality of the aircraft's occupants

The crew consisted of two cockpit crew and three flight attendants of French, Swiss and Swedish nationality.

Since passengers are not obliged to state their nationality when booking the flight, the airline was not able to provide any information in this regard.

1.3 Damage to aircraft

The aircraft was not damaged.

1.4 Other damage

There was no other damage.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Commander

1.5.1.1.1 General

Person	Swiss citizen, born 1967
Licence	Airline transport pilot licence aeroplane – ATPL(A)) according to the European Aviation Safety Agency (EASA)

All the available information indicates that the commander was rested and healthy when he came on duty. There are no indications that fatigue played a part at the time of the serious incident.

1.5.1.1.2 Flying experience

Total	12,186 hours
On the type involved in the incident	1009 hours
During the last 90 days	181 hours
Of which on the type involved in the incident	181 hours

1.5.1.2 Co-pilot

1.5.1.2.1 General

Person	Swiss citizen, born 1986
Licence	Commercial pilot licence aeroplane - CPL(A) according to the EASA

All the available information indicates that the co-pilot was rested and healthy when he came on duty. There are no indications that fatigue played a part at the time of the serious incident.

1.5.1.2.2 Flying experience

Total	917 hours
On the type involved in the incident	693 hours
During the last 90 days	196 hours
Of which on the type involved in the incident	192 hours

1.6 Aircraft information

1.6.1 General

Registration	HB-IPX
Aircraft type	A319-112
Characteristics	Twin-engine short- and medium-haul commercial aircraft
Manufacturer	Airbus Industrie, Toulouse, France
Year of manufacture	1996
Serial number	0612
Owner	Clariden Aircraft leasing Inc. 8058 Zurich, Switzerland
Operator	Swiss International Air Lines Ltd. Postfach, 4002 Basel, Switzerland
Engines (ENG)	TW1: CFM56-5B6/2P, S/N C779186 TW2: CFM56-5B6/2P, S/N C779980
Hours of operation	40,978 hours (airframe)
Number of cycles	34,779 (take-off - landing)
Maximum permissible masses	Maximum permissible take-off mass 68,000 kg Maximum landing mass 62,500 kg
Mass and centre of gravity	Both mass and centre of gravity were within the permissible limits according to the aircraft flight manual (AFM).
Maintenance	The last scheduled maintenance work (A-check) took place on 27 October 2012.
Technical restrictions	None
Category	IFR category I, II, IIIa, IIIb, B-RNAV (RNP 5), P-RNAV, GPS APCH, NAT-MNPS, VFR by day, VFR by night

1.6.2 Selected aircraft systems and equipment

1.6.2.1 General

The following sections refer to and describe only those systems and indications which had an impact on the serious incident.

Chapter 1.6.2.2 contains many technical terms and abbreviations relating to aircraft electrical systems. Annex 9 contains a glossary with the full text and explanations.

1.6.2.2 Electrical power supply system

Four electrical power sources are available: GEN 1, driven by engine 1, GEN 2, driven by engine 2, the generator of the auxiliary power unit (APU) and the external power source (cf. Figure 1). These four sources of power supply three-phase alternating current (115/200 V, 400 Hz). For the extremely rare case that all three generators fail in flight, an emergency generator is also available. This is driven by the blue hydraulic system, which in this case is pressurised by a pump, linked to the ram air turbine (RAT). If this power source also fails, single-phase alternating current can be generated for the most important systems for a limited time by the on-board batteries via a static inverter.

Generator 1 normally supplies AC BUS 1 and AC ESS BUS. Generator 2 supplies AC BUS 2. If AC BUS 1 is de-energized, the AC ESS BUS is automatically switched to AC BUS 2. Since this toggle function is not used in normal operation (hidden function), it is periodically checked by the aircraft maintenance service. The last check (Task 24-25-00-710-001A) was carried out on 21 October 2011. On the control panel for the electrical system there is also a pushbutton switch for manual switching of the AC ESS BUS to AC BUS 2. If GEN 1 or 2 fails, this is automatically replaced by the remaining generator or, if available, by the APU generator.

Control and monitoring of the AC power supply is managed by the generator control unit (GCU) (cf. Annex 2). GCU 1 controls GEN 1 and GCU 2 controls GEN 2.

The GCU has two main functions; it ensures that the frequency and voltage are maintained within tolerance and it monitors the currents in the AC power supply network. In the event of overcurrent or large current differences between the individual phases and in the event of fault currents[7], the GCU disconnects the corresponding generator from the system by opening the generator line contactor (GLC). The flight crew is made aware of this by the GEN 1(2) FAULT indicator lamp illuminating on the electrical system control panel, the sounding of a chime and the MASTER CAUTION warning lamp illuminating. By pressing the GEN 1(2) FAULT / OFF pushbutton switch twice, the corresponding generator can be reconnected (reset), provided that the reason for the disconnection no longer applies. There is no evidence that the crew of flight LX 1250 made use of this option, allowing the assumption that none of the generators was disconnected from the AC system at any time during the flight. In addition, on the basis of the recordings, AC BUS 1 and AC BUS 2 were supplied with power without interruption.

For the DC power system three identical transformer rectifiers (TR) are available. These convert the three-phase AC voltage into a 28VDC voltage. TR 1 normally supplies DC BUS 1 and DC ESS BUS via the DC BAT BUS. TR 2 supplies DC BUS 2. The ESS TR remains in the standby mode (cf. Figure 1). If DC BUS 1 is de-energized, the ESS TR is activated and takes over the supply of the DC ESS BUS. DC BUS 1 is subsequently supplied by TR 2, via DC BUS 2 and DC BAT BUS. The ESS TR, now supplied by AC ESS BUS, remains activated.

The chronology of failure events as they occurred in the serious incident is reproduced in Annex 5. Recordings of the direct access recording (DAR) can be found in Annex 8.

[7] The electrical current of each of the three phases is measured at various points in the AC system. If a difference is established between the measurements, the GCU separates the corresponding generator from the system by opening the generator line contactor (GLC) (differential protection).

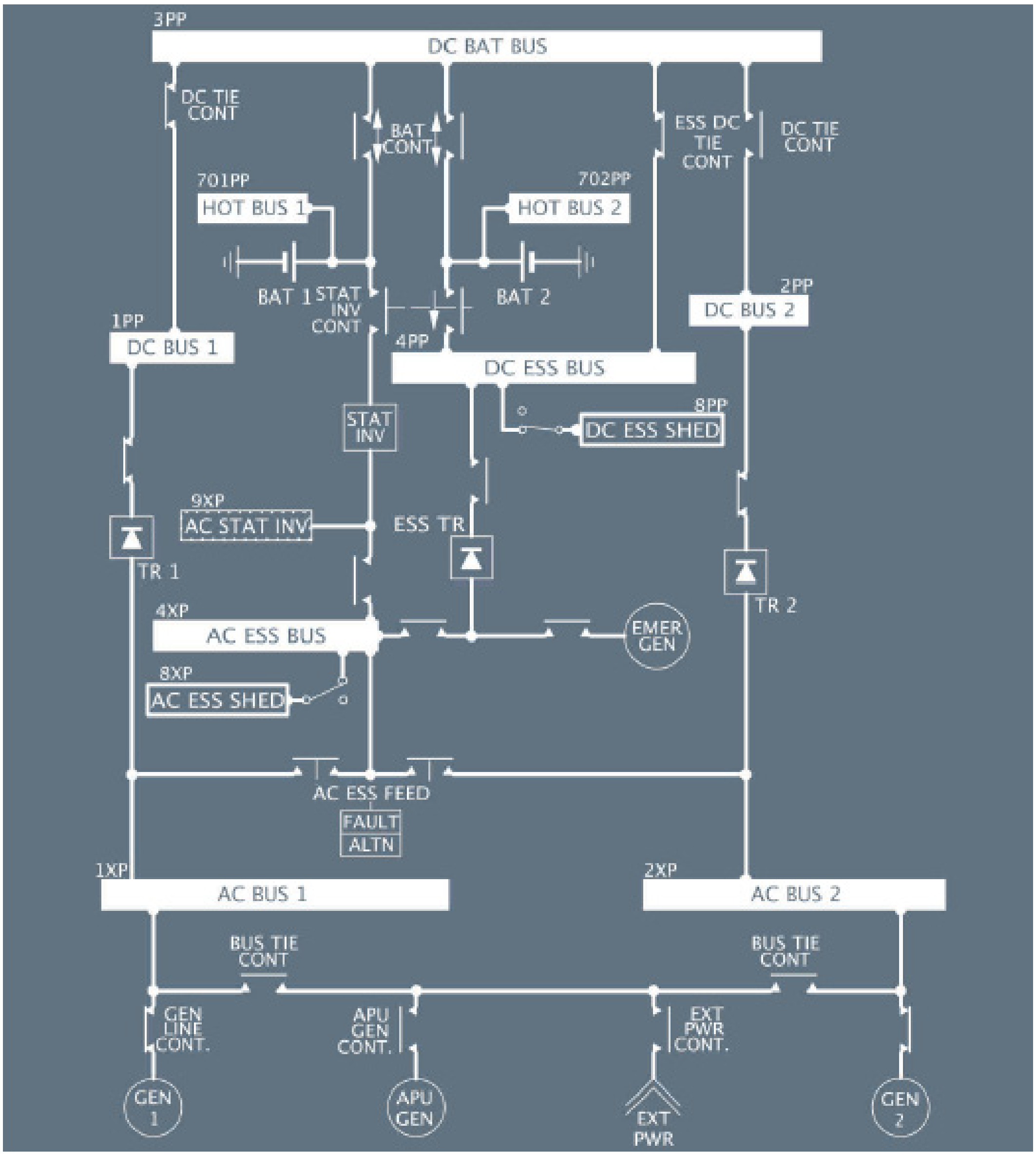

Figure 1: Block diagram of the electrical power supply

1.6.2.3 Electronic instrument system

The electronic instrument system (EIS) can be divided into two sub-systems; the electronic flight instrument system (EFIS) and the electronic centralized aircraft monitor (ECAM).

The EFIS includes the two primary flight displays (PFD) and the two navigation displays (ND). On the commander's and co-pilot's instrument panel, there is one PFD and one ND respectively. Essential parameters for the conduct of the flight are displayed on the PFD and the ND serves to display the navigation and flight planning data.

The ECAM includes two display units one above the other. On the upper one, the engine/warning display (E/WD), engine data and alert messages are displayed. On the system display (SD) below it, system diagrams (system pages) are displayed; these give the pilot an overview of the various systems and their switching states. The system to be displayed can be selected on the ECAM control panel. In the event of a fault, depending on the cause of the fault the corresponding page is automatically selected. For example, if there is a "DC BUS 1 FAULT", the ELEC page is displayed.

The three display management computers (DMC) process the data which they receive from the system data acquisition concentrators (SDAC) and the flight warning computer (FWC) and forward it to the PFD, ND, E/WD and SD (cf. Figure 2). In normal operation, DMC 1 and 2 are active and DMC 3 serves as a backup which can be activated if required.

The two identical FWC generate alert messages, aural alerts and synthetic voice messages. Signals for the red warnings reach the three DMCs via the FWCs. Signals for the amber cautions are forwarded from the SDACs via the FWCs to the DMCs. In addition to the alerts, the FWCs deliver the radio altitude callouts and the data for the system pages.

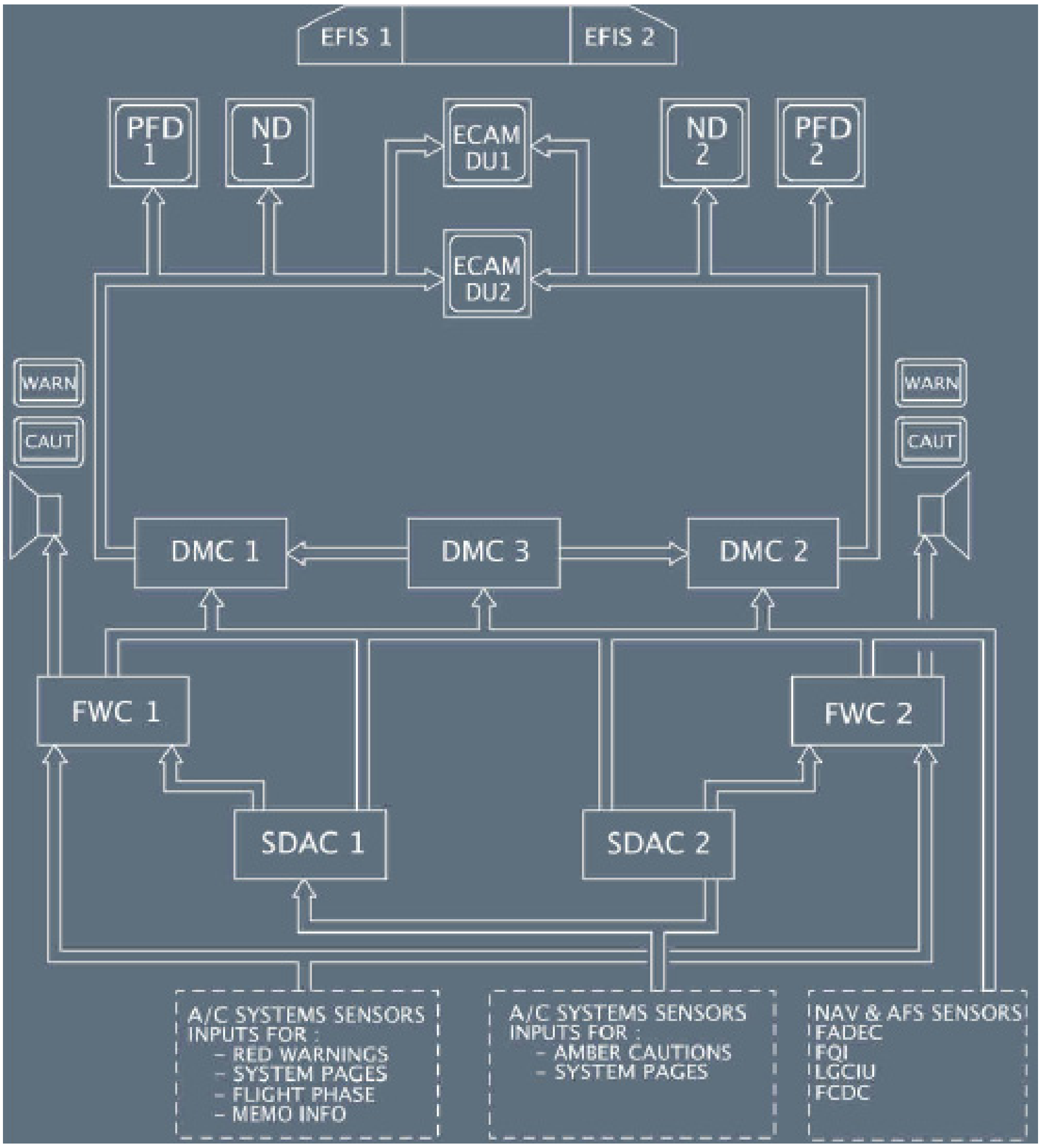

Figure 2: Block diagram of the electronic instrument system (EIS)

During the serious incident, the power supply to parts of the ECAM was intermittent, and this made a systematic analysis of the situation by the crew more difficult.

1.6.2.4 Centralized fault display system

The centralized fault display system (CFDS) allows maintenance personnel to analyse any system faults during the flight and to initiate appropriate repair actions. A post flight report (PFR) can be printed out in the cockpit after the flight. In addition, individual systems can be tested on the ground via the CFDS.

The CFDS essentially includes the centralized fault display interface unit (CFDIU), two multipurpose control display units (MCDU) and a printer. The MCDUs serve as control units for various systems, including the flight management and guidance system (FMGS). The CFDS receives BITE [8] data from various electronic aircraft systems and ECAM fault messages from the flight warning system (FWS) (cf. Figure 3).

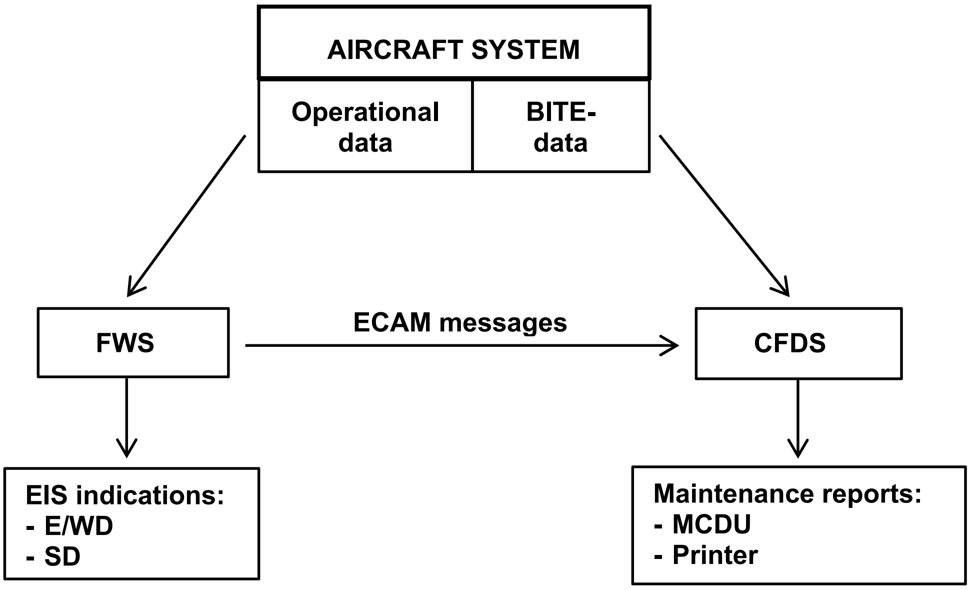

Figure 3: Data flow diagram of the centralized fault display system (CFDS)

The fault messages are divided into classes.

- Class 1 faults are visible to the crew (ECAM warning messages, flags). These have an operational impact. Such faults trigger a PFR at the end of the flight. If the fault cannot be rectified bevor the next flight the minimum equipment list (MEL) must be consulted.
- Class 2 faults have no operational consequences. These trigger a PFR at the end of the flight. Also at the end of the flight they are listed on the ECAM maintenance page so that the crew can make an entry in the flight log.

The CFDS can store data from several flights. If required, the data can be retrieved and printed out via the MCDU. In the case of the PFR the storage capacity for ECAM warning messages is limited to the previous 40 entries, i.e. all older entries are constantly overwritten. In the present case, this limit was reached. The recording therefore began only at 13:54 UTC with the entry “ELEC TR 1 FAULT” and ended at 14:40 UTC with the entries ENG 1 REVERSER FAULT, ENG 1 IGN B FAULT and ANTI ICE STBY AOA[9] (cf. Annex 1). The ANTI ICE STBY AOA entry

[8] BITE stands for built-in test equipment. Most of the electronic devices perform continuous self-tests (continuous BITE) and deliver fault messages to the CFDS.

[9] AOA: angle of attack

is a repetition of the same entry at 13:57 UTC. The two other entries also date back to the time of 13:57 UTC, but were suppressed during the flight.

During the flight, the CFDS generates a current flight report (CFR). If necessary, this can be viewed on the MCDU. Certain fault messages are also transmitted to a ground station via the aircraft communications addressing and reporting system (ACARS).[10] In the present case, the following messages were transmitted to the maintenance provider:

- 13:11:56 UTC: "ELEC DC BUS 1 FAULT"
- 13:28:02 UTC: "ELEC DC BUS 1 FAULT"
- 13:34:18 UTC: "ELEC TR 1 FAULT"

After the automatic tripping of circuit breaker (CB) AB11 at 13:57:41 UTC, the ACARS was no longer available. From this point in time, the CFR could no longer be transmitted.

1.6.2.5 Cockpit and cabin temperature regulation

Temperature regulation is divided into three zones: cockpit, forward cabin and aft cabin. Each of these zones can be regulated individually (cf. Figure 4).

Air from the pneumatic system is routed via two pack flow control valves and two air conditioning packs to the mixer unit and from there to the cockpit and into the cabin. Some of the cabin air is returned again to the mixer unit.

Temperature regulation is effected by the two pack controllers and the zone controller. Individual temperature regulation of the three zones is effected by means of hot air which is mixed via the hot air pressure regulator valve and the three trim air valves. Temperature regulation is controlled from the air conditioning panel in the cockpit (cf. Figure 4). In an emergency, ram air can be directed from outside the aircraft into the mixer unit. On the ground, conditioned air can be supplied from an external unit to the mixer unit.

The mixer unit mixes cold, fresh air from the air conditioning packs with cabin air which is fed back via special filters.

After the automatic tripping of circuit breaker (CB) AB11 at 13:57:41 UTC, air conditioning pack 1 failed. The zone controller also partially failed; the trim air valve for the cockpit was closed and the temperature in the cockpit began to fall.

[10] ACARS is a data transmission system. It uses specific VHF-COM frequencies. Messages can be transmitted specifically to one or more locations on the ground or vice versa to a specific aircraft.

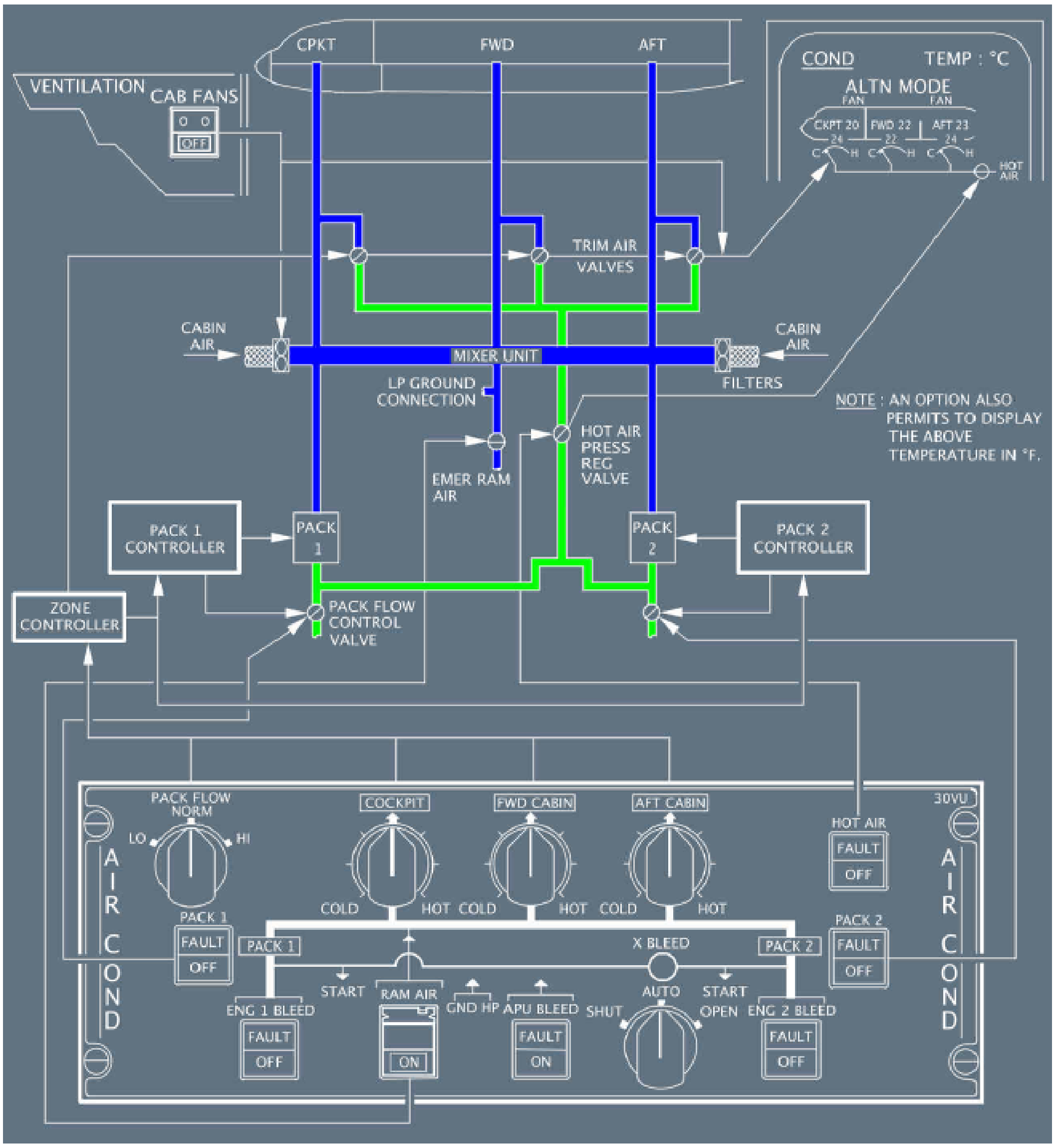

Figure 4: Block diagram of the air conditioning system

1.6.2.6 On-board warning systems

The aircraft is equipped with a mode-S transponder, a traffic alert and collision avoidance system (TCAS) and an enhanced ground proximity warning system (EGPWS).

None of the alert systems responded during the serious incident. After the automatic triggering of circuit breaker (CB) AB11 at 13:57:41 UTC, the EGPWS was no longer available.

1.7 Meteorological information

1.7.1 General weather situation

A trough extended at high altitude from Scandinavia to the Adriatic. On the ground, an area of high pressure extended from the British Isles to France. The high was opposed by a depression with its centre over the southern Baltic and determined the weather over southern Sweden.

1.7.2 Weather before and during the serious incident

The first half of the flight passed through the trough just to the west of the coldest air. Between Brandenburg and Stockholm the air was marginally less cold than over southern Germany, due to an occlusion. The flight crossed the axis of the trough and was always outside the turbulence area of the jetstream branches.

1.7.3 Aerodrome routine meteorological report

From 14:20 UTC, the following aviation routine weather report (METAR) was valid at Stockholm Arlanda (ESSA) airport:

METAR ESSA 111420Z 01015KT 4500 -SN BR FEW009 BKN011 M03/M03 Q1016 R01L/710134 R01R///99// R08/710145 TEMPO 2000 BKN020=

In clear text, this means:

On 11 December, the following weather conditions were observed at Stockholm Arlanda airport (ESSA) shortly before the time of issue of the aerodrome routine meteorological report at 14:20 UTC:

Wind	010 degrees, 15 kt
Meteorological visibility	4500 m
Weather	Light snowfall with mist
Cloud	1/8 - 2/8 at 900 ft AAL[11] 5/8 - 7/8 at 1100 ft AAL
Temperature	-3 °C
Dew point	-3 °C
Atmospheric pressure QNH	1016 hPa pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere.
State of the runways	Runway 01 left, 10% or less of the runway is covered with ice which is 1 mm thick. The coefficient of friction on braking is 0.34. Runway 01 right is unusable because of snow, slush, ice, snow drifts or snow clearance operations. Runway 08, 10% or less of the runway is covered with ice which is 1 mm thick. The coefficient of friction on braking is 0.45.
Landing weather forecast	Within the next two hours visibility falling occasionally to 2000 m with cloud of 5/8 - 7/8 at 2000 ft AAL. These temporary changes last individually and in total for less than one hour.

1.7.4 Astronomical information – Stockholm Arlanda 14:40 UTC

Position of the sun	Azimuth: 233 °	Elevation: -6 °
Lighting conditions	End of civil twilight	

[11] AAL: above aerodrome level

1.7.5 Forecasts

The following terminal aerodrome forecast (TAF) was valid at the time of the serious incident:

TAF ESSA 111130Z 1112/1212 36013KT 5000 -SN BKN020 TEMPO 1112/1202 2000 SN VV012 TEMPO 1202/1207 4000 BKN012 BECMG 1210/1212 30008KT=

In clear text this means:

On 11 December 2012, the following weather conditions were forecast for Stockholm Arlanda airport (ESSA) from 12 UTC for the following 24 hours:

Wind	from 360° at 13 kt
Meteorological visibility	5 km
Weather	Light snowfall
Cloud	5/8 - 7/8 at 2000 ft AAL
Trend	Between 12:00 UTC on 11 December and 02:00 UTC on 12 December 2012 visibility with moderate snowfall reducing to 2000 m. Vertical visibility extends to 1200 ft AAL. The sky is overcast. These weather conditions last in some cases for a maximum of one hour and occur during less than half of the described interval. Between 02:00 and 07:00 UTC on 12 December 2012 visibility reaches 4000 m with 5/8-7/8 cloud at 1200 ft AAL. These weather conditions last in some cases for a maximum of one hour and occur during less than half of the described interval. Between 10:00 UTC and 12:00 UTC on 12 December 2012 a regular or irregular backing of the wind to 300 degrees at 8 knots is expected.

1.8 Aids to navigation

1.8.1 Information on the aircraft's navigation equipment

HB-IPX is equipped with a multi-sensor flight management system. Navigation is based on GPS, DME, and VOR[12]. Primary navigation is with GPS.

In terms of its power supply, the navigation system of the A319 is designed to be redundant. During the flight, the flight management and guidance system (FMGS) was available until the landing. This also applies to the instrument landing system (ILS).

1.8.2 Ground-based and satellite-based navigation systems

On the crew side there is no evidence of problems with ground-based or satellite-based navigation systems.

[12] GPS: global positioning system, DME: distance measuring equipment, VOR: VHF omni-directional radio range

1.9 Communications

On the pilots' side, there is no evidence that there had been any problems with radio communications between the crew and air traffic control.

Radio transmissions between the aircraft and air traffic control are usually handled via the VHF 1 communication system. This is supplied by the DC ESS BUS, which was always energised during the serious incident and until the landing. The VHF 2 communication system, which is powered by DC BUS 2, was also available without interruption.

1.10 Aerodrome information

Stockholm Arlanda airport (ESSA) is located 40 kilometres north of the city of Stockholm in a sparsely populated area at an elevation of 137 feet above sea level. It has two parallel runways 01L/19R and 01R/19L, and a runway 08/26. The longest runway is 01L/19R with an available runway length of 3301 m. Runways 01R/19L and 08/26 have an available runway length of 2500 metres. On all runways the total length is available for both take-off and landing. All runways except runway 08 have an instrument landing system. Runway 08 has an approach by localizer.

1.11 Flight recorders

1.11.1 Flight data recorder

1.11.1.1 General information

Type	DFDR F1000
Manufacturer	Fairchild
Number of parameters	602
Recording medium	Solid State Memory
Recording time	> 25 hours

1.11.1.2 Results of the analysis

The data from the flight data recorder (FDR) was recorded in full and could be analysed.

1.11.2 Cockpit voice recorder

The cockpit voice recorder (CVR) recordings had already been overwritten and could not be analysed.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

There are no indications of the crew suffering any health problems during the flight involved in the incident.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 General

The investigations described in the following chapters were carried out following the actions taken by the maintenance provider (cf. chapter 1.18).

The components referenced below can be seen in Annex 2.

1.16.2 Transformer rectifier und contactor tests

On 14 May 2013 transformer rectifier (TR) 1 (P/N Y005-2, S/N 7833) was tested by the equipment manufacturer. The TR functioned flawless.

On 15 May 2013 the two contactors 5PU1 (P/N 640CC01Y1, S/N 5154) and 1PC1 (P/N 640CC01Y1, S/N 5139) were tested by the manufacturer. Following the electrical function check, the devices were dismantled and the contacts were inspected visually. Both contactors functioned flawless.

On 15 January 2015 the contactor 1PC2 (P/N 640CC01Y1, S/N 5138) was tested by the manufacturer. The contactor functioned flawless.

1.16.3 Circuit breaker tests

On 25 June 2013 the circuit breaker 3XN1[13] (P/N E0459-501, S/N 4077) was tested by Airbus in Toulouse. The visual inspection of the device on arrival gave the following result: The release button of the circuit breaker (CB) was pushed in. There were no external signs of overheating, i.e. no discoloration. Nor was any mechanical damage detectable (cf. Figure 5).

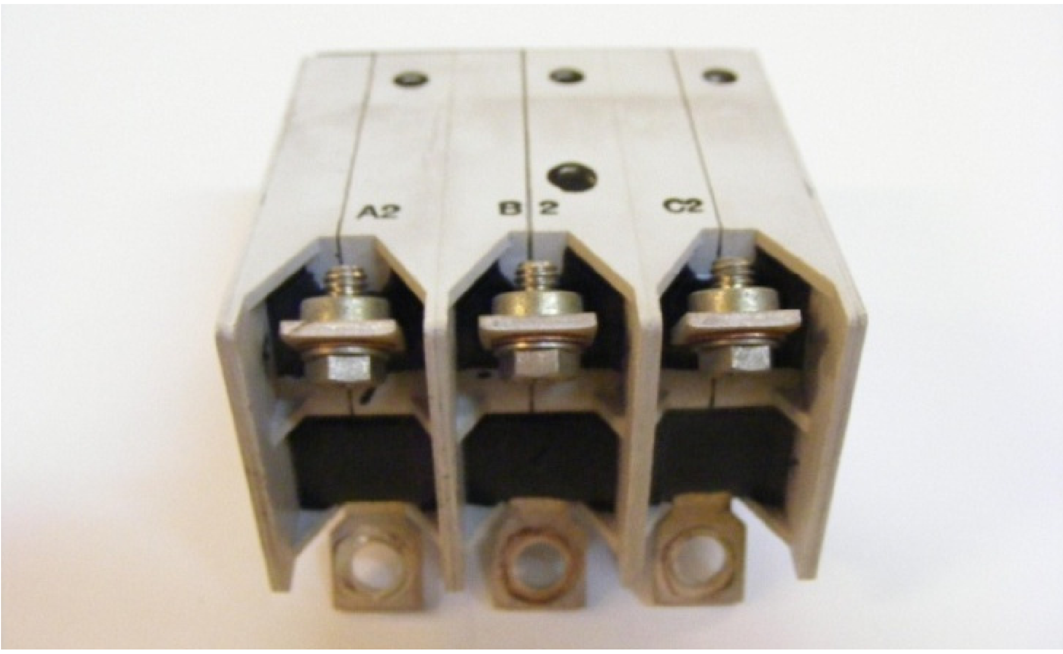

Figure 5*:* Circuit breaker 3XN1 before the test (source: Airbus)

[13]Circuit breaker 3XN1 is a three-phase CB. It includes three fuse elements which can be operated manually, by pushing or pulling, using a common release button. An overcurrent in one of the fuse elements causes all three circuits to open and the automatic tripping of the CB respectively.

On the CB the release button was now pulled. A check revealed that all three fuse elements (A1-A2, B1-B2, C1-C2) had electrical continuity; these should actually be interrupted. However, no connection existed between the individual fuse elements (A-B, A-C, B-C).

The release button of the CB was pushed in and pulled out again. After this the above-mentioned faulty connections had disappeared.

The release button of the CB was pushed in again. When a voltage was applied to contacts A1, B1 and C1, the CB tripped without delay. The power source was disconnected immediately.

The release button of the CB was pushed in once again and then the power source was switched on again. This time, the CB made unusual noises and smoke appeared (cf. Figure 6). The power was disconnected immediately. The CB had tripped. The test was then aborted.

Figure 6: Front and rear of circuit breaker 3XN1 after the test (source: Airbus)

The intended test, with the aim of determining the tripping current of the 50 A circuit breaker, could not be carried out in these circumstances. It is believed that internal arcing occurred in the CB between the fuse elements.

To clarify the precise facts of the case, circuit breaker 3XN1 was x-rayed from different sides on 6 November 2013 by the manufacturer. A new CB was x-rayed under the same conditions for comparison. The comparison showed that on the CB from the HB-IPX, several parts were missing or had melted.

The CB was then dismantled. The image obtained from the x-rays was confirmed. Based on the level of destruction it is assumed that a short-circuit had occurred between phases B and C. However, it must be stated that the considerable extent of destruction occurred on the occasion of the tests at Airbus on 25 June 2013 and not during the serious incident.

It can also be assumed that it is highly probable that electrical arcing had already occurred between two phases during flight LX 1250, but with much less impact.

1.17 Organisational and management information

1.17.1 Operator

Swiss International Air Lines emerged in 2002 from the former Basel regional airline Crossair, whose air operator certificate (AOC) it also took over.

Swiss International Air Lines owns two subsidiary airlines, Swiss European Air Lines and Edelweiss Air.

Another subsidiary, Swiss Aviation Training AG, is mainly engaged in the training of pilots.

Since April 2006, Swiss has been a member of STAR ALLIANCE, a consortium with which a significant number of airlines are associated worldwide.

Since July 2007, Swiss has been a wholly owned subsidiary of Deutsche Lufthansa AG.

Swiss has its Airbus fleet serviced by SR Technics Switzerland.

1.18 Additional information

1.18.1 General

The following chapters mention measures taken after the serious incident by the airline's maintenance company. All involved components have been tested or removed from the event aircraft. Subject aircraft has been operating since without any known events of that kind.

1.18.2 Measures taken after the landing at Stockholm Arlanda

A team of specialists was sent by the maintenance company to Stockholm Arlanda who carried out the following work:

- Transformer rectifier (TR) 1 was replaced and a test was carried out according to the aircraft maintenance manual (AMM) 24-32-51 (WO 3529725-1).
- The “AC ESS FEED” push button on the ELEC control panel was swapped with the identical “CTR TK PUMP 2” push button on the FUEL control panel (WO 3529725-1).
- Circuit breaker 3XN1 “BUS 103XP SUPPLY” was swapped with the identical “AFT GALLEY FEED A” circuit breaker 3MC (WO 3529726-1).
- In the area of BUS 103XP, the wiring was checked according to AMM 24-58-02 (WO 3529726-1).
- In accordance with AMM 22-96-00/22-97-00 an auto flight system (AFS) test and a side stick movement test were carried out (WO 3529727-1).
- Contactor 1PC1 and relay 20XN1 were replaced (WO 3529724-1).

1.18.3 Measures taken after the return to Zurich

On 14 December 2012 circuit breaker 3MC “AFT GALLEY FEED” (ex 3XN1) was replaced (WO 6199655-1).

On 20 December 2012 the generator line contactor (GLC) 1, 9XU1 was replaced (WO 6200715-2).

On 21 December 2012 a general visual inspection was carried out on the following components, in accordance with WO 6202762-1:

- GEN 1 connector 400VC1
- Terminal block 400VT1
- Terminal block 1999VT
- GLC 1, 9XU1
- Bus bar 1XP

On 18 February 2013, contactor 5PU1 was replaced and at the same time a general visual inspection of connection point 5PU1/103PP/101PP was carried out in the area of DC BUS 1 (1PP) (cf. Figure 7). No irregularities, and in particular no burning marks were found.

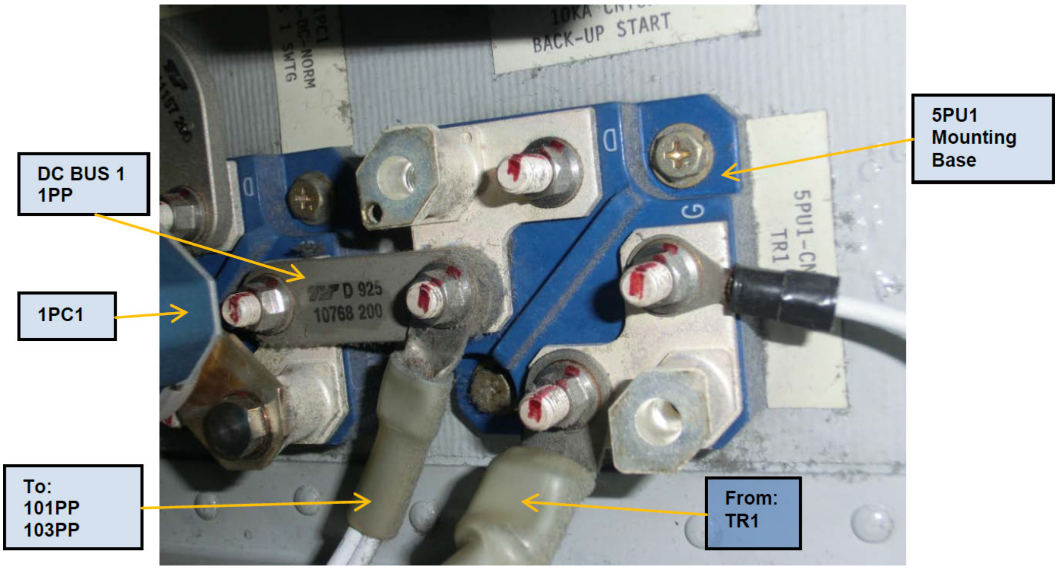

Figure 7: Mounting base after disassembly of contactor 5PU1

On 18 February 2013 the contact resistance of the three phase circuit breaker 1XC, which feeds the AC ESS BUS, was tested. No discrepancies were found.

On 30 April 2014 a functional test of the electrical system was carried out on aircraft HB-IPX with the engines running. The purpose of this check was to bring about a configuration which is not used in day-to-day operations (hidden function) (cf. chapter 1.6.2.2). This was to make sure that the new configuration was stable on the ECAM display.

For this purpose the power supply from TR 1 to DC BUS 1 was interrupted and the following was noted:

- TR 1 went to “FAULT” status after 5 seconds (ECAM display)
- DC BUS 1 and DC BAT BUS are powered from DC BUS 2
- The ESS TR is powered from the AC ESS BUS
- The DC ESS BUS is powered from the ESS TR

No irregularities were detected during this functional test.

On 8 November 2014 the contactor 1PC2 was replaced (WO 9518532).

1.18.4 Comments of the aircraft manufacturer

1.18.4.1 General

According to the manufacturer, no similar event has been reported within the Airbus A320 family before the present serious incident.

1.18.4.2 Change in configuration of the power supply

According to the recordings, the ESS TR was activated at 12:39:20 UTC and from this time on the DC ESS BUS was supplied with 28 V DC by the ESS TR, and not by the TR 1. This change in the configuration of the power supply can be seen on the lower display of the ECAM when the corresponding system page is called up. No associated advisory was output to the crew. Only the subsequent failures of DC BUS 1 and TR 1 were reported to the crew in the form of ECAM alerts (cf. chapter 1.6.2.3).

The ECAM philosophy implemented by the manufacturer envisages that an advisory with automatic retrieval of the respective system page only occurs if a drift in a parameter is perceptible. On the basis of such drift, the crew can, if necessary, anticipate additional operational measures. In the event of intermittent advisories, a contrary effect cannot be ruled out: as a result of dealing with the problem (trouble-shooting), crews might be diverted from more important tasks. In the present case, from the moment of the first DC BUS 1 fault to the failure of TR 1, it was a matter not of actual drift but a “fluctuating sequence”.

In line with the existing ECAM philosophy, the manufacturer does not see any operational support by informing the crew of this change in the configuration of the power supply in the form of an advisory.

1.18.4.3 Absence of indication of thrust reverser failure

After the landing at 14:40 UTC, the left engine's reverser did not function. According to their statement, the crew were surprised by this fact and stated that so far they had always assumed that the information about the non-available systems (INOP SYST) displayed on the ECAM status page was reliable.

In the present case, according to the manufacturer, due to the current system design it is not possible to indicate to the crew an expected failure of the reversers before they are activated. This is related to the lack of monitoring of SUB BUS 103 XP. Accordingly, the note “*The warning may be caused by a sub bus failure. Consequently, only a part of the above-listed systems may be lost.”* in the abnormal procedures of the flight crew operational manual (FCOM) under ELEC AC (DC) BUS FAULT is not applicable.

A risk assessment by the manufacturer, taking into account the controllability of the aircraft as a result of thrust asymmetry, the increased landing distance required and the probability of occurrence, assumes an acceptable risk.

2 Analysis

2.1 Technical aspects

2.1.1 General

The technical faults in the present serious incident can be classified into six fault events (FE) (cf. Annex 5), which are analysed individually below.

Chapter 2.1.2 contains many technical terms and abbreviations relating to aircraft electrical systems. Annex 9 contains a glossary with the full text and explanations.

2.1.2 Analysis of the fault events

2.1.2.1 Switchover to ESS TR

According to the recordings, the ESS TR was activated approximately 8 minutes after take-off at 12:39:20 UTC and from this time on the DC ESS BUS was supplied with 28 V DC by the ESS TR, and no more by the TR 1. This switchover takes place when contactor 4PC opens and contactor 3PE closes (cf. Annex 2). Contactor 4PC opens if contactor 1PC1 opens for >100 ms. Contactor 1PC1 opens if sub-busbar 103PP experiences a voltage drop. Once contactor 4PC has opened, the ESS TR remains activated. The ESS TR obtains power from the AC ESS BUS via contactor 15XE1. This closes when contactor 4PC opens.

It is assumed that the sub-busbar 103PP experienced a voltage lowering of more than 100 ms which caused the contactor 1PC1 to briefly open.

Since the power supply via TR1 was not affected[14] and contactor 5PU1 remained closed, there are two plausible explanations for the opening of contactor 4PC and therefore for the switchover to the ESS TR: a contact resistance inside contactor 5PU1 or a loose contact at connection point 5PU1/103PP/101PP (point A in Annex 6).

Contactor 5PU1 was removed from the aircraft on 18 February 2013 and examined in detail by the manufacturer. No abnormal behaviour was found. On the same day, a visual inspection was carried out at connection point 5PU1/103PP/101PP. No fault could be found in this check either. The fact that up to 18 February, i.e. for approximately two months since the serious incident, the aircraft had been deployed in flight operations without any further failure in the electrical system supports these findings. The exact cause of this fault could not be established, even with the assistance of the aircraft manufacturer. However, it has not occurred again in operation to date.

The short duration of the voltage interruption at the DC ESS BUS had no effect on the power supply to systems. The change in configuration was displayed on the ECAM ELEC system page. It was not mentioned by the crew.

2.1.2.2 Switching between TR 1 and TR 2

Between 13:13 UTC and 13:30 UTC, DC BUS 1 experienced several brief voltage lowering events. As a result, contactor 1PC1 was opened and contactor 1PC2 was closed. Consequently, the DC BAT BUS was supplied for a short time by TR 2 and then by TR 1 again. The recorded current profile of both the transformer rectifiers (TR) confirmed these facts. Contactor 5PU1 remained closed, which indicates that the internal monitoring function of TR 1 had detected no malfunction

[14] According to the recording (cf. Annex 8), the supplying AC BUS 1 was always energized.

and that the power supply from TR 1 was ensured. It can also be assumed that the voltage lowering events lasted less than five seconds.

There are two plausible explanations for the multiple brief voltage lowering events at DC BUS 1: a contact resistance inside contactor 5PU1 or a loose contact at the connection point 5PU1/103PP/101PP (point A of annex 6).

The explanation in chapter 2.1.2.1, also applies to this fault. The voltage lowering events at DC BUS 1 triggered various intermittent ECAM alerts (cf. Annex 5).

2.1.2.3 Automatic cut-out of TR 1

At 13:34:18 UTC TR 1 went to "FAULT" status. As a result, contactor 5PU1 was permanently opened[15]. This meant that now, in addition to contactor 1PC1, contactor 1PC2 was also closed. From this time onwards, the DC BAT BUS as well as DC BUS 1 was supplied with 28 V DC by TR 2. The corresponding recordings confirm this load take over (cf. Annex 8).

A TR goes to "FAULT" status if overheating is detected in it, or when the output current drops below a defined value for more than 5 seconds. In the present case the "TR 1 FAULT" status had been preceded by marked current fluctuations.

There are two plausible explanations for the marked current fluctuations: a contact resistance inside contactor 5PU1 or a loose contact at connection point 5PU1/103PP/101PP (point A of Annex 6). The explanation in chapter 2.1.2.1, also applies to this fault. For safety reasons, TR 1 was removed after the serious incident and tested by the manufacturer, without any evidence of malfunction.

Approximately eight minutes after the automatic shutdown of TR 1, on the advice of the service centre in Zurich the crew interrupted the power supply to TR 1 by opening circuit breaker AB10. This approach would have been useful if up to this time TR 1 had not automatically switched off. In the present case, this did not have any effect.

2.1.2.4 Voltage lowering on DC BUS 1 and DC BAT BUS

After TR 1 was automatically disconnected and DC BUS 1 and DC BAT BUS were supplied by TR 2, the two buses experienced distinct voltage lowering events several times between 13:34:20 UTC and 13:55:42 UTC. According to the recordings, the DC BUS 2 which was supplying power remained energised without interruption and the two contactors 1PC1 and 1PC2 remained constantly closed. The recorded current profile of TR 2 confirmed the above-mentioned interruptions in supply. It should be pointed out here that the output current of TR 2 temporarily fell to the level prior to the switchover, which means that the DC BUS 1 and DC BAT BUS were completely separated from DC BUS 2. This state lasted for several minutes. At 13:55:42 UTC the power supply of DC BUS 1 and DC BAT BUS normalised for no apparent reason and remained constant for the remainder of the flight.

The configuration in which TR 2 additionally supplies DC BUS 1 and DC BAT BUS is not used in normal operation. It is intended for the case in which TR 1 fails. To learn more about the possible cause of the fault during the serious incident, the cited configuration was induced on the occasion of a test with the engines running (cf. chapter 1.18.3). No irregularities were detected during the functional check.

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[15] The "FAULT" status of a transformer rectifier (TR) can only be reset on the ground by the aircraft maintenance company

As a contact resistance inside contactor 1PC2 could not be excluded, the contactor was tested by the manufacturer on 15 January 2015. The contactor functioned flawless.

2.1.2.5 Automatic tripping of circuit breaker AB11

At 13:57:41 UTC circuit breaker AB11 (3XN1) automatically tripped. As a result, sub bus 103XP was de-energised. Annexes 1 and 5 show the systems concerned; among other things, the power supply of the aircraft communications addressing and reporting system (ACARS) failed, as a result of which the current flight report (CFR) could no longer be transmitted.

On the basis of the insights gained during testing on the manufacturer's premises (cf. chapter 1.16.3) it is likely that the CB heated up as a result of internal electrical arcing between two phases and therefore tripped. However, the cross-current between phases caused by the arcing was not sufficient to cause the internal monitoring in GCU 1 to respond and disconnect AC BUS 1 from the generator[16]. The recurring start-up current of a fuel pump in the left tank caused by the fault in the DC 1 network may have favoured the tripping of circuit breaker AB 11. It cannot therefore be excluded that the above-mentioned arcing in the CB was also present and latent on previous flights but did not cause it to trip.

The important systems for the safe conduct of the flight continued to be supplied after the tripping of the CB. Owing to the failure of the temperature regulation system, the temperature in the cockpit fell to values below zero degrees.

2.1.2.6 Brief voltage interruption on AC ESS BUS and SUB BUS 131XP

According to the recordings, between 13:58 UTC and 14:20 UTC, i.e. for 22 minutes, no faults occurred in the electrical system. Between 14:20 UTC and 14:21 UTC, the power supply of SUB BUS 131XP failed for a short time. SUB BUS 131XP is supplied with 26 V AC from AC BUS 1 (phase A) via circuit breaker 5XN1 and transformer 15XN1 (cf. Annex 7). Among other things, autopilot 2 was disengaged as a result of the simultaneous failure of angle of attack (AOA) sensors 1 and 3.

At 14:22 UTC the power supply of the AC ESS BUS briefly failed several times. As a result, the power supply to the ESS TR and consequently to the DC ESS BUS was interrupted. The AC ESS BUS is normally supplied from AC BUS 1 via contactor 3XC1 (cf. Annex 7). In the event of failure of AC BUS 1, automatic switching takes place to AC BUS 2 via contactor 3XC2. Switching can also be carried out manually on the control panel for the electrical system. On the basis of the recordings, AC BUS 1 remained constantly energised during the above-mentioned fault.

Point “A” in Annex 7 designates the point at which a loose contact was assumed. A detailed visual inspection of the corresponding connections was carried out on the aircraft. Circuit breaker 1XC was tested. No discrepancies could be detected. To date no further faults have occurred in this area. The reason for this malfunction could not be determined.

Annex 1 shows the affected systems. For the crew noticeable, the commander's PFD and ND, as well as the upper ECAM display unit, failed temporarily.

In order to learn more about the possible cause of the fault during the serious incident, a configuration was induced on the occasion of a test with the engines running, in which the ESS TR was activated (cf. chapter 1.18.3). No irregularities were detected during the function check.

[16] A current of 45 amps would have been necessary for this to occur.

2.1.3 Other technical analyses

On the basis of the insights gained during testing on the manufacturer's premises, it is likely that arcing between two phases occurred in circuit breaker 3XN1 during the flight. It is known that when this occurs, a spectrum of frequencies is generated. It cannot be entirely ruled out that interference had an effect on TR 1 and GCU 1 via the AC network, but neither can it be proved.

The fact is that in all the checks carried out, nothing abnormal was found except on circuit breaker 3XN1 and since its removal from the aircraft no further faults in the electrical system of HB-IPX have been reported to date.

2.2 Human and operational aspects

2.2.1 Crew

Approximately eight minutes after take-off in Zurich, at 12:39:20 UTC, a configuration change occurred in the electrical system: the ESS TR was activated and from this point on the DC ESS BUS was supplied by ESS TR and not anymore by TR 1. This configuration change was not mentioned by the crew in the air safety report (ASR) and was probably not even noticed. The above-mentioned changeover had no effect on the supply to systems and also did not trigger any alerts. The new configuration is indicated on the ELEC system page, if it is selected.

In line with the existing ECAM philosophy, the manufacturer does not see any operational support by informing the crew of this power supply configuration change in the form of an advisory. In the event of intermittent advisories, it cannot be ruled out that crews might be diverted from more important tasks as a result of troubleshooting. In principle this approach may be considered as appropriate, since on activation of the ESS TR no immediate action on the part of the crew was required; the change in configuration of the power supply, however, was permanent and took place automatically. Nonetheless, until the appearance of the first ECAM alert “FAULT DC BUS 1” after a flight time of approximately one hour, the crew were under the assumption that the aircraft's electrical system was in the standard configuration. On a flight far from alternate aerodromes, identification of this anomaly may result in operational measures.

From 13:13 UTC to 13:30 UTC the situation was for the first time difficult to analyse, with DC BAT BUS being supplied alternately by TR 2 or TR 1 with intermittent ECAM warnings “DC BUS 1 FAULT”, “BRAKE SYSTEM 1 FAULT”, “BLOWER FAULT” and “EXTRACT FAN FAULT”. After TR 1 had shut down automatically at 13:34:18 UTC, voltage lowering events at DC BUS 1 and DC BAT BUS occurred between 13:34:20 and 13:55:42 UTC, which were not directly observable by the crew. The subsequent ECAM alerts “APU FIRE DET FAULT” and “APU FIRE LOOP A FAULT” were visible to the crew. In addition the CARGO DISCH indicator lights illuminated. In addition, the crew noticed during this period that the side stick solenoid on the co-pilot’s side was audibly actuated several times. From this point it was no longer clear to the crew which events were to be interpreted as possible causes or as symptoms. From 13:57 UTC at the latest, when circuit breaker AB11 (3XN1) tripped, a systematic analysis of the technical problem was practically impossible. In the subsequent phase of the flight, additional alerts occurred which the crew were no longer able to assign to a technical scenario which they could understand.

From this point on, the crew largely relied for their assessment of the situation on the state of the aircraft as displayed on the STATUS page under INOP SYST and on their observations, e.g. that the indicator light in the button of the ANTI ICE ENG1 did not illuminate, despite the button being pressed.

The crew clarifications carried out via SATCOM with the maintenance company in relation to the technical situation and possible causes of the fault, the envisaged alternate landings and the involvement of the *maître de cabine* were appropriate and forward-looking. This also applied to the consultation with the cabin concerning preparing for a possible emergency descent in the event of smoke or a malfunction of the cabin pressurisation control system. The decision to continue the flight to Stockholm at the time was appropriate to the situation.

At 14:22:14 UTC, the crew of HB-IPX were informed by the responsible air traffic control officer (ATCO) that snow clearance would shortly take place. In this period, the crew had to deal with the temporary loss of various systems, including, among others, the commander's primary flight display (PFD) and navigation display (ND) and the upper ECAM display unit. Transmitting the urgency message (*Pan Pan, Pan Pan, Pan Pan*) was appropriate and also gave the crew the possibility to immediately approach on the longest available runway as number one in sequence.

The crew stated that they had had no indication that the left engine's reverser would not be operational; in particular, REVERSER 1 was not displayed on the STATUS page under INOP SYS. They were therefore surprised at the non-availability of the reverser on landing. The “ENG 1 REVERSER FAULT” alert was recorded according to the post flight report at 14:40 UTC, but was not, however, available to the crew as information before landing.

Because of the absence of monitoring of SUB BUS 103XP it is not possible, according to the manufacturer, to indicate to the crew an expected failure of the reversers before they are activated. It should be mentioned in this context that the list of failed systems indicated on the STATUS page of the lower ECAM display under INOP SYST may be incomplete. In the present case essential information was missing to the crew for a comprehensive situation analysis.

2.2.2 Conduct of air traffic control units during the serious incident

The reaction of air traffic control to place LX 1250 in first position for an approach on runway 01L without speed restrictions after transmission of the urgency message was helpful for the crew.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for IFR traffic.
- The mass and centre of gravity of the aircraft were within the permissible limits at the time of the serious incident.
- The investigation revealed no evidence of pre-existing technical defects which might have caused or influenced the serious incident.
- The last periodic check (A-check) was carried out on 27 October 2012.
- The design of the electrical system in terms of redundancy and availability can be considered to be appropriate. The present serious incident is regarded as an isolated case fleet-wide. Within the Airbus A320 family, no similar event has been reported before the present serious incident.
- As a result of the electrical problems, the non-availability of the reverser of the left engine was not indicated during flight for systemic reasons.

3.1.2 Crew

- The pilots were in possession of the required licence for the flight.
- There are no indications of the crew suffering any health problems during the serious incident.

3.1.3 Operational aspects

- The multiplicity of faults which occurred at short intervals in the electrical system and the resulting loss of important instruments made it difficult for the crew to carry out a systematic analysis of the situation.
- The failure of the integral lighting at dusk and the cockpit temperature regulation system with the subsequent pronounced drop in temperature also hampered work in the cockpit.
- The cooperation between the cockpit and the cabin crew was forward-looking and appropriate to the situation.
- The support provided by the air traffic control units was helpful to the crew.

3.1.4 History of the serious incident

- At 12:31 UTC, aircraft HB-IPX took off from runway 28 in Zurich (LSZH) on flight LX 1250 to Stockholm (ESSA).
- During the climb, at 12:39:20 UTC the DC BUS 1 experienced a brief voltage lowering event, which led to the switchover of the DC ESS BUS from TR 1 to the ESS TR.
- Between 13:13 UTC and 13:30 UTC the DC BAT BUS was supplied with power several times by TR 2 and then again by TR 1.
- At 13:34:18 UTC, TR 1 automatically shut down.
- The DC BUS 1 and the DC BAT BUS were subsequently powered by TR 2.

- The commander discussed the situation with the co-pilot and the head of the cabin crew. The procedures in the event of smoke were discussed.
- Between 13:34:20 UTC and 13:55:42 UTC the DC BUS 1 and the DC BAT BUS experienced several short voltage lowering events.
- The voltage at the above-mentioned busses normalised at 13:56 UTC and remained constant for the remainder of the flight.
- At 13:57:41 UTC, during the descent to FL 350, circuit breaker AB11 tripped automatically. Various systems then failed (cf. Annex 1). Among other things, cockpit temperature regulation was affected.
- Between 14:20 UTC and 14:21 UTC, the power supply to SUB BUS 131XP was briefly interrupted. Between 14:22 UTC and 14:25 UTC the AC ESS BUS failed briefly several times. As a result, various systems then failed momentarily (cf. Annex 1).
- At 14:21:54 UTC flight LX 1250 reported to the air traffic control unit “Stockholm approach control”.
- At 14:24:05 UTC, the crew of flight LX 1250 transmitted an urgency message *(Pan Pan, Pan Pan, Pan Pan)*.
- After receiving heading and altitude instructions for an instrument approach, flight LX 1250 landed on runway 01L at 14:40 UTC.
- As a result of the electrical problem, the left engine reverser did not function.
- The passengers were able to vacate the aircraft normally.

3.1.5 General conditions

- Owing to light snowfall, clearance of runway 01L was imminent.
- Measurement of the braking action for the first, middle and last third of runway 01L produced values of 0.28, 0.28 and 0.24, respectively.

3.2 Causes

The serious incident is attributable to repeated voltage lowering events and faults in the power supply to various busses.

The exact cause could not be determined.

4 Safety recommendations, notifications relating to safety and measures taken since the serious incident

4.1 Safety recommendations

None

4.2 Notifications relating to safety

None

4.3 Measures taken since the serious incident

None

Payerne, 16 March 2015 Investigation Office STSB

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Berne, 31 March 2015

Annexes

Annex 1: CFDS – Post flight report

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+--------------------+
:    MAINTENANCE     :        DB/N
: POST FLIGHT REPORT :     SWR01
+--------------------+

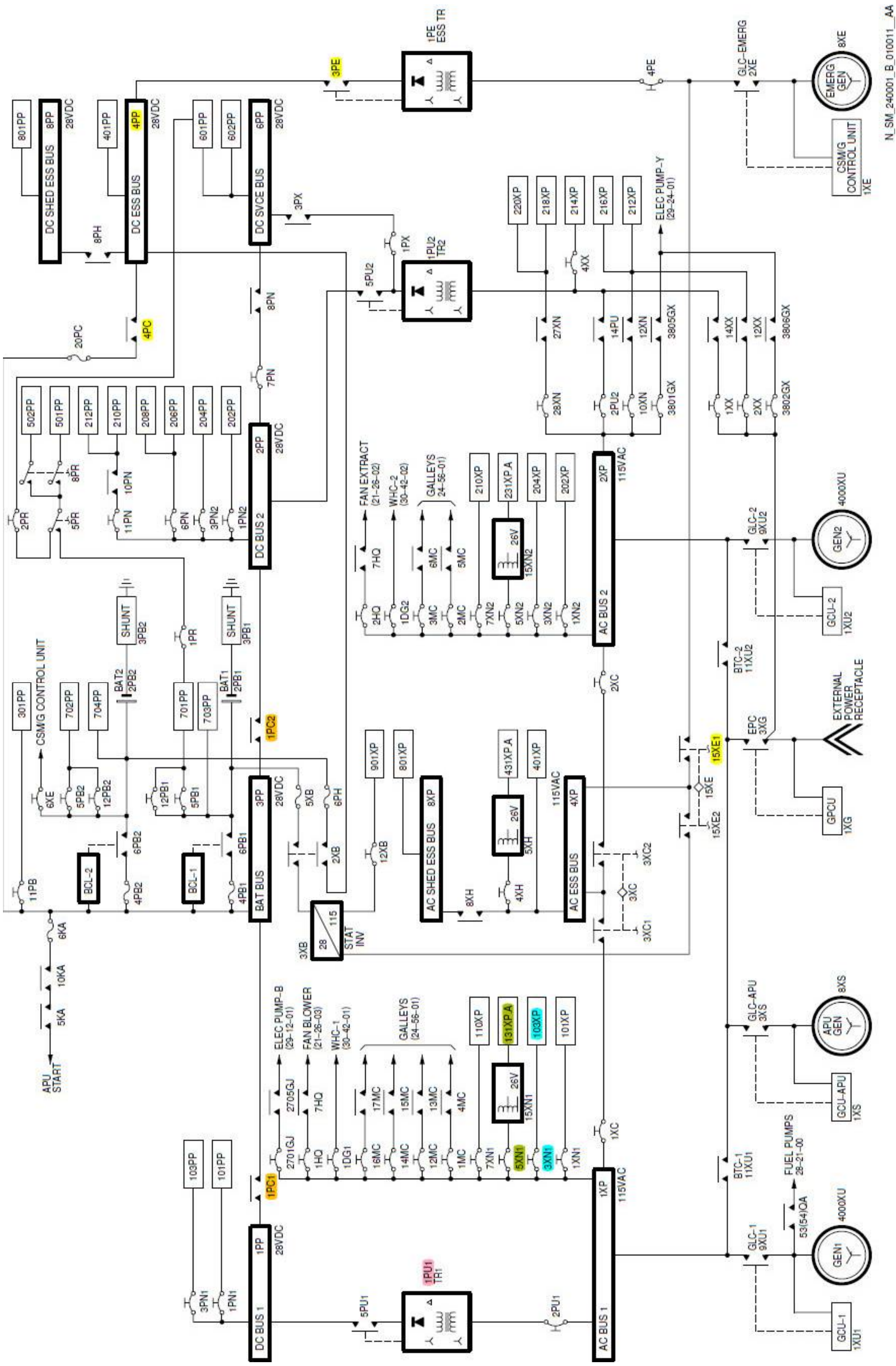
A/C ID   DATE    GMT        FLTN      CITY PAIR
.HB-IPX  11DEC   1206/1441  SWR250K   LSZH ESSA

ECAM WARNING MESSAGES
---------------------
```

Explanation	GMT	PH	ATA	
TR 1 off since 1334	1354	06	24-00	ELEC TR 1 FAULT
Loss of DC Bus 1	1354	06	21-63	COND
Loss of DC Bus 1	1355	06	24-00	ELEC DC BUS 1 FAULT
Loss of BAT Bus	1355	06	26-00	APU FIRE DET FAULT
Loss of BAT Bus	1355	06	26-00	APU FIRE LOOP A FAULT
TR 1 off since 1334	1355	06	24-00	ELEC TR 1 FAULT
Loss of DC Bus 1	1355	06	21-63	COND
Loss of DC Bus 1	1356	06	21-26	VENT BLOWER FAULT
CB AB11 tripped	1357	06	21-61	PACK 1
CB AB11 tripped	1357	06	34-00	NAV GPWS FAULT
CB AB11 tripped	1357	06	34-48	NAV GPWS TERR DET FAULT
CB AB11 tripped	1357	06	21-61	AIR PACK 1 REGUL FAULT
CB AB11 tripped	1357	06	23-00	COM ACARS FAULT
CB AB11 tripped	1357	06	30-31	ICE DETECT
CB AB11 tripped	1357	06	28-00	FUEL L TK PUMP 1 LO PR
CB AB11 tripped	1357	06	30-31	ANTI ICE STBY PITOT
CB AB11 tripped	1357	06	30-31	ANTI ICE STBY AOA
CB AB11 tripped	1358	06	21-63	COND ZONE REGUL FAULT
Temp loss of 131XP	1420	06	34-00	NAV ADR 3 FAULT (2)
Temp loss of 131XP	1421	06	27-00	F/CTL
Temp loss of 131XP	1421	06	34-00	ADR
Temp loss of AC ESS	1422	06	34-00	NAV ILS 1 FAULT
Temp loss of AC ESS	1422	06	31-00	FWS FWC 1 FAULT
Temp loss of AC ESS	1422	06	22-00	AUTO FLT FAC 1 FAULT
Temp loss of AC ESS	1422	06	26-00	SDCU
Temp loss of AC ESS	1422	06	34-00	NAV ILS 1 FAULT
CB AB11 tripped	1423	06	34-00	NAV GPWS FAULT
Temp loss of AC ESS	1423	06	21-26	VENT EXTRACT FAULT
Temp loss of AC ESS	1424	06	24-00	ELEC AC ESS BUS FAULT
Temp loss of AC ESS	1424	06	34-00	NAV ILS 1 FAULT
Temp loss of AC ESS	1424	06	31-00	FWS FWC 1 FAULT
Temp loss of AC ESS	1424	06	22-00	AUTO FLT FAC 1 FAULT
Temp loss of AC ESS	1424	06	26-00	SDCU
Temp loss of AC ESS	1424	06	34-00	NAV ILS 1 FAULT
CB AB11 tripped	1424	06	34-00	NAV GPWS FAULT
Temp loss of AC ESS	1425	06	21-26	VENT EXTRACT FAULT
other*	1427	06	22-00	AUTO FLT AP OFF
CB AB11 tripped	1440	08	77-00	ENG 1 REVERSER FAULT
CB AB11 tripped	1440	09	77-00	ENG 1 IGN B FAULT
CB AB11 tripped	1440	09	30-31	ANTI ICE STBY AOA

* Unintended touching of the side-stick by the co-pilot

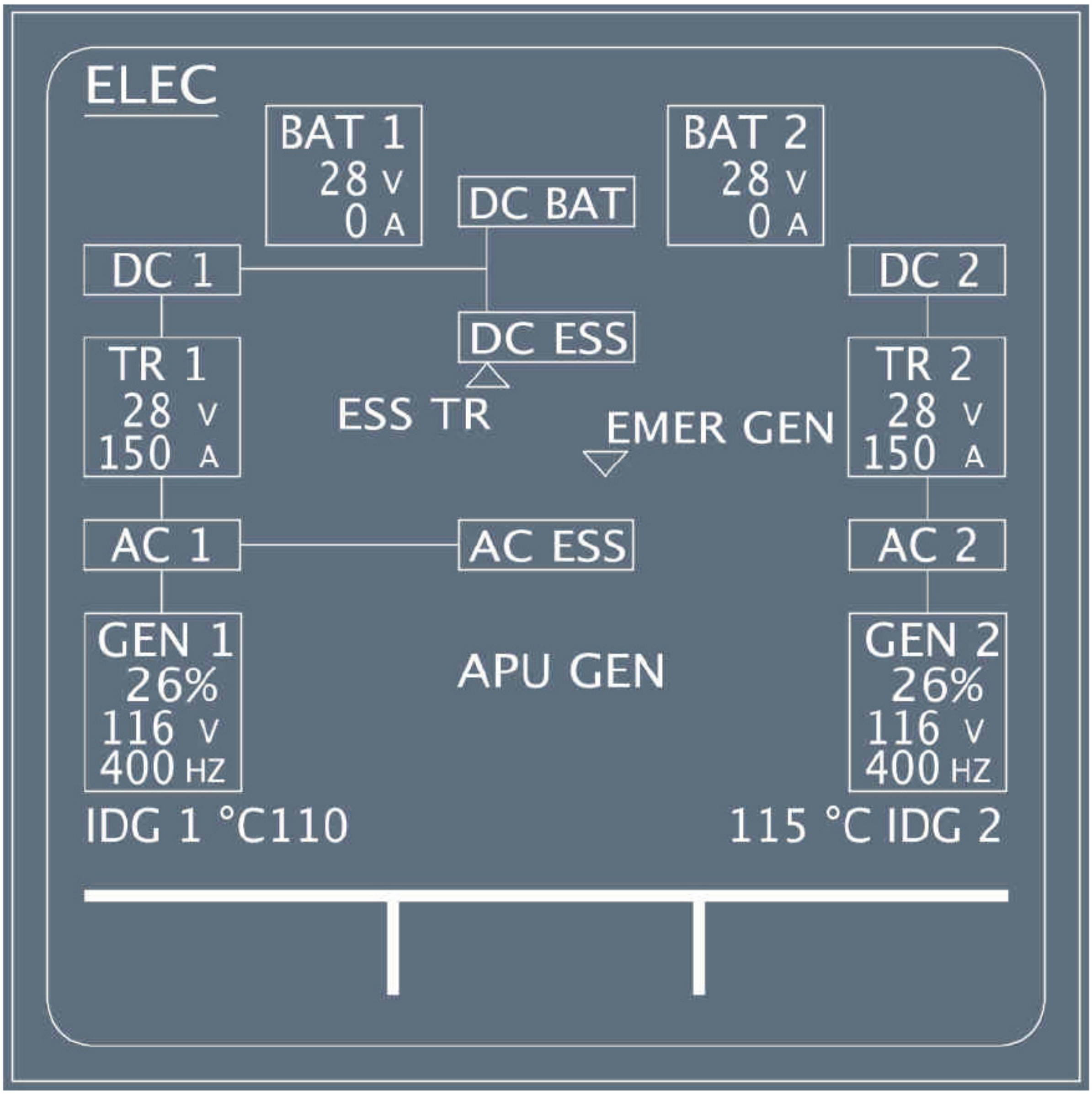
Annex 2: Block diagram of the electrical system



Note

The individual fault events (FE) are highlighted in colour: yellow (FE-1), orange FE-2 and 4 respectively, pink (FE-3), light blue (FE-5) and green (FE-6) (cf. Annex 5). Source: A318/A319/A320/A321, Aircraft Schematic Manual, Figure 24-00-01, P 0005, Sheet 1, “Generation and Distribution (AC/DC)”.

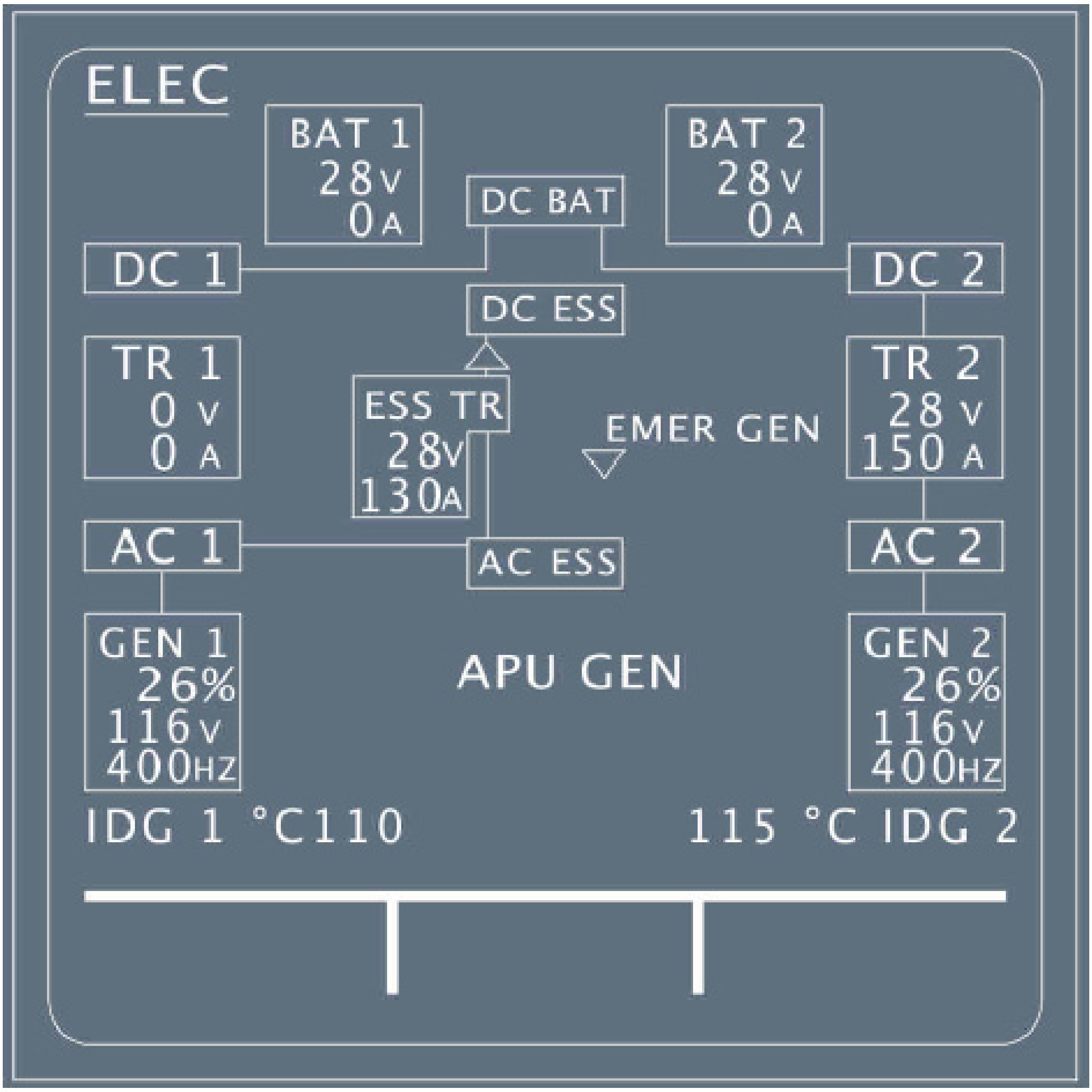
Annex 3: ECAM ELEC system page – Normal power supply



- Generator (GEN) 1 supplies AC BUS 1 and AC ESS BUS and transformer rectifier (TR) 1 with three-phase alternating current.
- Generator (GEN) 2 supplies AC BUS 2 and transformer rectifier (TR) 2 with three-phase alternating current.
- TR 1 supplies DC BUS 1, DC BAT BUS and DC ESS BUS with direct current.
- TR 2 supplies DC BUS 2 with direct current.
- The essential transformer rectifier (ESS TR) is in the standby mode.
- The batteries (BAT 1 and BAT 2) are charged as required via DC BAT BUS.
- The generator (APU GEN), driven by the auxiliary power unit (APU), is not in use.

Note: AC = alternating current
DC = direct current

Annex 4: ECAM ELEC system page – Power supply after 13:56 UTC



- Generator (GEN) 1 supplies AC BUS 1, AC ESS BUS and ESS TR with three-phase alternating current.
- Generator (GEN) 2 supplies AC BUS 2 and transformer rectifier (TR) 2 with three-phase alternating current.
- TR 1 is inactive.
- TR 2 supplies DC BUS 2, DC BAT BUS and DC BUS 1 with direct current.
- The essential transformer rectifier (ESS TR) supplies DC ESS BUS with direct current.
- The generator (APU GEN), driven by the auxiliary power unit (APU) is not in use.

Note: AC = alternating current
DC = direct current

Annex 5: Chronology of the fault events (FE)

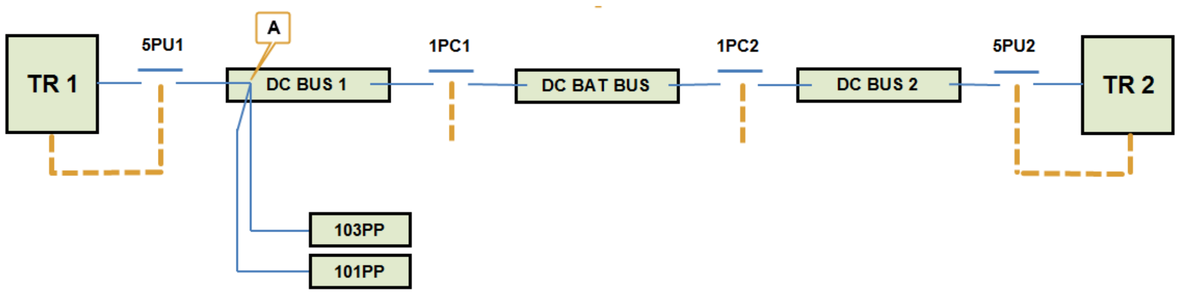
Note: This report contains many technical terms and abbreviations relating to the aircraft's electrical system. Annex 9 contains a glossary with the full text and explanations.

FE	UTC	Fault event	Consequences
1	12:39:20	Sub-busbar 103PP experienced voltage lowering for a short time (>100 ms, <5 seconds).	Contactor 15XE1 was closed. The ESS TR was activated. Contactor 3PE closed. Contactor 4PC opened. From this point onwards, the DC ESS BUS (4PP) was supplied from the ESS TR. This switchover had no effect on the power supply to systems. The change in configuration was displayed on the ECAM display but was not mentioned by the crew.
2	13:13 to 13:30	The DC BAT BUS was supplied several times from TR 2 and then again from TR 1 (contactor 1PC1 and 1PC2 opened and closed alternately).	The following alerts were displayed to the crew (intermittently): "DC BUS 1 FAULT" "BRAKE SYSTEM 1 FAULT" "BLOWER FAULT" "EXTRACT FAN FAULT"
3	13:34:18	TR 1 switched off (contactor 5PU1 opened).	Contactor 1PC2 closed. 1PC1 remained closed. DC BUS 1 and DC BAT BUS were powered from TR 2 (via DC BUS 2). The change in configuration was displayed on the ECAM display.
4	13:34:20 to 13:55:42	Multiple voltage lowering events on DC BUS 1 and DC BAT BUS, even though these were being powered by TR 2.	According to the post flight report (cf. Annex 1) additional warning messages were generated: "APU FIRE DET FAULT" "APU FIRE LOOP A FAULT" and the CARGO DISCH indicator lights illuminated. The side stick solenoid on the co-pilot's side was audibly actuated several times. The side stick itself remained inactive. After 13:56 UTC there was normal power supply at DC BUS 1 and DC BAT BUS; Annex 4 shows the configuration after 13:56 UTC.
5	13:57:41	Circuit breaker AB11 (3XN1) tripped automatically. Bus 103XP was de-energised.	Failure of various systems (cf. Annex 1), including the temperature control in the cockpit and the integral lighting in various control panels.
6	14:20 to 14:21 14:22 to 14:25	Bus 131XP failed briefly. AC ESS BUS failed briefly several times.	Temporary failure of various systems (cf. Annex 1). Among other things, the PFD and ND on the commander's side and the upper ECAM display failed temporarily.

<u>Comments</u>

The following faults go back to the tripping of circuit breaker AB11 at 13:57:41 UTC:
- During the descent, the ENG 1 "ON" light on the anti-ice panel did not illuminate.
- During the landing at Stockholm Arlanda (ESSA) the left engine reverser did not function.

Annex 6: Simplified representation of the BAT BUS switching logic



Normal power supply:

- 5PU1, 5PU2 and 1PC1 are closed
- 1PC2 is open
- TR 1 supplies DC BUS 1 and DC BAT BUS
- TR 2 supplies DC BUS 2.

Voltage lowering at sub bus 103PP, for less than 5 seconds[17]:

- 5PU1 and 5PU2 remain closed
- 1PC1 opens
- 1PC2 closes
- TR 2 supplies DC BUS 2 and BAT BUS

Voltage at sub bus 103PP normalises:

- 5PU1 and 5PU2 remain closed
- 1PC1 closes
- 1PC2 opens
- TR 1 supplies DC BUS 1 and BAT BUS
- TR 2 supplies DC BUS 2

TR 1 "FAULT" status[18]**:**

- 5PU1 opens
- 5PU2 remains closed
- 1PC1 remains closed
- 1PC2 closes
- TR 2 supplies DC BUS 2, BAT BUS and DC BUS 1

TR 2 "FAULT" status:

- As for TR 1 "FAULT" status, i.e. TR 1 supplies DC BUS 1, BAT BUS and DC BUS 2

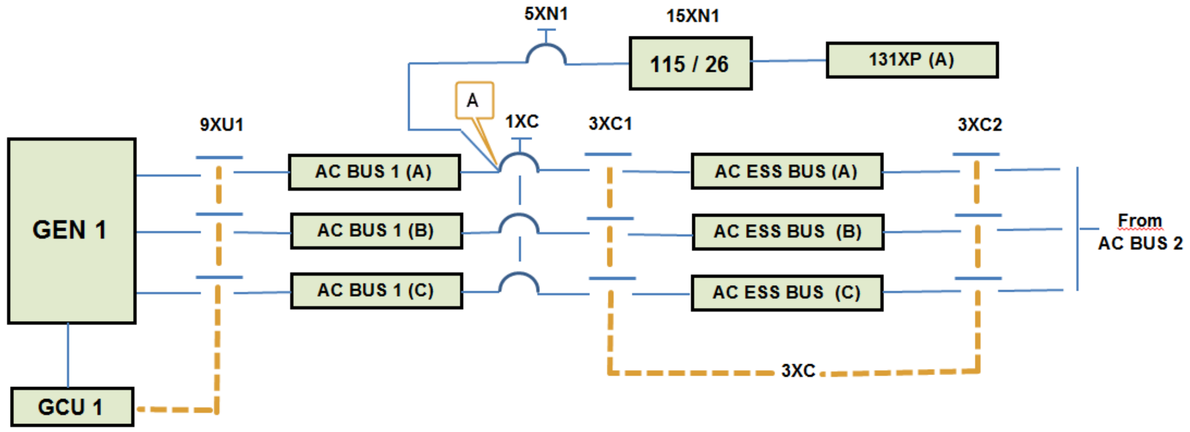
Point "A":

Point at which a loose contact was suspected. A detailed visual inspection of the corresponding connections on the aircraft was carried out. Result: no irregularities were detected.

[17] This scenario happened once at 12:39:20 UTC and was repeated several times between 13:13 and 13:30 UTC (cf. Annex 5).

[18] "FAULT" status means: Overtemperature in the TR or current falls below a defined value for more than 5 seconds.

Annex 7: Simplified representation of the AC ESS BUS switching logic



Normal power supply:

- 9XU1 is closed
- 3XC1 is closed
- 3XC2 is open
- GEN 1 supplies AC BUS 1 and AC ESS BUS with three-phase alternating current
- GEN 1 supplies various sub busses (including 103XP) via AC BUS 1
- GEN 1 supplies sub bus 131XP via AC BUS 1 and transformer 15XN1
- GEN 2 supplies AC BUS 2 with three-phase alternating current

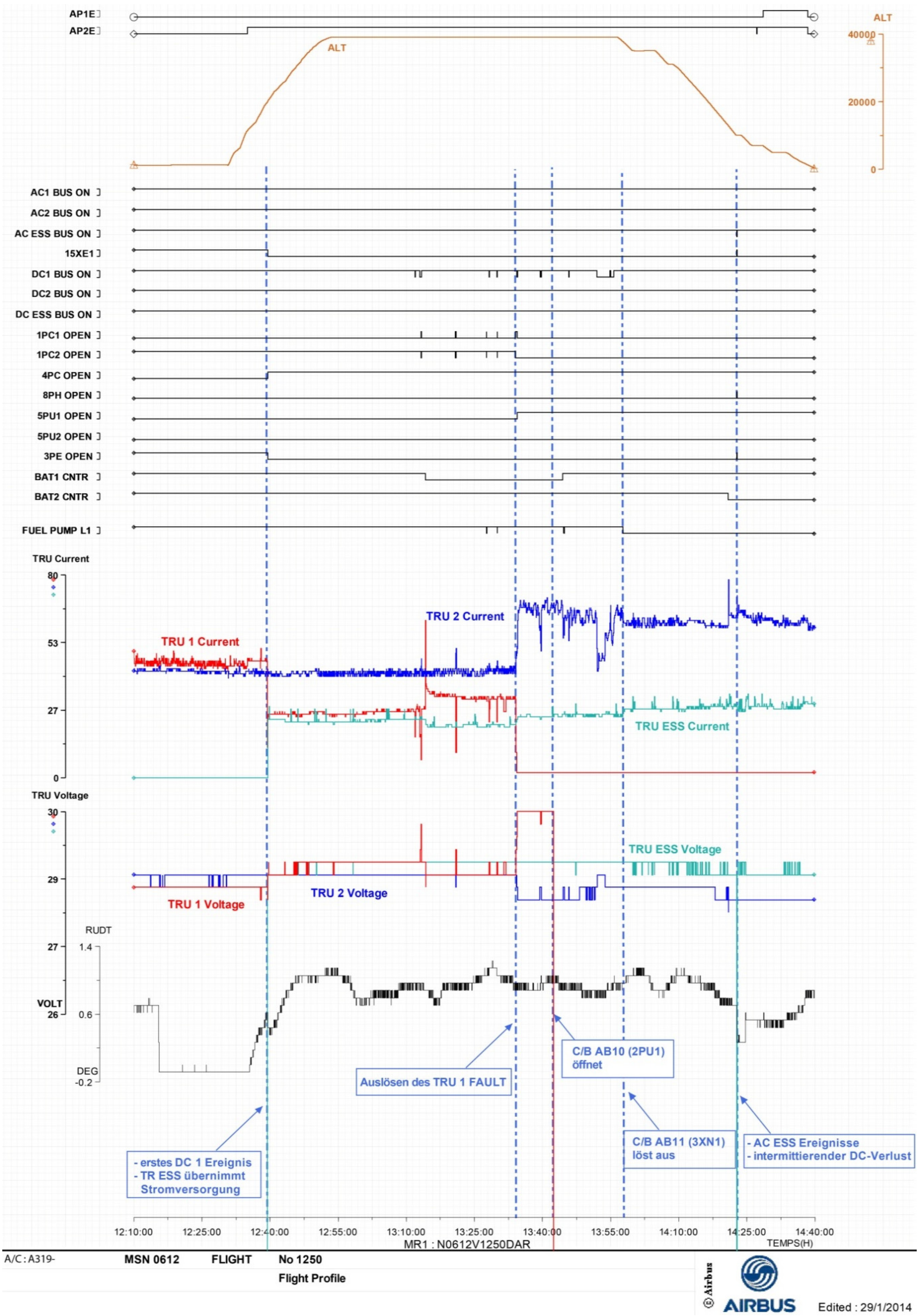
AC BUS 1 fails:

- 3XC1 opens
- 3XC2 closes (automatic operation, can be carried out manually if necessary)
- GEN 2 supplies AC BUS 2 and AC ESS BUS with three-phase alternating current

Point “A”:

Point at which a loose contact was suspected. A detailed visual inspection of the corresponding connections on the aircraft was carried out. Result: no irregularities were detected.

Annex 8: DAR recordings of flight LX 1250



Annex 9: Glossary

Abbreviation	Term	Explanations
AP	Auto pilot	Automatic flight guidance system
AC BUS 1	Alternating current bus 1	Alternating current bus 1, supplies the commander’s systems, among other things
AC BUS 2	Alternating current bus 2	Alternating current bus 2, supplies the co-pilot’s systems, among other things
AC ESS BUS	Alternating current essential bus	Alternating current bus for essential systems
ACARS	Aircraft communications addressing and reporting system	Data transmission system
APU	Auxiliary power unit	Auxiliary power unit
APU GEN	Auxiliary power unit generator	Three-phase alternating current generator (400 Hz), generates 115 / 200 volts
CB	Circuit breaker	Circuit breaker, provides overcurrent protection
DC BAT BUS	Direct current battery bus	Direct current bus, can be supplied from DC BUS 1, DC BUS 2 or the on-board batteries (high priority)
DC BUS 1	Direct current bus 1	Direct current bus 1, supplies the commander's systems, among other things
DC BUS 2	Direct current bus 2	Direct current bus 2, supplies the co-pilot’s systems, among other things
DC BUS 1 FAULT	Direct current bus 1 fault	Fault on direct current bus 1
DC ESS BUS	Direct current essential bus	Direct current bus for essential systems
ECAM	Electronic centralized aircraft monitor	Central monitoring of aircraft systems
EFIS	Electronic flight instrument system	Electronic flight instrument system, includes two ND and two PFD
ESS TR	Essential transformer rectifier	Transformer rectifier; 115 volts AC to 28 volts DC for essential systems, normally in standby state.
EXT PWR	External power	External power supply (e.g. when docked)
GEN 1	Generator 1	Three-phase alternating current generator (400 Hz), generates 115 / 200 volts
GEN 2	Generator 2	Three-phase alternating current generator (400 Hz), generates 115 / 200 volts
ND	Navigation display	Screen for navigation data
PFD	Primary flight display	Screen for primary flight data (attitude, altitude, airspeed)
SUB BUS	Sub bus	Auxiliary bus (e.g. 131XP)
TR 1 / 2	Transformer rectifier 1 / 2	Transformer rectifier; 115 volts AC to 28 volts DC.