

A defective contact — a minor component of a control unit in the Airbus A319-111 electrical power generating system — was identified as the likely cause of an intermittent current-sensing fault that cascaded into an extensive malfunction and left the flight crew without several major systems and unable to communicate with air traffic control.

The severe consequences of the malfunction and the crew's unsuccessful attempts to restore the electrical system were among the findings of the incident investigation that prompted the U.K. Air Accidents Investigation Branch (AAIB) to issue a raft of recommendations that included modifications of the electrical system and its associated minimum equipment list (MEL) provisions, and re-

vision of transport airplane certification standards.

The serious incident occurred on Sept. 15, 2006, during a scheduled flight with 138 passengers and six crewmembers from Alicante, Spain, to Bristol, England. The commander, 42, had 8,800 flight hours, including 393 hours in type. The copilot, 34, had 3,208 flight hours, including 560 hours in type.

Partial-Panel Puzzle

The A319 pilots were powerless to rectify an electrical system gone haywire.

BY MARK LACAGNINA





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The aircraft, operated by easyJet, was less than a year old and had accumulated 1,962 hours of service. It had an “enhanced” electrical power generation system, which is similar to the “classic” system originally used in A320-series aircraft, including the A319 and A321, but has different integrated drive generators with control units providing extra monitoring and control functions.

Independent Networks

A brief description of the electrical system might help in understanding what happened during the incident flight. The system, designed by Hamilton Sundstrand, has two main networks, no. 1 and no. 2. Each network has an engine-driven, 90 kVA (kilovolt-ampere) alternating-current (AC) integrated drive generator (IDG).

Figure 1 (p. 18) shows the system in normal operation, with both engine-driven generators — labeled “IDG1” and “IDG2” in the diagram — on line, the generator line contactors (“GLC1” and “GLC2”) closed and the transfer bus tie contactors (“BTC1” and “BTC2”) open, resulting in each generator powering its own network.

The AC current is converted downstream by transformer rectifiers into 28-volt direct current (DC).

“The no. 1 and no. 2 networks are normally independent of one another, so that the failure of one network should not adversely affect the other,” the report said. “Each generator is individually capable of supplying the aircraft’s electrical requirements after automatic shedding of some galley loads.”

Three instrument displays were among more than 100 components and systems lost in flight.

In addition to powering the no. 1 AC bus and DC bus, the no. 1 generator powers the AC and DC *essential* buses, which feed the aircraft’s most critical electrical subsystems and components.

A 90-kVA auxiliary power unit (APU) AC generator can be used on the ground or in the air to substitute for either of the engine-driven generators. Another in-flight backup is a 5-kVA emergency generator that is driven hydraulically by a ram air turbine (RAT). “The RAT deploys either automatically, usually because of loss of both main AC bus bars, or on manual selection,” the report said.

The electrical system normally is operated automatically by generator and APU control units that govern the associated line contactors and transfer bus tie contactors. Manual operation is accomplished via an overhead control panel on the flight deck.

The system also incorporates two 24-volt, 23-ampere-hour batteries, each of which has a “hot” bus that supplies power continuously to components such as the no. 2 air data and inertial reference system (ADIRS), the parking brake, the engine and APU fire-suppression systems, and the elevator/aileron computer.

Previous Trips

The aircraft’s no. 1 engine-driven generator had tripped off line during a flight to London Stansted Airport the day before the incident, and the generator control unit was replaced that night. The generator tripped off line during subsequent maintenance ground tests, but it was successfully reset, and the aircraft was released for service.

The next morning, the no. 1 generator tripped off line again about 20 minutes after the A319 departed from London for a flight to Alicante. The pilots — not the same as those on the later incident flight — performed the corrective actions displayed by the electronic centralized aircraft monitor (ECAM), including one attempt to reset the generator. The attempt was unsuccessful, so the crew isolated the generator and engaged the APU. Maintenance personnel advised the crew by radio that the flight could be continued with the electrical system in this configuration.

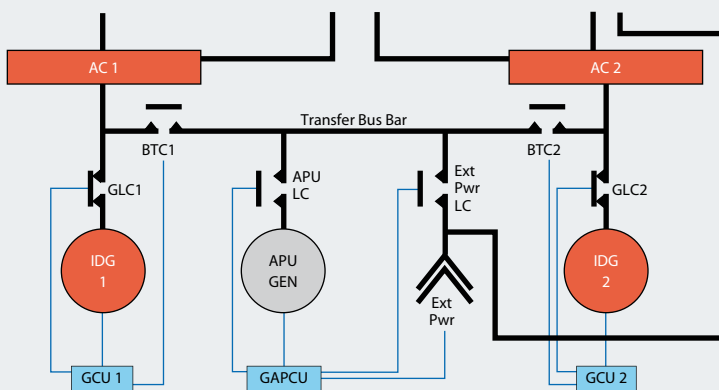
A company engineer in Alicante determined that the malfunction was an acceptable deferred defect under the provisions of the MEL and that the aircraft could continue in service with the no. 1 generator inoperative provided that the APU was operational — to substitute for the inoperative generator — and that the aircraft be flown no higher than Flight Level (FL) 335 (approximately 33,500 ft).

The MEL did not require maintenance action, an investigation of why the generator tripped off line or a review of previous electrical system faults, the report said.

In the dispatch configuration, the no. 1 generator line contactor was open, the APU line contactor was closed, and the no. 1 transfer bus tie contactor was closed, allowing the APU to power the no. 1 network.

“When the two flight crews changed over aircraft at Alicante, the respective commanders had a short discussion about the no. 1 generator problem,” the report said. “A flight plan was filed for FL 320 for the flight from Alicante to Bristol, and the commander asked for extra fuel to be uplifted, to allow for the additional fuel burn of the APU during the flight.”

Normal Configuration of the A319 Electrical System



Note: Instead of the normal configuration, the incident aircraft was dispatched for the flight from Spain to England with the no. 1 integrated drive generator (“IDG1”) inoperative and the auxiliary power unit (“APU GEN”) engaged; the no. 1 generator line contactor (“GLC1”) was open, the APU line contactor (“APU LC”) was closed and the no. 1 transfer bus tie contactor (“BTC1”) was closed.

Source: U.K. Air Accidents Investigation Branch

Figure 1

Loud ‘Clunk’

The A319 departed from Alicante at 0926 coordinated universal time as Flight EZY6074. The commander was the pilot flying. The aircraft was in visual meteorological conditions (VMC) at FL 320 near Nantes, France, at 1052 when the crew heard a loud “clunk” and several systems became inoperative.

“The commander’s initial assumption was that either the APU had shut down or the APU generator had failed,” the report said. “He saw that his own electronic instrument displays had blanked and so, after checking that the copilot’s instruments were available, handed over control. The copilot flew the aircraft manually, using manual thrust and without the flight director, which had disappeared.”

Figure 2 shows the condition of the electrical system immediately after the malfunction. Basically, the no. 1 network had been de-energized. The no. 1 transfer bus tie contactor — labeled “BTC1” in the diagram — had opened, isolating the APU generator, which was still operating but was now unable to power the network.

The report lists more than 100 systems and components that were rendered inoperative by the malfunction. Among them were the commander’s primary flight display and navigation display, the no. 1 transponder, the multipurpose control and display unit, the autopilot, the auto-throttles, and most of the captions (annunciators) and lights on the overhead panel.

The ECAM displayed the corrective action: resetting the “AC ESS FEED” selector from normal to alternate. This action was intended to reset the AC essential feed contactor and allow the AC essential bus — and most of the other buses on the no. 1 network — to be powered by the no. 2 engine-driven generator.

Manual Correction Required

The report noted that restoration of the electrical system in A320-series aircraft following such a malfunction is a *manual* operation that requires about one minute, according to Airbus. However, if the no. 1 AC bus fails in newer Airbus models,

Post-Malfunction Configuration of the A319 Electrical System

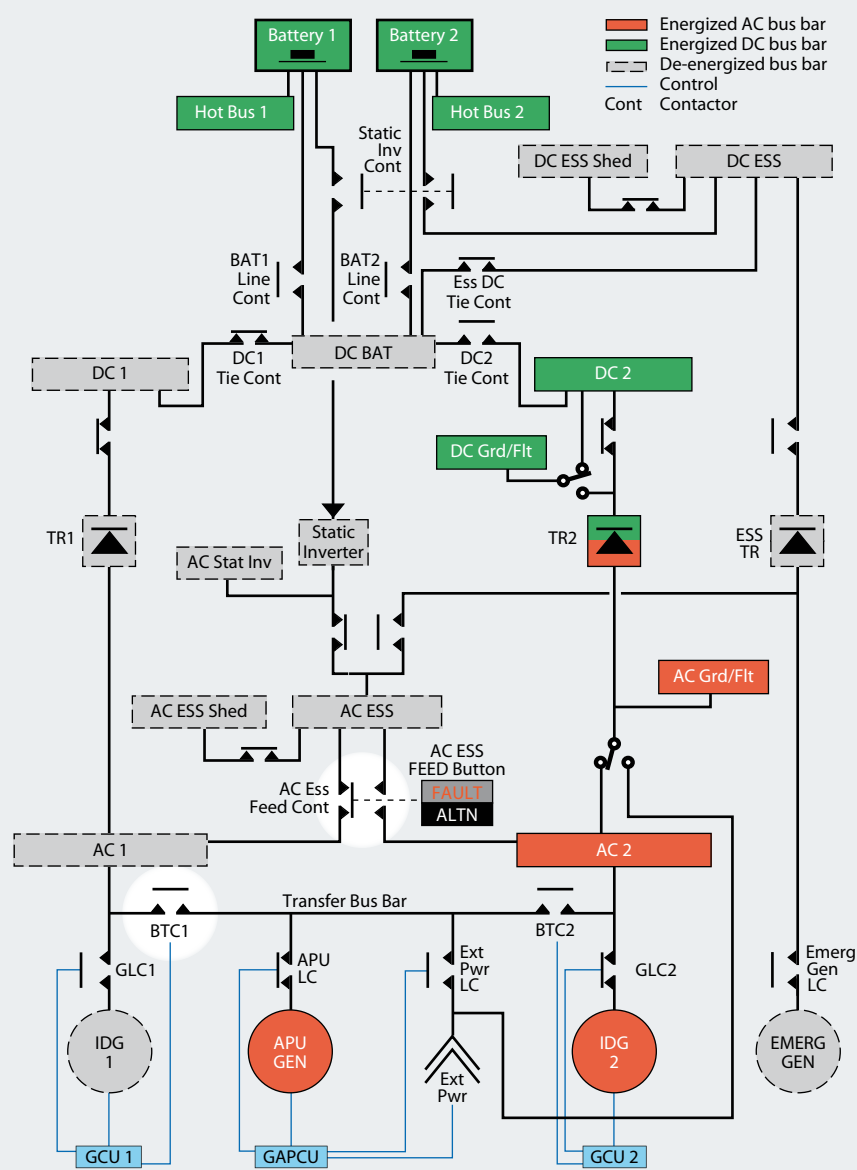


Figure 2

the AC essential bus *automatically* is switched to the no. 2 AC bus.

Before attempting to manually restore power to the AC essential bus, the commander noticed that neither of the two captions on the "AC ESS FEED" selector was illuminated. "He also noted

that there were now no lights showing on the overhead panel, except for the 'ON BATTERY' caption light on the ADIRS panel," the report said. "These observations by the commander were confirmed by the copilot, who was monitoring the ECAM actions." The ADIRS,

which is on a hot battery bus, continued to provide navigation guidance.

The selectors on the overhead electrical system control panel are push-button switches. "The physical position of the button does not change significantly between settings," the report said. "When a push-button is released, its physical depression varies by only 1–2 mm [0.04–0.08 in]. ... Annunciator captions in each push-button illuminate to indicate the status or fault condition of the associated function."

The commander pressed the "AC ESS FEED" push-button but noticed no effect. "The push-button selector switch caption remained unlit, and the electrical system failed to reconfigure," the report said. "He stated that he was unable to verify the selection made on the switch ('ALTN' or 'NORMAL') because the button does not remain depressed after making a selection."

The ECAM also indicated that the RAT "was operating, although it had not actually deployed," the report said.

Incommunicado

The commander also noticed that the lights on his radio management panel and both audio control panels no longer were illuminated. He attempted unsuccessfully to contact the Brest (France) Air Traffic Control Center (ATCC) on the no. 1 and no. 2 VHF radios, using the previously assigned frequency. He then declared an emergency on 121.5 MHz but received no response.

"The copilot attempted the same using [his radio management panel], but this also proved unsuccessful," the report said. "The commander then tried switching to the [no. 3 audio control panel] but was still unable to re-establish communications with Brest ATCC."

The crew's efforts to contact ATC likely were driven by concerns related to "the current safety climate," the report said. "They were concerned that they might be intercepted by military aircraft because of the loss of radio communications and that, given the aircraft's degraded status, they might not be able to follow an interceptor or land at another airfield.

"Furthermore, they were concerned that if they deviated from a flight-planned route to divert to an en route airfield, it might be considered a hostile action, which could lead to offensive measures being taken against their aircraft."

The crew's efforts to re-establish radio communication with ATC had the unfavorable result of interrupting and delaying their compliance with the corrective actions displayed by

the ECAM. Consequently, 10 minutes elapsed from the onset of the electrical system malfunction to the commander's selection of the no. 2 transponder, which was on a bus on the no. 2 network and therefore operable. He also selected the emergency transponder code, 7700. However, the crew did not know if the transponder signal was being received by ATC.

Brest ATCC did not have primary radar, and when the secondary radar returns from the aircraft's transponder ceased, the controller handling the aircraft made several attempts to contact the crew by radio. The controller then instructed the flight crew of another aircraft that was westbound at FL 320 to descend to FL 310. A few moments later, one of the pilots in the westbound aircraft told the controller that an easyJet aircraft had passed overhead, northbound.

"The radar controllers were relieved that the [A319] had been found but also alarmed that it had come so close to another aircraft," the report said. At the closest distance, the A319 was 600 ft above the other aircraft and about 2.7 nm (5.0 km) north.

The commander's selection of the no. 2 transponder was successful. Secondary radar contact resumed at about 1103, but radio communication with the aircraft was not re-established.

Pressing Ahead

After reviewing the ECAM messages and the actions that had been taken to restore the inoperative systems and components, the commander made another attempt to reset the AC essential bus feed switch. Again, he noticed no effect.

He consulted the landing performance data in the quick reference handbook and found that the aircraft could be landed safely on the runway at Bristol. "The pilots had already received the weather forecast for Bristol, which was favorable [with visibility more than 10 km (6 mi) and a few clouds at 1,000 ft], and realized that they would not be able to obtain weather information if they diverted," the report said. "The commander thus decided that the best course of action was to continue to Bristol."

Airbus A319



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The A319 is a member of a family of narrowbody, twin-engine, short- to medium-range airliners featuring fly-by-wire flight control systems with sidestick controllers and major primary structures built with composite materials.

The A320 was introduced first, in 1988. The A321, the stretched version, followed in 1993. The A319, which is 3.8 m (12.5 ft) shorter than the A320, entered service in 1996. Maximum passenger accommodations are 180, 220 and 145, respectively.

The incident aircraft is an A319-111, one of nine A319 models that include a corporate jet. It has CFM International CFM56-5B5 engines rated at 97.9 kN (22,014 lb). Standard maximum weights are 64,000 kg (141,094 lb) for takeoff and 61,000 kg (134,481 lb) for landing. Maximum operating speeds are 0.82 Mach and 350 kt. Maximum altitude is 39,000 ft.

Source: *Jane's All the World's Aircraft*

The copilot remained the pilot flying, and the crew was able to remain in VMC for the remainder of the flight, which was conducted according to their flight plan and the normal arrival profile at Bristol. Nearing Bristol, the commander made several unsuccessful attempts to contact ATC with a mobile telephone. However, ATC was tracking the aircraft on secondary radar and had cleared the area of all other aircraft.

The flaps extended normally, but “when the commander selected the landing gear down, none of the gear indicator lights illuminated, and there was no accompanying sound of landing gear deployment,” the report said. “He used the emergency gear extension system to extend the landing gear by gravity.

“Full flap was used for landing, and after touchdown heavy manual braking was applied. The aircraft stopped quickly. It was taxied to a parking stand, where a normal shutdown was attempted, but the engines continued to run after the master switches were selected off. The commander succeeded in shutting them down using the engine fire switches.”

History of Problems

Investigators were unable to determine why the flight crew was unable to restore the electrical system. “The system was subsequently found to operate normally, and testing of the relevant components uncovered no defects,” the report said. “However, it remained possible that a temporary anomaly, that was not repeated or uncovered, had prevented the system from producing the expected effect.”

The malfunction of the electrical system was traced to a defective contact in the no. 1 generator control unit (“GCU1” in the diagram), which performs system testing and monitoring as well as regulating the output of

the engine-driven generator and several system contactors.

The defect had caused the GCU to erroneously detect a “welded” generator line contactor, a condition that occurs if the contactor remains closed after being selected open. Consequently, the GCU locked the no. 1 transfer bus contactor open “to prevent it from closing and potentially creating a hazard by allowing other power sources to motor the IDG through the apparently closed [generator line contactor],” the report said.

This particular GCU had been installed in three different aircraft within a five-month period. “In each case, the unit remained in service for only a short time until it was removed because a fault had been indicated,” the report said.

The incident aircraft had experienced 10 electrical system problems in the month preceding the accident. They included failures of the APU generator to come on line, faults in the no. 1 generator and no. 1 APU control units, and a report of “severe electrical interruptions.”

The report said that a substantial number of control unit problems in the incident aircraft — and in other A320-series aircraft — apparently had been caused by defective static random access memory (SRAM) devices. Airbus in 2006 issued an operators’ information telex (OIT 999.0106/06) listing the serial numbers of 2,200 generator and APU control units potentially affected by the defective SRAM devices.

“Normal practice was for a [generator or APU control unit] rejected from service to be sent by the operator to an overhaul and repair facility and initially subjected to a standard acceptance test,” the report said. “A substantial proportion of such units passed the test and were consequently released back to service [with the notation] ‘no fault found.’” The facility kept no record of

units that were repeatedly rejected, then returned to service.

“Given the history of intermittent faults experienced on the A320-series [electrical systems] caused by [generator control unit] SRAM defects ... it is possible that maintenance personnel considered that the problem on the outbound flight was caused by an intermittent SRAM defect and was therefore not a serious issue,” the report said.

Noting that the incident aircraft was cruising in VMC when the malfunction occurred, the report said that the outcome might have been far more serious if the malfunction had occurred at low altitude during a critical phase of flight, such as approach or departure.

Based on the findings of the investigation, the AAIB issued 14 recommendations, including a call for modification of the A320-series electrical system to automate the transfer of power to the AC essential bus when the no. 1 AC bus is lost. Airbus responded with a service bulletin recommending such a modification, and the European Aviation Safety Agency told AAIB that it will issue an airworthiness directive mandating compliance with the manufacturer’s bulletin.

Among other recommendations were revision of certification standards to ensure that flight deck control selectors provide “immediate and unmistakable indication of the selected position”; reconsideration of A320-series master MEL provisions allowing dispatch with an inoperative engine-driven generator; and revision of maintenance procedures to ensure that control units with excessive rejection rates or recurrent faults are not returned to service. 🌀

This article is based on AAIB Accident Report 4/2009: “Report on the Serious Incident to Airbus A319-111, Registration G-EZAC, Near Nantes, France, on 15 September 2006.” The report is available at <www.aaib.gov.uk>.