Dual generator trip, Airbus A310-300 (P4ABU), Shannon Airport, August 24, 2002

Micro-summary: **This A310 had electrical problems and suffered a burst tire on landing.**

Event Date: **2002-08-24 at 0459 UTC**

Investigative Body: **Air Accident Investigation Unit (AAIU), Ireland**

Investigative Body's Web Site: **http://www.aaiu.ie/**

Cautions:

1. Accident reports can be and sometimes are revised. Be sure to consult the investigative agency for the latest version before basing anything significant on content (e.g., thesis, research, etc).

2. Readers are advised that each report is a glimpse of events at specific points in time. While broad themes permeate the causal events leading up to crashes, and we can learn from those, the specific regulatory and technological environments can and do change. ***Your company's flight operations manual is the final authority as to the safe operation of your aircraft!***

3. Reports may or may not represent reality. Many many non-scientific factors go into an investigation, including the magnitude of the event, the experience of the investigator, the political climate, relationship with the regulatory authority, technological and recovery capabilities, etc. It is recommended that the reader review all reports analytically. Even a "bad" report can be a very useful launching point for learning.

4. Contact us before reproducing or redistributing a report from this anthology. Individual countries have very differing views on copyright! We can advise you on the steps to follow.

AAIU Synoptic Report No: 2003-018
AAIU File No: 2002/0042
Published: 08/12/03

In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Accidents, on 24 August 2002, appointed Mr. John Hughes as the Investigator-in-Charge to carry out a Field Investigation into this occurrence and prepare a Synoptic Report.

Aircraft Type and Registration:	A310-300 P4ABU
No. and Type of Engines:	Two CF680C2
Aircraft Serial Number:	431
Year of Manufacture:	1987
Date and Time (UTC):	24 August 2002 04.59 hours
Location:	Runway 24, Shannon Airport.
Type of Flight:	Private VIP
Persons on Board:	10 Crew 13 Pax
Injuries:	None
Nature of Damage:	Burst tyre at position 8 on landing
Commanders Licence:	UK ATPL
Commanders Age:	64 years
Commanders Flying Experience:	22,000 hours
Information Source:	ATS Shannon

SYNOPSIS

P4ABU was established on the localiser for Runway 24, 12 NM from touchdown at 04:57 hours. The crew reported a technical problem and requested to remain on the approach frequency for radar guidance. The crew then reported the runway in sight and an electrical failure on board. The aircraft burst a starboard tyre on landing and the crew also subsequently reported brake damage. The aircraft taxied to the apron under its own power. The ATS at Shannon notified the Chief Inspector of Accidents. The nominated Inspector visited the aircraft the following day and interviewed the crew.

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft, which was registered in Aruba, South America, had taken off from Jeddah at 01:30 local time. The aircraft was bound for Washington with a technical stop at Shannon en route. Having established on the runway localiser for RWY 24 at Shannon the aircraft broke cloud at 1800 ft. The crew reported that at that time both generators failed. Afterwards, the Captain raised an entry in the aircraft log which read: *"On short finals, both generators off, AC Bus1 and AC Bus2 off, DC Normal Bus off. The only power available appeared to be from the Standby Generator"*.

The Captain said that as the runway was clearly in sight and the undercarriage gear down with flaps in the 20/20 configuration he decided to land immediately instead of initiating a missed approach. He did not wish to re-enter IMC conditions with limited instrumentation and electrics.

The PNF informed ATC that the crew had technical difficulties and requested the approach to be radar monitored. The radar controller observed the aircraft drifting left and right of the centre line. The crew requested that fire services be put on standby. A smooth landing was executed, but on touchdown No.8 main tyre burst. The time of landing was 04.59 hours.

As the aircraft came to a halt the fire services inspected the undercarriage gear. The Captain then decided to taxi the aircraft to the terminal area. There were no reported injuries during this incident. It is reported that the Captain said that the oil temperature of the No.2 Integrated Drive Generator (IDG) exceeded 330ºC after landing.

After the full stop on the runway the PNF started trouble shooting the electrical system but was unable to get GEN1 or GEN2 back on line. However, the APU generator powered the systems normally.

The passengers were transferred to another private aircraft at Shannon for the onward journey to the USA. The on board avionic flight mechanic received instructions on a troubleshooting process from the Operator's Contractor in Jordan.

A maintenance BITE test request from the Ground Power Control Unit (GPCU) indicated that both electrical generators had experienced a Shorted Rotating Diode (SRD) event during the flight. The IDG's were removed from the aircraft and replaced with serviceable items the following day.

1.2 Personnel Information

PF (Commander)

Personal Details	
Licence	UK ATPL
Last Periodic Check	17/04/02
Medical Certificate	Class 1, 02/04/02

Flying Experience:

Total all types	22,000	hours
Total all types PI	18,000	hours
Total on type	8500	hours
Total on type PI	8000	hours
Last 90 days	60	hours
Last 28 days	60	hours
Last 24 hours	7	hours

PNF

Personal Details	
Licence	LBA ATPL
Last Periodic Check	19/04/02
Medical Certificate	01/07/02

Flying Experience:

Total all types	21000	hours
Total all types PI	20000	hours
Total on type	5000 +	hours
Total on type PI	5000	hours
Last 90 days	60	hours
Last 28 days	60	hours
Last 24 hours	7	hours

1.3 General Aircraft Information

The electrical system consists of two 90 KVA engine driven brushless generators for normal single channel operation with automatic transfer of busbars in the event of a generator failure. Each has an overload rating of 135 KVA for 5 minutes or 180 KVA for 5 seconds.

A third generator is directly driven at constant speed by the APU and can be used in flight to compensate for the loss of one or both standard generators. DC power is generated via three 150 A transformer - rectifiers.

Standby power can be achieved by an AC/DC Standby Generator run from the "green" hydraulic engine driven pumps. This system should come on automatically if both generators fail. This supplies:

The AC Essential Bus (No.2 only)
The DC Essential Bus
The AC Emergency Bus

If both generators are lost, and the Standby Generator fails to start or come on line, an emergency electrical system automatically provides single-phase AC power through a static inverter from the DC Essential Bus to feed the Captain's flight instruments. However, in this case, the AC Essential Bus No. 2 (above) is not supplied.

A blue AC EMER ON INV light illuminates when AC EMER BUS is powered from the DC ESS BUS via the static inverter and the batteries are disconnected from the DC NORM BUS automatically.

There is also available a "Land Recovery" press-button switch which allows the recovery of power to certain systems and equipment for approach and landing. The FCOM states that this facility should be used when power is no longer available from the engine generators.

The BAT OVRD switch overrides the battery charge controller and forces all three aircraft batteries to connect directly to the DC ESS BUS.

The IDG can be disconnected from the engine gearbox in flight but once disconnected it can only be reconnected on the ground. The IDG oil temperature indication is green in normal operation and flashes between 142ºC and 185ºC. The amber IDG FAULT light illuminates, and the Master Caution warning comes on, in the case of:

IDG oil overheat (greater than 185ºC)
IDG low oil pressure (less than 140 psi)

1.4 Crew Comments

The pilot flying (PF) the aircraft said that he was absolutely certain that the crew received no indication of a fault what-so-ever before departure. They had no indication of any malfunction of the IDG prior to the incident. He said that he certainly would have remembered such a fault in his own endeavours to find some reason for the double generator failure. When all the bus warning lights came on the crew immediately thought there was a dead short across the complete electrical system. As the wheels were down, 20º of flap set, and the runway in sight, the Captains main concern was to land. The First Officer's flight instruments were all lost. Their worry was that this short might cause a fire. They decided to land immediately rather than start a troubleshooting process. They did not want to try troubleshooting on the approach or introducing another source of power which might have exacerbated the problem. For the same reason,

the crew did not press the "Land Recovery" button or the "Battery Overide" button at any time during this event. They were not aware of a flashing green light indicating that the IDG oil temperature had exceeded 142º C, nor a permanent amber light to indicate that the temperature had exceeded 185º C.

In his report to the Investigation the Captain said that *"the aircraft broke cloud at 1800ft, both generators failed resulting in failure of AC Bus1, AC Bus2 and Normal Bus. It appeared that only the emergency Bus was powered by the S/B inverter."*

1.5 Aircraft Maintenance

The aircraft had undergone an "A" check on 26 May '02. The following work on both IDGs had been carried out and signed for:

"Replace scavange filter, drain IDG and replenish oil"

A few days prior to this incident the technical support of the aircraft was transferred to a contractor in Jordan. This incident occurred during the handover period where engineers from both the previous contractor and the new contractor were onboard. The airframe hours at the time of the incident was 5770 hours.

It was stated by the Captain that both IDGs had been serviced on the day prior to this flight.

1.6 Tests and Research

The IDGs were removed and sent to the manufacturers in the USA for investigation and repair. The Generator Control Units were also removed at the first opportunity (12 flights later) and returned to the manufacturers repair facility in France for extraction of the Non Volatile Memory (NVM) contents. The data extracted from the NVM of both GCUs was examined and compared with the findings of the IDG investigation in order to offer the most probable series of events. Both GCUs contained fault history identifying Shorted Rotating Diodes (SRD) trips during the event flight. The GCU controlling the left IDG also identified that an SRD condition had been detected during the previous flight.

A Report on the above items concluded that:

" the Right IDG was the first channel to trip during the final approach. This IDG was found to have three shorted diodes from a total of six. In this condition, an IDG would not be capable of carrying load and would most likely de-excite the generator almost immediately. The IDG investigation also found evidence of Jet fuel contamination in the oil. This contamination would have an adverse effect on the oil cooling to the diode pack itself, and likely exacerbated the failure. This is corroborated

by the Captains observation, that the number 2 (right) IDG was at 330 deg C after landing.

Upon tripping its line contactor and associated Generator Control Relay, both the left and right Bus Tie Contactors (BTC) would automatically close, allowing the Left IDG to supply both main AC load busses. As the left IDG was already compromised due to the SRD occurrence on the previous flight, it is likely that the resultant increased load demand and consequential increase in current through the exciter, caused the software based SRD equation requirements to become satisfied, and the second channel tripped within 2.5 seconds from the first. This would appear to the flight crew as being a more or less simultaneous loss of electrical power."

1.7 Laboratory Report

A detailed materials lab report included the following:

The right IDG was the initiating unit that tripped first. Inspection of the generator revealed three shorted diodes. A strong odour of jet fuel caused the IDG to be completely torn down to inspect for damage and to ensure that the residual jet fuel was removed from all the components. During this inspection, a blackish residue was observed on the rotor poles and stator. Two shorted diodes were found in the left IDG.

Oil samples from both units and deposits removed from the rotor poles and stator of the right IDG were submitted to Mass Spectroscopy Examination (MSE) to determine the amount of jet fuel present in the oils and composition of the deposits.

Approximately 20% Jet A aviation fuel was found in the oil sample removed from the right IDG. No fuel was detected in the sample from the left IDG.

The deposits found on the rotor poles and stator of the right IDG were identified as oil degradation products/coked oil. The coked oil is the product of oxidation and thermal breakdown at elevated temperatures. Carbon, oxygen, nitrogen and phosphorus present in the deposits were indicative of oil degradation from both the base oil and oil additives. The presence of copper and lead found, likely stems from minute wear debris. No evidence was found to suggest fuel contamination caused the deposit formation.

1.8 Generator Manufacturer's Repair Report

The repair reports did not contain histories of the IDGs such as hours flown, time since overhaul or time since repair as these did not appear to be available. The left IDG was completely disassembled for overhaul due to the lack of available maintenance history and evidence that it had been in service for a high amount of calendar time. The right IDG was

completely torn down in order to inspect for any damage and to ensure that the residual jet fuel was removed from all components.

1.9 Generator Manufacturer's Recommendations

The IDG manufacturer recommended that in the event of an SRD condition being detected, that the appropriate action per the Airbus AMM. is followed. This action recommends replacement of the IDG. It was their further recommendation that IDGs, with a manufacturing date of 1991 or earlier, be checked for incorporation of Mod dot 40. This change, issued as a Service Bulletin, incorporates a 100-ohm special resistor assembly instead of the original 50-ohm resistor assembly and 1600 volt diodes installed as a product improvement over the previous 600 volt diodes. Incorporation of the bulletin results in improved reliability of the IDG.

However they state that, *"the incorporation of this bulletin is optional, based on operator's experience"*

The change has been incorporated on the defective IDGs as part of the repair and overhaul.

1.10 Contractor's Comments

The new aircraft contractor said that the fuel leak into the IDG oil cooler would have been internal and slow. Such a fault could only be discovered during the previous "C" check where the maintenance program requires that the fuel oil cooler be removed for inspection and cleaning.

The contractor also stated that NVM for the left IDG showed that a fault of SRD existed prior to the subject flight. They said that this most probably occurred during the ground taxi run, while positioning from the parking area to the pick-up point at Jeddah. Since the aircraft departed with both generators operational, it was assumed that sometime between ground failure and the beginning of the subject flight, the generator was reset from the cockpit without further investigation.

1.11 Aircraft Manufacturer's Comment

The aircraft manufacturer stated that in the case of a "Short Rotating Diode", the Electronic Centralized Aircraft Monitoring (ECAM) system will show a GEN FAULT warning which is displayed to the flying crew who then have to apply the ECAM procedure. This procedure is to switch OFF the generator and then try to bring the generator back on line by depressing the generator push-button again. The FCOM states that a GEN FAULT warning may result from a transient fault condition. Resetting the generator off and then on, may be successful in recovering the affected generator.

If after the reset, the diode is still in short circuit, the generator will not come back on line.

If after the reset, the diode goes into open circuit, the generator will come back on line. In this case, as the Short Rotating Diode fault has been recorded in the GPCU NVM, the GPCU BITE DISPLAY, located on the electrical power maintenance panel, will be set to ON. The exact code of the fault can then be retrieved by maintenance staff on the display window located on the front face of the GPCU. Even if the generator has been successfully reset, the Trouble Shooting Manual(TSM) indicates that for a trip code of "EA" the IDG should be replaced.

The IDG oil cooling system should be removed, cleaned and reinstalled every 4C check with oil changes every 2A check. The FO's EFIS and FMS systems are supplied by AC Bus 2 and would have been lost during this event. The Captain's PFD (Primary Flight Display) will remain available when supplied by the AC EMER BUS and his ND (Navigation Display) will remain available when its CRT is supplied by the AC ESS BUS.

The manufacturer also stated that with the Standby Generator operative, the QRH for the aircraft allows for the recovery of services to ND1, DME1, FMS1, PITCH FEEL1, RUDDER TRAVEL1, PITCH TRIM1, YAW DAMPER1, HF1, including some fuel pumps.

Also the FCOM procedure recommends the setting of the "Land Recovery" switch to ON if both generators are lost. Switching to ON restores Spoilers and Speedbrakes 1,4,6 and 7, Fowler flaps, Slats and Anti-skid system. Power to the Krueger flaps (nearest to wing root) however, remains lost.

2. ANALYSIS

2.1 According to the manufacturer, a generator with damaged rotating diodes can connect to its busbar and will operate with degraded performance. Under this condition, the generator can carry its normal bus loads but will not sustain the maximum design load it is designed to withstand. It is noted that on the flight prior to the event, the left IDG non-volatile memory logged two occurrences of an SRD fault. The A310 Trouble Shooting manual (24-00-00) indicates that a "Gen Diode/Field" trip annunciation may require the immediate replacement of the IDG. However, the generator was reset and such indications were not carried forward on the Tech Log for this aircraft.

The hours flown for this aircraft were 5770 hours. The IDGs were on the aircraft since aircraft manufacture in 1987. The fact that there was fuel found in the right IDG which seeped in from the oil cooler casts doubts on the previous maintenance practices on this aircraft especially during heavier maintenance visits where a seepage into the oil cooler was more likely to be discovered. It is also likely that the oil which was replaced during servicing in May 2002 could have contained quantities of fuel. Both generators were substandard without the crew being aware of this at take-

off. With high-tech diagnostic circuitry installed on this aircraft, this should not have happened.

On the loss of two generators the Standby Generator would have come on automatically. The Captain's PFD and ND should have been available. Certain other services could have been recovered for landing using the "Land Recovery" button. However, under the circumstances there was probably little time to consider this facility.

This event occurred at a time when the aircraft electrical loads would normally be highest (landing lights, wipers on). The workload on the crew during the approach would also have been high. They would not have expected a double generator failure which necessitated the completion of the flight using emergency power. It was fortunate that they could see the runway in good time and did not have to make a "go-around" in poor weather conditions with limited instrumentation and electrics.

3 CONCLUSIONS

3.1 Findings

On short finals for landing on RWY 24 at Shannon, both aircraft generators tripped within 2.5 seconds of each other, cutting off all AC and DC power, and leaving the emergency power as the only available supply of electrical power.

3.2 Causes

Both left and right generators carried defects into this flight. When an ensuing fault occurred on the right generator during the approach, it tripped from the system. The left generator could not carry the electrical load and it too tripped from the system.

4. SAFETY RECOMMENDATIONS

4.1 The aircraft manufacturer should review this occurance and request that the generator manufacturer's Service Bulletin compliance be raised from "Optional" to "Recommended" **(SR No. 32 of 2003)**