SERIOUS INCIDENT

Aircraft Type and Registration:	DA 42 NG, G-HAKA	
No & Type of Engines:	2 Austro E4-C piston engines	
Year of Manufacture:	2015 (Serial no: 42.N158)	
Date & Time (UTC):	8 December 2020 at 1020 hrs	
Location:	Leeds Bradford Airport, West Yorkshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	2,013 hours (of which 930 were on type) Last 90 days - 44 hours Last 28 days - 16 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot, operator's safety report and further enquiries by the AAIB	

Synopsis

The aircraft lost electrical power shortly after takeoff because the alternators had not been switched ON. The pilot did not notice the incorrect switch setting before takeoff, or when carrying out the abnormal checklists in flight. The engines continued to operate, and the pilot returned to the departure airport with the aid of the standby artificial horizon and a mobile phone based flight planning application.

As a result of this serious incident, the AAIB submitted an observation to the aircraft manufacturer, and the operator took safety action to better inform its pilots.

History of the flight

The pilot and passenger intended to fly to Southampton Airport where the aircraft was required for aerial work. Neither engine would start, and the pilot reported no glow-plug indications and poor engine turnover when using the starter motors. Engineers from the operator's maintenance provider eventually started the engines with the aid of a ground power unit. Engine ground runs and a download of the engine Electronic Control Units (ECUs) showed no anomalies. A maintenance release form was signed off on the basis that the main aircraft battery charge state was probably low, and the pilot and passenger reboarded the aircraft approximately 1 hour 45 minutes behind schedule.

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The pilot reported that the engines started, but the LOW VOLTS cautionary alert was displayed shortly after the cockpit checks were complete. This was disregarded "*as a likely result of the earlier problems and something that would clear with engine running*".

Following a normal takeoff there was an audible alert and the pilot again observed low voltage cautions for both main electrical busbars[1]. The pilot decided to return to Leeds Airport but did not declare an emergency because "*the checklist suggests 30 minutes time available*". The abnormal checklist for LOW VOLTS refers to two more checklists; 4B.3.7-VOLTAGE and 4B.4.6 - L/R ALTN FAIL. The pilot reported that the checks required by 4B.3.7 were completed, but not those in 4B.4.6 because an alternator failure was not displayed. The first action in checklist 4B.3.7 is to ensure that the alternators are switched ON.

Following the checklist, the pilot reduced electrical loads but the busbar voltages decreased to 21 volts as the aircraft was on the downwind leg. After completing the pre-landing checks the pilot used a GPS tracking device to send a message to the operator informing them of the problem and selected the ILS approach plate on an electronic tablet. The electrical load was further reduced by switching off the lights apart from the strobes. As the aircraft started the turn onto the base leg the busbar voltages decreased rapidly and the pilot informed ATC that communications might be lost. They provided vectors to intercept the ILS, clearance to land and requested confirmation of the number of people on board. The pilot responded and having acquired the localiser the landing gear was lowered and the aircraft captured the glideslope for the landing. Shortly after, all electrical power was lost, which resulted in the loss of the electronic flight displays.

The pilot switched on the emergency power for the standby artificial horizon, levelled off, and started a turn to the right. The cloud base was approximately 700 to 800 ft agl so, when a suitable gap was found, the pilot descended whilst maintaining sight of the ground. With the aid of a mobile phone based flight planning application, the pilot was able to return to the airport where an uneventful landing was carried out.

Aircraft information

The DA42 NG is a four-seat, twin-engine aircraft designed to Joint Aviation Requirements (JAR) 23[2]. The aircraft is equipped with two Austro diesel engines and is equipped with a Garmin G1000 glass cockpit display suite.

G-HAKA is equipped with mission equipment specific to the aircraft's role, and which increases the loads on the electrical system.

Footnote

1 The pilot took a photograph during the flight, which shows that the stall warning system was also showing a failure.

2 The Joint Aviation Requirements were issued by the Joint Aviation Authorities (JAA) as a set of common requirements that participating countries would comply with. The European Aviation Safety Agency (EASA) has taken over most of the JAA functions and the JARs have been replaced by EASA Certification Standards. JAR-23 defined the requirements for Normal, Utility, Aerobatic and Commuter Category Aeroplanes.

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Power generation and electrical distribution

The aircraft has two alternators, one being driven by each engine. They are connected to the respective main electrical busbars (left and right) via alternator relays and circuit breakers. The main busbars are connected to the battery busbar via another circuit breaker.

If the main aircraft battery fails, the alternator field windings are energised by ECU back-up batteries and, if the alternators fail, these back-up batteries can power the ECUs for 30 minutes so that the engines continue to operate.

Each alternator has its own control unit, which includes diagnostic functions to warn the pilot of certain failure conditions using a caution message (L/R ALTN FAIL) on the G1000. The alternators can be switched ON or OFF using toggle switches on the left side of the instrument panel, below the ECU test buttons. Selecting an alternator switch to ON connects the output of the respective alternator to its main electrical busbar. If the engine is running and the switch is in the OFF position, the alternator will still provide power to the alternator control unit, fuel pumps, ECU, and ECU back-up batteries, but the main busbar will be powered by the main aircraft battery.

A voltmeter shows the main busbar voltages on a horizontal scale, Figure 1. Under normal operating conditions, with both alternators switched ON, the displayed voltages will show the alternator output. If an alternator is switched OFF, the respective voltmeter will show the main battery voltage, because the affected busbar will now be powered by the battery. If both alternators are switched OFF, both voltmeters will show the main battery voltage. The status of the alternator switches is not shown on the G1000.

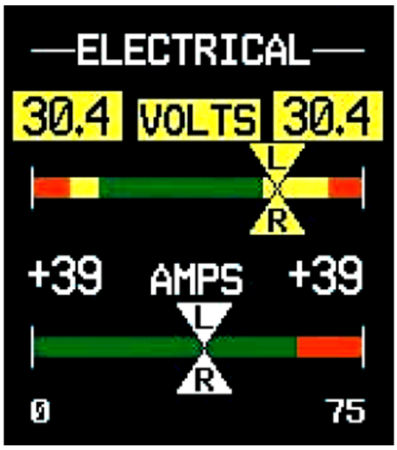

Figure 1

Schematic showing the voltmeter and ammeter displays on the G1000
(Schematic from the manufacturer's AFM)

A sensor on each alternator output measures the electrical current, which is displayed on the G1000 ammeter. If an alternator switch is OFF, but the associated engine is running, the respective ammeter will still show an electrical current because the alternator will be supplying power to the alternator control unit, fuel pumps, ECU and ECU back-up battery.

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A non-rechargeable battery provides an emergency power source for a standby artificial horizon, which is activated when the pilot selects the EMERGENCY switch to ON.

Operator's investigation

The main aircraft battery was found to be depleted after the incident. Engine ground runs showed no anomalies and a check flight was successfully completed. The operator concluded that the most likely scenario was that the alternators were not switched ON before the incident flight.

Engine runs and maintenance checks prior to the incident flight

When the pilot was initially unable to start the engines, the maintenance provider carried out engine ground runs before downloading the ECUs to check for faults. This work was conducted in accordance with the AFM, the aircraft maintenance manual (AMM) and the engine maintenance manual (EMM).

The AMM procedure for downloading the ECU referred to the EMM, and contained a cautionary note that stated:

> '*WHEN OPERATING THE AIRPLANE ELECTRICAL SYSTEM WITH ENGINE MASTER ON (LH OR RH) AND THE ENGINE IS NOT RUNNING ALWAYS CONNECT AN EXTERNAL SUPPLY WITH A PRESET VOLTAGE OF 29V TO THE AIRPLANE. OTHERWISE THE ALTERNATORS MAY BE DAMAGED.*'

The ECU download procedure did not mention the alternator switches, but five similar cautionary notes in other sections of the AMM all included this additional text:

> '*e.g. EVENT LOG READOUT*' and '*ADDITIONALLY, IF MAM 42-551 IS INSTALLED, SWITCH OFF BOTH (LH AND RH) ALTERNATOR SWITCHES*'.

Modification MAM 42-551 was installed on G-HAKA during build, so these other cautionary notes indicated that the alternators should be switched OFF when downloading the ECUs. The ground engineers were reported to have switched the alternators OFF because this is what the aircraft manufacturer had taught them to do. They did not switch the alternators ON again when they completed their work.

Checklists and pilot actions

The pre-flight inspection checklist in the AFM includes a check that the alternator switches are ON. The before engine start checklist also includes a check that the switches are ON.

The pilot reported to the AAIB that under normal operating conditions, the alternator switches are always ON, because the AFM does not require them to be switched OFF after a flight. The pilot also reported that "fundamental to the loss of electrical power, I twice checked the Alternator Switches and saw them as On when they were, in fact, Off".

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The LOW VOLTS abnormal checklist indicates that possible causes include a fault in the power supply or the alternators being OFF. It directs the pilot to a separate VOLTAGE checklist (4B.3.7), but it also contains a cautionary note that '*if both low voltage indications are ON, expect failure of both alternators and follow 4B.4.6 – L/R ALTN FAIL*'. In the case of G-HAKA, both low voltage indications were on, but there were no associated alternator indications, so checklist 4B.4.6 was not relevant.

Checklist 4B.3.7 is split into two scenarios: on the ground and in-flight. The first action in both scenarios is to check that the alternators are switched ON. If the fault occurs on the ground and cannot be cleared, the flight should be terminated. If the fault occurs in flight and cannot be cleared, the checklist directs the pilot to procedure 4B.4.6. The pilot reported that the LOW VOLTS indication occurred on the ground shortly after starting the engines, but believed it was associated with the earlier problems and dismissed it without referring to the abnormal checklists. It is not known if the LOW VOLTS indication cleared prior to takeoff but, with the alternators switched OFF, there would be no mechanism for this.

Once airborne, the pilot heard an audible alert, and when they checked the G1000, both LOW VOLTS cautions were displayed. A photograph that was taken during the incident flight showed that the stall warning system was also showing a fault.

Other information

The aircraft manufacturer reported that they were aware of one previous similar event.

Analysis

Initial problems when trying to start the engines

The pilot was unable to start the engines and the most likely scenario is that the main aircraft battery charge state was low.

Engine ground runs

The maintenance provider started the engines and ground runs showed no anomalies. They switched the alternators OFF when they downloaded the ECUs, but this was not a requirement of the download procedure in the AMM. It was noted that five other procedures in the AMM contained cautionary notes that the alternators should be switched OFF during an event log readout, which is what the engineers said the aircraft manufacturer had taught them to do. The alternator switches were left in the OFF position when the work was complete.

The AAIB believe that the contradicting cautionary notes can cause confusion and, potentially, aircraft system damage. The AAIB highlighted the anomaly as an observation to the aircraft manufacturer so that the AMM can be reviewed and amended accordingly.

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Incident flight

The pilot reported that the LOW VOLTS cautionary alert was displayed shortly after the engines were started and the cockpit checks were complete. This was dismissed as being associated with the earlier problems.

Shortly after takeoff, the pilot heard an audible alert and observed that both LOW VOLTS indications were displayed. A photograph taken during the flight showed that the stall warning system was also displaying a fault, and the aircraft manufacturer stated that this was the probable cause of the audible alert. It is not known if the LOW VOLTS indications cleared prior to takeoff[3] but checklist 4B.3.7 stated that if the fault could not be rectified on the ground, the flight should be terminated.

The pre-flight and engine start checklists include checks that the alternator switches are ON. The pilot reportedly checked the switches on two occasions, believing them to be ON when they were OFF. It was stated that the alternator switches are normally left in the ON position because the AFM does not require them to be switched off after flight. It is, therefore, probable that confirmation bias[4] resulted in the pilot seeing what they expected when the switches were checked.

The G1000 display system does not depict the alternator switch status and has two voltmeters, one for each of the main busbars. If the alternator switches are OFF, the voltmeters continue to show the busbar voltage, which will be the main aircraft battery voltage. Furthermore, if the alternator switches are in the OFF position and the engines are running, the ammeters will show a current demand because the alternators will be supplying electrical power to the alternator control units, fuel pumps, ECUs and ECU back-up batteries. This could potentially reinforce the belief that the alternators are switched ON when they are OFF.

The electronic display suite shut down when the main aircraft battery voltage reduced below the requirement to power the system. The engines continued to run because the alternators continued to supply electrical power to the alternator control units, fuel pumps, ECUs and ECU back-up batteries.

Conclusion

The most likely scenario is that the alternators were not switched ON prior to takeoff and the pilot did not identify the incorrect switch position. When the aircraft battery depleted the electronic displays failed, but the engines continued to operate because, despite being OFF, the alternators continue to power the ECUs and fuel pumps.

The pilot successfully returned to the airport with the aid of a mobile phone and the standby artificial horizon.

Footnote

[3] If the alternator switches were OFF, there is no mechanism for the LOW VOLTS cautions to have cleared.

[4] Confirmation bias is the human trait whereby we seek to identify aspects around us that prove a hypothesis, understanding or perception we have.

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Safety actions

The operator issued an Operational Crew Instruction to:

1. Require pilots to complete the before engine start checklist as a read-and-do checklist instead of from memory.
2. Highlight the fact that the G1000 does not show if an alternator is switched ON or OFF.
3. Highlight the requirements of the low voltage abnormal checklist and require pilots to study it prior to their next flight in a DA 42.
4. Remind pilots that the AFM does not permit flight with a discharged battery under IFR or night VFR conditions.

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