COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-091/CENIPA/2019

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-MPN**
MODEL:	**ATR-42-320**
DATE:	**15JUN2019**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination, and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted considering the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the distinct factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Final Report has been made available to the ANAC and the DECEA so that the technical-scientific analyses of this investigation can be used as a source of data and information, aiming at identifying hazards and assessing risks, as set forth in the Brazilian Program for Civil Aviation Operational Safety (PSO-BR).

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with Appendix 2, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Considering the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This Final Report pertains to the 15 June 2019 accident involving the model ATR-42-320 aircraft of registration marks PR-MPN. The occurrence was typified as "[SCF-NP] System/Component Failure or Malfunction (Non-Powerplant)."

The aircraft departed from SBEG (*Eduardo Gomes* Airport, *Manaus*, State of *Amazonas*), bound for SWCA (Aerodrome of *Carauari,* State of *Amazonas*) on a scheduled public air transport flight with four crew and thirty-four passengers on board.

Shortly after takeoff from SBEG, an electrical failure occurred, and the aircraft returned to the airport of departure, where it landed with the landing gear retracted. Emergency evacuation was carried out through the rear main door.

The aircraft sustained substantial damage.

The four crew members and thirty-two passengers emerged unharmed, while two passengers sustained minor injuries.

Both France (State of aircraft manufacture) and the USA (State of System/Component Failure or Malfunction manufacture), by means of, respectively, the *Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile* (BEA) and the National Transportation Safety Board (NTSB), designated accredited representatives for participation in the investigation of this accident.

TABLE OF CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

APP	Approach Control
APP-MN	*Manaus* Approach Control
ASDA	Accelerate-Stop Distance Available
BTC	Bus Tie Contactor
CA	Certificate of Airworthiness (CofA)
CAP	Crew Awareness Panel
CAC	Crew Alerting Computer
CCAS	Centralized Crew Alerting System
CENIPA	Brazil's Aeronautical Accidents Investigation and Prevention Center
CMA	Aeronautical Medical Certificate
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DECEA	Department of Airspace Control
EADI	Electronic Attitude Direction Indicator
EHSI	Electronic Horizontal Situation Indicator
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
GPWS	Ground Proximity Warning System
IFR	Instrument Flight Rules
IFRA	IFR Flight Rating – Airplane
LDA	Landing Distance Available
METAR	Meteorological Aerodrome Report
MGM	General Maintenance Manual (GMM)
MOM	Maintenance Organization Manual
OM	Maintenance Organization
PF	Pilot Flying
PIC	Pilot in Command
PLA	Airline Transport Pilot License - Airplane
PM	Pilot Monitoring
PN	Part Number
PPR	Private Pilot License – Airplane
QRH	Quick Reference Handbook
RBAC	Brazilian Civil Aviation Regulation
SBEG	ICAO location designator - *Eduardo Gomes* Intl Airport, *Manaus*, AM
SWAC	ICAO location designator – Aerodrome of *Carauari*, AM

SN	Serial Number
SIC	Second in Command
SOP	Standard Operating Procedures
TCU	Towering Cumulus Cloud
TODA	Take Off Distance Available
TORA	Take Off Run Available
TPR	Regular Public Air Transport Service Aircraft Registration Category
TWR-EG	*Eduardo Gomes* Airport Control Tower
UTC	Coordinated Universal Time
VFR	Visual Flight Rules

1. FACTUAL INFORMATION.

Aircraft	**Model:** ATR-42-320 **Registration:** PR-MPN **Manufacturer:** ATR - *GIE Avions de Transport Régional.*	**Operator:** *MAP Transportes Aéreos Ltda.*
Occurrence	**Date/time**: 15JUN2019 – 16:45 (UTC) **Location:** *Aeródromo Eduardo Gomes* (SBEG **Lat.** 03°02'28"S **Long.** 060°03'02"W **Municipality – State:** *Manaus – Amazonas*.	**Type(s):** [SCF-NP] System/component failure or malfunction (non-powerplant)

1.1. History of the flight.

At approximately 16:39 UTC, the aircraft departed from SBEG (*Eduardo Gomes* Aerodrome, *Manaus*, AM), bound for SWCA (Aerodrome *of Carauari,* AM) on a scheduled public air transport flight with four crew and thirty-four passengers on board.

Shortly after takeoff, an electrical failure occurred, prompting the aircraft to return for landing at SBEG.

The aircraft landed with all three landing gear legs retracted.

Figure 1 - View of the aircraft after landing at SBEG with the landing gear retracted.

The aircraft sustained substantial damage.

The four crew members and thirty-two passengers emerged unharmed, while two passengers sustained minor injuries.

1.2. Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	-	2	-
None	4	32	-

1.3. Damage to the aircraft.

Due to ground friction during the landing with the landing gear retracted, there was substantial damage to the underside of the fuselage, as shown in Figures 2 and 3.

Figure 2 - Damage to the central underside of the fuselage.

Figure 3 - Damage to the forward underside of the fuselage.

Damage was also observed on the landing gear doors, wheels, and tires of the aircraft (Figure 4).

Figure 4 - Damage to the wheels, tires, and landing gear doors.

1.4. Other damage.

NIL

1.5. Personnel information.

1.5.1. Crew's flight experience.

Hours flown		
	PIC	SIC
Total	12,312:00	5,000:00
Total in the last 30 days	45:00	71:00
Total in the last 24 hours	08:00	06:00
In this type of aircraft	5,600:00	4,340:00
In this type in the last 30 days	45:00	71:00
In this type in the last 24 hours	08:00	06:00

Note: data on the flight hours obtained through information provided by the aircraft's operating company, supplemented by information provided by the crew members.

1.5.2. Personnel training.

The Pilot in Command (PIC) completed the PPR course (Private Pilot - Airplane) in 1999, at *Aeroclube do Amazonas*, *Manaus*, Amazonas State.

The Second in Command (SIC) completed the PPR course (Private Pilot - Airplane) in 2008, at *Aeroclube de Sorocaba*, *São Paulo* State.

1.5.3. Category of licenses and validity of certificates.

The PIC held a *PLA* License (Airline Transport Pilot - Airplane) and had valid ratings for AT47 aircraft type (which included the ATR-42-320 model) and *IFRA* (Instrument Flight - Airplane).

The SIC also held a valid *PLA* License and ratings for the AT47 aircraft type, as well as for IFRA.

1.5.4. Qualification and flight experience.

The PIC completed the company's reduced initial training program in 2019, as he had previously flown the ATR-42 model with another airline.

The reduced initial training, as outlined in the airline's Operational Training Manual, consisted of a theoretical instruction phase totaling 97 hours and 30 minutes, and a flight phase lasting 23 hours.

The flight curriculum segment included:

- Operational Route Experience - 20 hours; and
- *Check Ride - Type Rating - 3 hours.*

The theoretical training was completed approximately one month before the accident. Overall, the pilot demonstrated good performance. However, in the segment related to "General Emergencies," he was approved with the minimum passing grade.

After completing the training, the PIC took normal operational route instructions, totaling 22 hours and 5 minutes, once again demonstrating good performance. Subsequently, he underwent the company's initial evaluation and passed the examination.

The PIC's experience at the previous airline where he had worked was also analyzed. His history revealed reports of difficulties during flight simulator training, particularly with manual piloting (without autopilot), lack of knowledge regarding aircraft systems, and low situational awareness.

Additionally, it was found that, following the pilot's failure in requalification training due to poor manual flight management and difficulties with the Quick Reference Handbook (QRH), the company's technical board reviewed his performance.

The SIC, in turn, completed the company's initial training program in 2011, as outlined in the Operational Training Manual. This training consisted of a theoretical instruction curriculum totaling 155 hours and a flight curriculum totaling 52 hours of instruction.

The flight segment consisted of:

- *Cockpit Procedures Training* - 12 hours;
- *Full Flight Simulator* ATR42 - 36 hours; and
- *Check Ride - Type Rating* - 4 hours.

The SIC exhibited satisfactory performance throughout the entire training. Regarding the initial flight simulator program, the training on abnormal electrical system procedures was properly conducted during the simulated flight sessions 3, 6, 7, 8, and 9. Instructors' comments highlighted that the pilot showed a good level of Crew Resource Management (CRM); however, it was noted that he needed further study of the company's Standard Operating Procedures (SOP) and aircraft systems.

1.5.5. Validity of medical certificate.

The pilots held valid CMAs (Aeronautical Medical Certificates).

1.6. Aircraft information.

The SN 020 aircraft was a product manufactured by ATR - GIE *Avions de Transport Régional* in 1986. It was registered under the category of Regular Public Air Transport Services (TPR).

The aircraft's Certificate of Airworthiness (CA) was valid.

The maintenance records were up-to-date.

The last inspection of the aircraft (1YE type) was conducted on 11 June 2019 by the Maintenance Organization (OM) *Manaus Aerotáxi*, in *Manaus*, AM. The aircraft flew 5 hours and 6 minutes after the inspection.

At the time of the accident, the aircraft had accumulated a total of 45,506 hours and 42 minutes of flight time.

Regarding the electrical system, three types of electrical currents were available, being one Direct Current (DC) and two Alternating Currents (AC).

The aircraft's electrical power was supplied by the following sources:

- a primary Nickel-Cadmium (Ni-Cd) battery rated at 24 Volts DC (VDC) and 27 A/h of electrical charge;
- an emergency Ni-Cd battery rated at 24 VDC and 15 A/h of electrical charge;
- two Starter-Generators (DC-GEN);
- two Variable Frequency AC Generators (ACW); and
- two external power outlets (AC and DC).

The aircraft was also fitted with two static inverters powered by DC energy, designed to provide AC power.

Electrical distribution was conducted via busbars to supply power to different pieces of equipment, with two separate networks (right and left). These networks could be interconnected in the event of a failure in one of the Starter-Generators through the Bus Tie Contactor (BTC).

The Starter-Generators were driven by the engine accessory gearboxes and had the dual function of supplying electrical power at a nominal voltage of 28.5 VDC with a capacity of 400A and serving as starter motors for engine start-up.

When operating in the "generator" mode, each Starter-Generator supplied DC power to its respective associated busbar (DC BUS 1 or DC BUS 2) via a specific contactor.

Regarding the DC power distribution on the aircraft, it was delivered through the following busbars:

- Two main busbars: DC BUS 1 and DC BUS 2;
- HOT MAIN BAT BUS and HOT EMER BAT BUS;
- DC EMER BUS, DC ESS BUS, and DC STBY BUS;
- UTLY BUS 1 and UTLY BUS 2;
- DC SVCE BUS; and
- GND HDLG BUS.

The DC BUS 1 was powered by Starter-Generator No. 1, while the DC BUS 2 was powered by Starter-Generator No. 2. In the event of a generator failure, the respective busbar would be supplied by the other generator via the BTC.

Under normal operating conditions, the DC BUS 1 provided electrical power to the following busbars:

- HOT EMER BAT BUS (during battery charging);
- DC EMER BUS;
- DC STBY BUS;
- UTLY BUS 1;

- DC SVCE BUS; and
- INV 1 (AC system).

Under normal operation, the DC BUS 2 provided electrical power to the following busbars:

- *HOT MAIN BAT BUS (during battery charging);*
- *DC ESS BUS;*
- *UTLY BUS 2; and*
- *INV 2 (AC system).*

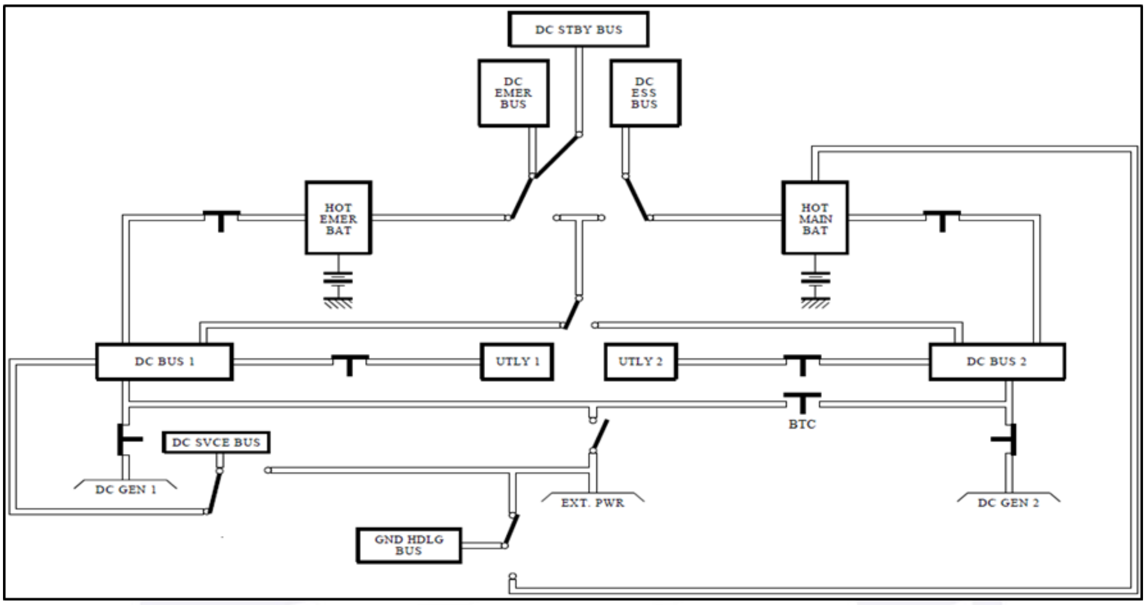


Figure 5 - DC electrical power distribution.

The architecture of the DC electrical system consisted of networks 1 and 2, located on the left and right sides of the aircraft, respectively, and operating independently. The primary power supply was provided by the respective Starter-Generators through the DC BUS 1 and DC BUS 2.

In case of a failure in one of the generators, the affected network would be powered by the opposite side's network via a Bus Tie Contactor (BTC).

Under normal flight conditions, each generator would supply its respective busbar, and the BTC would remain open, isolating the right and left networks.

In the event of a failure of the power supply to the *DC STBY BUS*, the following systems would become inoperative: control of the flaps and primary indication of the landing gear position.

Should a failure occur with the power supply to the *DC EMER BUS*, the following systems would become inoperative: VHF-1 communication radio, Control of the Blue Pump (hydraulic pump for the blue hydraulic system), and engine torque indication.

In the event of an electrical power failure in DC BUS 2, the following systems would become inoperative: Electronic Attitude Direction Indicator (EADI) and Electronic Horizontal Situation Indicator (EHSI), both on the SIC side, VHF-2 communication radio, Green Pump (hydraulic pump for the green hydraulic system), and Secondary landing gear position indication.

Among the main pieces of equipment rendered inoperative in the event of a DC ESS BUS failure were the interphones that enabled communication between the pilots, as well as between the pilots and the cabin crew.

The electrical power supply for the EADI and the EHSI on PIC side was provided by the DC STBY BUS and DC BUS 1, respectively.

Regarding the AC electrical system, the aircraft was fitted with two static inverters, designed to provide Alternating Current (AC) electrical power at a constant frequency of 400 Hz. Each of these inverters was supplied by its respective DC generator. Inverter 1 was powered by DC Bus 1, which received power from Starter-Generator No. 1, and Inverter 2 was powered by DC Bus 2, which in turn received power from Starter-Generator No. 2. Each static inverter provided 115 VAC and 26 VAC outputs.

Under normal flight conditions, the Inverter 1 powered the AC BUS 1 and the AC STBY BUS. The Inverter 2 powered the AC BUS 2.

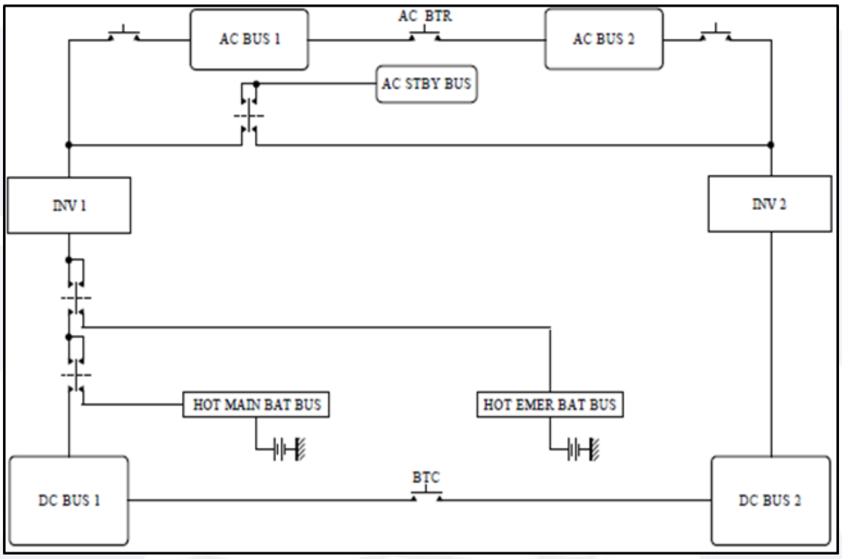


Figure 6 - AC electrical power distribution.

Should a power failure occur in one of the DC BUS, the corresponding inverter would lose its power supply. In this situation, the respective AC busbar would be isolated from its inverter and connected to the other AC busbar through an AC Bus Tie Relay (ACBTR), thereby being electrically powered by the remaining inverter.

To facilitate the understanding of this accident, in the event of an AC STBY BUS failure, one of the inoperative conditions of the aircraft included the flap position indication.

Still regarding the AC electrical system, the ATR-42-320 was fitted with two three-phase generators driven by the propeller reduction gearboxes of the engines. These generators had a nominal output voltage ranging from 115 V to 200 V, but provided power at a frequency range between 341 Hz and 488 Hz, referred to as the AC Wild (ACW) System.

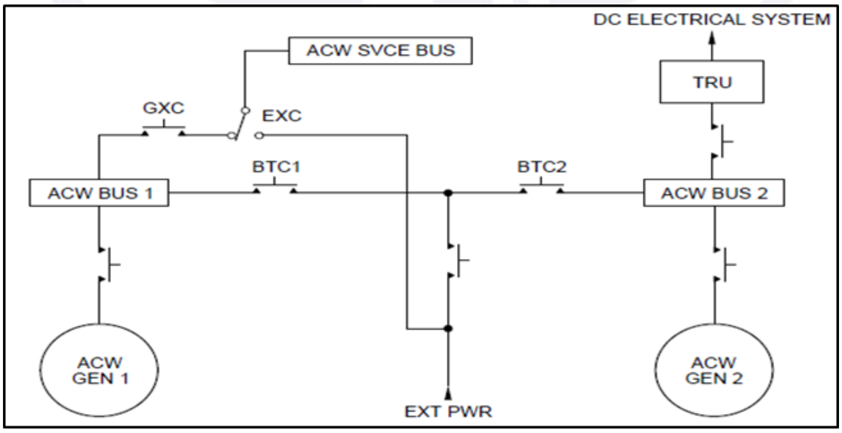


Figure 7 - ACW electrical power distribution.

The electrical system was controlled and monitored via a panel located on the aircraft's Overhead Panel. Each Starter-Generator had a button that, when pressed, energized the generator and, when deactivated, de-energized it. The button also featured an amber FAULT light, indicating a system failure.

The Overhead Panel included two amber lights labeled DC BUS OFF, which illuminated when the respective busbars (DC BUS 1 and DC BUS 2) were not being supplied with electrical power. The panel also had amber arrow-shaped indicators to show when the DC ESS BUS was being powered by the Main Battery and when the DC EMER BUS was being powered by the Emergency Battery.

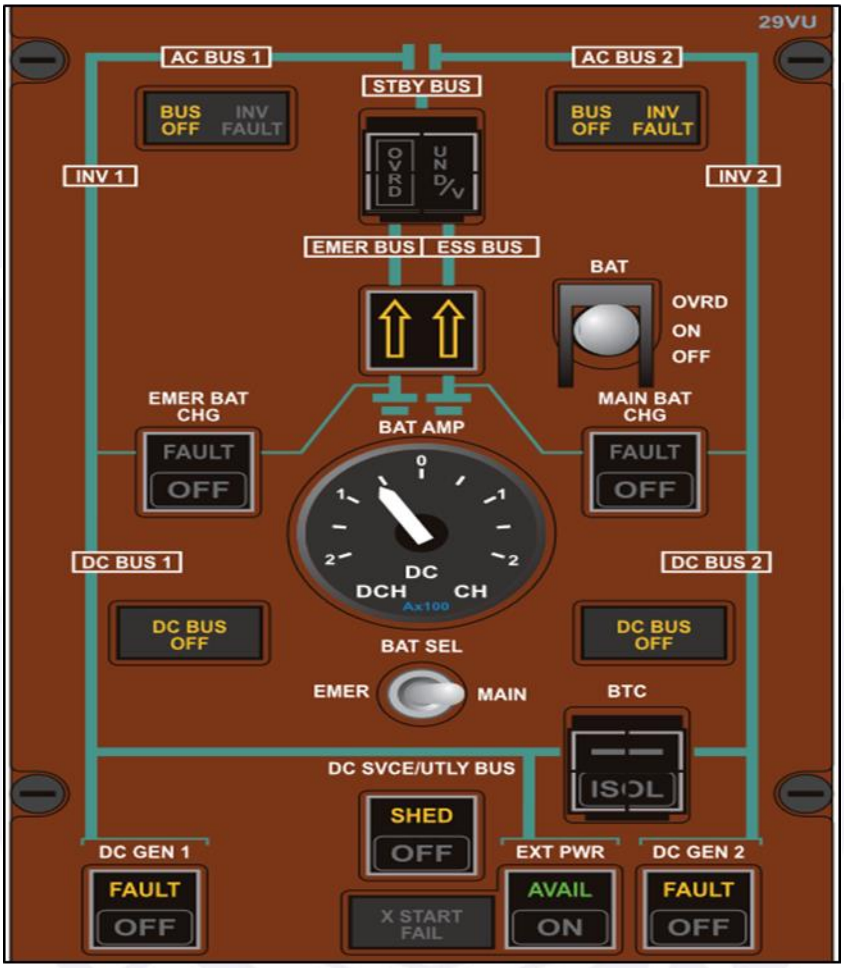


Figure 8 - Electrical panel located on the Overhead Panel.

Relatively to the monitoring of the electrical system, in the event of a power supply failure in the DC BUS 1, the following indications would be presented to the crew:

- amber lights DC BUS OFF (1), INV 1 FAULT, and DC SVCE/UTLY BUS SHED on the Overhead Panel;

- a single shime from the aural system;

- Master Caution amber light and an amber ELEC inscription on the Crew Awareness Panel (CAP), which displays system fault messages.

In case of a power supply failure in the DC BUS 2, the crew would have the following indications:

- a flashing Master Caution amber light;
- an amber ELEC inscription on the Crew Alerting Panel (CAP), which displays system fault messages;

- a single-tone aural alert; and
- amber lights illuminated on the Overhead Panel: DC BUS OFF (2), INV 2 FAULT, and DC SVCE/UTLY BUS SHED.

In the event of a DC ESS BUS power supply failure, there would be the following indications for the crew:

- a flashing Master Caution amber light;
- an amber ELEC inscription on the Crew Awareness Panel (CAP);
- a single-tone aural alert;
- amber lights illuminated on the Overhead Panel: DC GEN 2 FAULT, DC BUS OFF (2), INV 2 FAULT, and DC SVCE/UTLY BUS SHED; and
- the right amber arrow on the Overhead Panel would illuminate, indicating that the busbar was now being powered by the Main Battery.

In case of a failure in the inverters due to overvoltage or undervoltage, the crew would observe the following indications:

- a flashing Master Caution amber light;
- an amber ELEC inscription on the CAP;
- a single-tone aural alert;
- an amber INV FAULT light on the Overhead Panel for the corresponding side (AC BUS 1 or AC BUS 2).

As for the hydraulic system, The ATR-42-320 aircraft was equipped with two hydraulic systems: Blue (left side) and Green (right side), both pressurized by pumps powered by the ACW electrical system (Blue Pump powered by ACW BUS 1 and Green Pump powered by ACW BUS 2).

The Blue System supplied hydraulic pressure to the following components:

- flap extension and retraction system;
- spoilers;
- nose landing gear steering;
- right engine propeller brake; and
- parking and emergency brakes for the four main landing-gear wheels.

The Green System supplied hydraulic pressure to the following components:

- landing gear extension and retraction system; and
- normal braking system for the four main landing-gear wheels.

Should a failure occur in one of the pumps, the respective system could be supplied by the remaining hydraulic pump through the crew's activation of the Cross-feed Valve (X FEED), located on the hydraulic system control panel (Overhead Panel). This valve allowed pressurized hydraulic fluid from the operating pump's system to be directed to the inoperative pump's system.

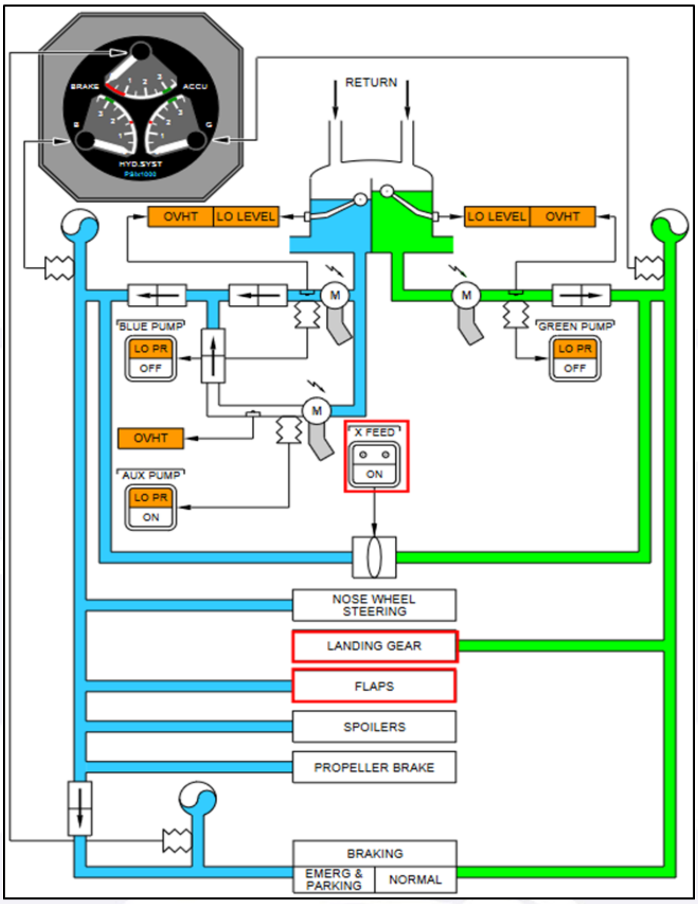


Figure 9 - Representation of the ATR-42 hydraulic system, highlighting the X FEED line, landing gear, and flaps.

The aircraft possessed a landing gear assembly comprising two main legs and one nose leg. The entire system was hydraulically operated and electrically controlled. The hydraulic pressure for landing gear operation was supplied by the Green System. In the event of hydraulic or electrical failure, the landing gear could be extended using the gravity drop method.

The aircraft's landing gear also featured two isolated position indication systems: a primary system and a secondary system.

The main indication system obtained information about the status of the landing gear legs through proximity sensors and locking switches. This system exhibited the landing gear status on an indication panel located on the main instrument panel. This panel was positioned near the landing gear control lever and consisted of three indicator lights, one for each gear leg. The indicator lights were powered by the STBY BUS.

The secondary system, in turn, showed the landing gear status on a panel located on the *Overhead Panel*. This system also consisted of three indicator lights, one for each gear leg, powered by the DC BUS 2.

The landing gear was considered fully extended and locked if three green lights appeared on either the primary or secondary indication systems.

Both the primary and secondary landing gear indication systems featured three indicators, one for each gear leg. A green downward arrow represented a gear leg locked in the extended position. If a gear leg was not locked according to the selection of the control lever, a red "UNLK" inscription would appear on the corresponding indicator.

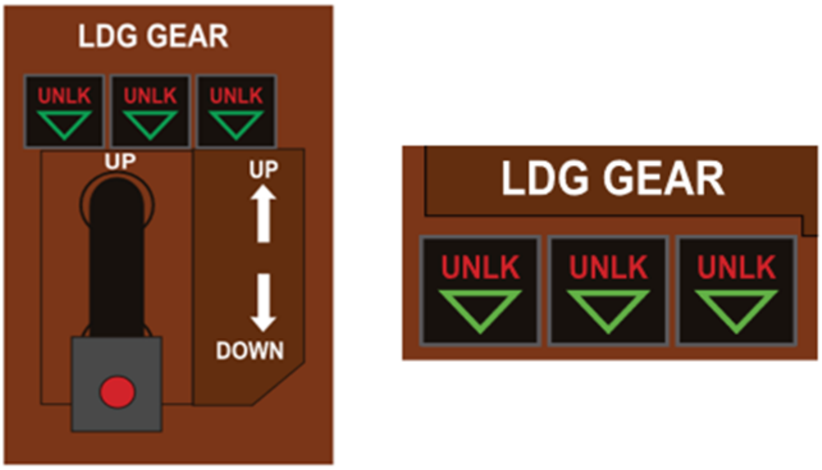


Figure 10 - Primary and secondary landing gear indicators.

The landing gear control lever possessed a red light. This light would illuminate while any of the landing gear legs were in transit after the control lever was activated, and would turn off once the landing gear was fully extended and locked. If the landing gear was not properly extended and locked, the following indications would occur: the red light on the control lever would remain illuminated, and a failure message would be activated on the Centralized Crew Alerting System (CCAS).

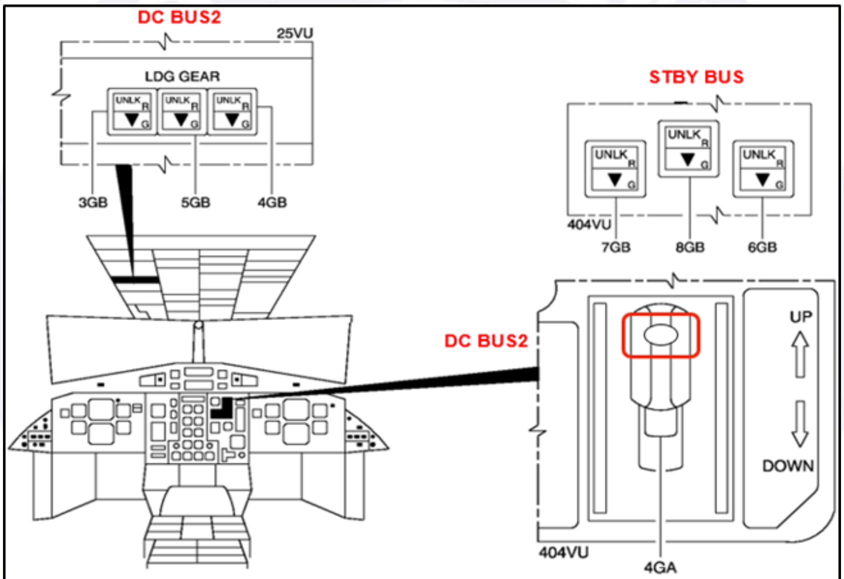


Figure 11 - Location of landing gear position indicator panels and power supply busbars.
Source: Flight Crew Operations Manual (FCOM).

The Centralized Crew Alerting System (CCAS) was designed to compute and provide alerts regarding system failures or conditions of operational significance. The system utilized four types of indications:

- MASTER WARNING and MASTER CAUTION lights;
- lights on the Crew Alerting Panel (CAP);
- LOCAL ALERT lights on the panel of the affected system; and
- aural alerts for the crew.

The central component of the CCAS was the Crew Alerting Computer (CAC), which was responsible for receiving, computing, and processing system failures. The CAC directed signals to the appropriate visual and aural indicators.

The secondary landing gear position indication system on the Overhead Panel was also responsible for sending a signal to the CCAS if any landing gear leg was not fully extended and locked, regardless of the position of the control lever. Based on this signal, the CCAS would generate an alert signal for the crew on the Crew Alerting Panel (CAP).

Among the types of alarms for different operational conditions were:

- aural alert for the exceeding of the maximum flap extension speed;
- aural alert for the condition of the landing gear not being fully extended and locked.

The aural alert for the condition of the landing gear not being fully extended and locked would be triggered when any landing gear leg was not down and locked, and the following conditions were met:

- flaps set to 30° and altitude below 500 ft. AGL (measured by radio altimeter); or
- flaps set to 45°.

The electrical power for the CCAS was supplied by the DC ESS BUS and DC BUS 1.

The secondary landing gear position indication system was electrically powered by the DC BUS 2. Since this system was responsible for providing the landing gear position input to the Crew Alerting Computer (CAC) for generating or not generating alarm messages, the absence of electrical power from the DC BUS 2 would render the secondary system inoperative. Consequently, no landing gear position input would be sent to the CAC, and the alarm would not be activated.

The aircraft also counted with a Ground Proximity Warning System (GPWS), which provided visual and aural alerts to the crew in cases where the flight trajectory might result in inadvertent ground contact. The system generated alerts upon entering risk envelopes for predefined scenarios. One such scenario involved approaching terrain with the landing gear or flaps not in a landing configuration.

In such a situation, if the aircraft entered the terrain proximity envelope at a speed above 175 kt. with the landing gear not extended and locked, the "TOO LOW TERRAIN" alarm would sound. If the speed were below 175 kt., the "TOO LOW GEAR" alarm would activate to alert the crew about the landing gear condition and proximity to the ground.

To activate the alarm related to proximity to the ground with the landing gear or flaps not in the landing configuration, the GPWS system relied on inputs from the flap position transmitter and the landing gear control lever position transmitter.

The flight control system comprised movable control surfaces, actuation mechanisms, and position control systems to provide movement of the aircraft along the longitudinal, vertical, and lateral axes.

Pitch control was provided by two elevators, operated via their respective control columns in the cockpit, which were mechanically interconnected.

The aircraft featured an electrically controlled pitch trim system consisting of two trim tabs located on the trailing edge of each elevator. In "Normal" operation mode, pitch trim adjustments were made via a switch on the control column. In "Standby" mode, adjustments were performed using a switch on the central console.

In the event of desynchronization between the trim tabs on the two elevators, the aircraft's autopilot would disengage and the pitch trim system would become inoperative in both the "Normal" and "Standby" modes.

1.7. Meteorological information.

The Meteorological Aerodrome Reports (METAR) for SBEG, the site of the accident, provided the following information:

METAR SBEG 151600Z 34006KT 9999 SCT020 FEW025TCU 29/24 Q1013=

METAR SBEG 151700Z 34006KT 9999 SCT020 FEW025TCU 29/24 Q1012=

METAR SBEG 151800Z 26006KT 9999 SCT018 FEW025TCU BKN080 28/25 Q1011=

The enhanced satellite image generated at 16:10 UTC on 15 June 2019, showed the presence of few Towering Cumulus (TCU) formations near the aerodrome, with base at 2,500 ft.

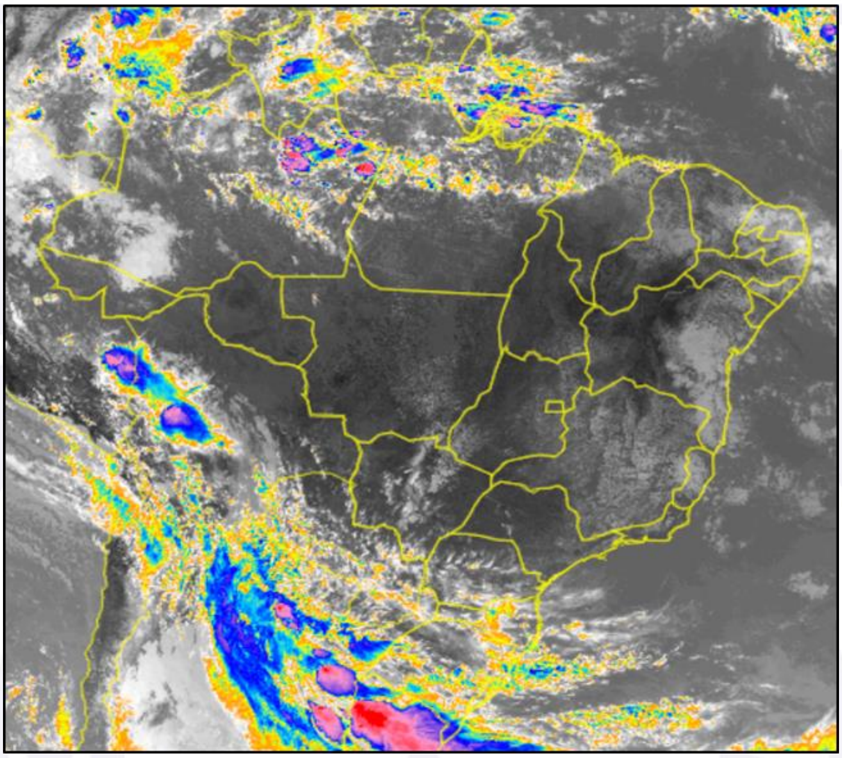


Figure 12 - Enhanced satellite image generated at 16:10 UTC on 15 June 2019.

The conditions were above the minimums required for the flight, with visibility exceeding 10 km and with few clouds at 2,500 ft., including TCUs. The wind was from 340º at 6 kt.

1.8. Aids to navigation.

All navigation and landing aids were operating normally during the approach of the aircraft to the aerodrome.

1.9. Communications.

According to the audio transcripts of communications between PR-MPN and air traffic control units, it was verified that the crew maintained radio contact with *Manaus* Approach Control (APP-MN) and *Eduardo Gomes* Airport Control Tower (TWR-EG). No technical abnormalities with the communication equipment were reported during the flight.

Following the electrical failure experienced by PR-MPN, *Manaus* Approach Control provided RADAR vectoring for the final approach to runway 11 at SBEG, while coordinating local traffic to prioritize the landing of the airplane with technical problems.

To support the analysis of the sequence of events leading up to the aircraft's landing, the Investigation Committee highlighted specific transmissions extracted from the Cockpit Voice Recorder (CVR). These excerpts may help in understanding the dynamics of the accident.

After the takeoff of PR-MPN, TWR-EG reported: "*MAP 5914 departed at zero-zero, contact control on one-one-niner decimal seven.*"

Immediately after the message from TWR-EG, the PIC asked the SIC: "*What... what did we lose? The DC?*"

The SIC's response was: "*We lost the Essential Bus*." Following an unintelligible piece of communication, the SIC informed: "*Control, MAP 5914 request return to the downwind leg of one-one, we have an electrical problem*."

APP-MN transmitted: "*Authorized right turn to enter the southern sector, MAP 5914.*"

Once again, the PIC commented on the electrical failure: "*We have lost the essential*." Shortly after, the SIC remarked: "*We're only with standby power, right, Captain*?"

APP-MN cleared the aircraft to descend: "*MAP 5914, descent authorized to fifteen hundred feet.*" The SIC acknowledged: "*Fifteen hundred feet, descending, MAP 5914.*"

The SIC informed the chief flight attendant about the situation: "*We have an electrical problem on the aircraft, we're returning*." The cabin attendant replied: "*Okay. I noticed it here. Do you want me to inform the passengers or will you…?*"

The SIC responded: "*Everything went dark for us here. I'll inform them shortly.*"

Following this, APP-MN cleared MAP 5914 to enter the downwind leg for runway 11 at SBEG: "*MAP 5914, visual with Eduardo Gomes?"*

The SIC read back the clearance and confirmed: "*Visual with Eduardo Gomes, MAP 5914*."

Subsequently, APP-MN instructed: "*Cleared base, one-one-eight-three.*" The SIC acknowledged: "*Adjusting to base, MAP 5914.*"

The SIC informed on the reading of the checklist: "*Let's go... approach checklist: seat belt - on; landing lights - on; set altitude - check; cabin crew... I've already informed her here.*"

The PIC questioned on the landing gear status: "*Landing gear down?*"

The SIC replied: "*Landing gear... checked, landing gear down, takeoff data.*"

APP-MN called: "*MAP 5914, are you on the control frequency?*"

The SIC responded: "*On your frequency now, MAP 5914, joining final.*" Shortly later, APP-MN instructed a frequency change: "*Roger, call tower one-one-eight-three, MAP 5914.*" The SIC read back: "*Roger, call tower one-one-eight-three, MAP 5914.*"

The SIC made the initial call to TWR-EG, and received landing clearance: "*MAP 5914, cleared to land runway one-one, wind zero-zero degrees at five knots, QNH one-zero-one-three.*"

On the final leg for landing, the PIC asked the SIC: "*Landing complete*?" The SIC responded: "*Landing gear.*"

The PIC confirmed: "*Down, three green lights.*" The SIC uttered: "*Flap.*" The PIC replied: "*Everything here is okay."*

The SIC then called out speed and altitude during the final descent:

"*One-twenty*... *One-ten*... *Passing one hundred feet*... *eighty*... *fifty*... *forty*... *twenty*... *fifteen*... *ten*... *five*."

In the sequence, the aircraft touched down on the runway with the landing gear retracted.

1.10. Aerodrome information.

The aerodrome was public and managed by INFRAERO. It operated both VFR and IFR during day- and night-time.

The runway was asphalt-sealed, with thresholds 11/29. It measured 2,700 x 45 meters and had an elevation of 264 ft.

The declared distances for Takeoff Run Available (TORA), Takeoff Distance Available (TODA), Accelerate-Stop Distance Available (ASDA), and Landing Distance Available (LDA) corresponded to those described in the aerodrome chart.

RWY	TORA(m)	TODA(m)	ASDA(m)	LDA(m)
11	2700	2700	2700	2700
29	2700	2700	2700	2700

Figure 13 – SBEG's declared runway distances.

1.11. Flight recorders.

The aircraft was equipped with a Cockpit Voice Recorder (PN 2100-1020-02, SN 190688) manufactured by L-3 Communications, and a Flight Data Recorder (PN 2100-4043-00, SN 147122) also manufactured by L-3 Communications.

The voice and data recorders were sent to the CENIPA's Flight Recorder Data Readout and Analysis Laboratory, where the pertinent data was successfully downloaded.

The equipment operated normally and contained data related to the accident flight.

The CVR data pertaining to internal communications and those with air traffic control units are detailed in section 1.9 of this report.

The data extracted from the FDR was analyzed to identify the type of electrical failure that occurred, as well as the affected busbars, in order to determine which systems were operational during the flight and to which busbars they were connected.

Initially, it was verified that the flaps operated normally. This fact confirmed that the DC STBY BUS was being powered.

Since the flap position indicator was functioning, it was also determined that the AC STBY BUS was available, since the indicators were powered by the referred busbar.

All external communications made by the aircraft were conducted via the VHF-1 communication radio, indicating that the *DC EMER BUS* was being powered and, thus, supplying power to the VHF-1.

The inoperability of the EADI and EHSI instruments on the SIC side, which were non-functional at the onset of the failure, along with the inoperability of the VHF-2 communication radio, pointed to a likely power failure of the DC BUS 2, which was the source of power for the said components.

Additionally, the data recorded by the FDR revealed a spike in electrical current on the DC BUS 2 at the initial moment of the failure, followed by a drop to near-zero values with small oscillations thereafter. These findings are consistent with a failure of the DC BUS 2.

The FDR data also recorded an electrical current of 97 Amperes on the DC BUS 1 at the initial moment of the failure. The electrical current on the DC BUS 1 remained around this value, even after the drop of the current on the DC BUS 2, until the aircraft landed. This indicated that there was no increase in the electrical demand from the DC BUS 1 during the failure.

In summary, based on the data extracted from the flight recorders, it was determined that the following busbars were supplying electrical power:

- DC STBY BUS (flap control);
- AC STBY BUS (flap position indicator);
- DC EMER BUS (VHF-1); and
- DC BUS 1 (FDR data).

Moreover, it was possible to identify a failure in the DC BUS 2, as the EADI and the EHSI, both on the SIC side, and the VHF-2 communication radio were not functioning, as well as the fact that the electrical current recorded by the FDR showed values close to zero.

Lastly, it was observed that approximately six seconds after the onset of the electrical failure (16:39:43 UTC), multiple abrupt variations occurred in the parameters of the left elevator trim tab, which persisted until the end of the recordings.

Figure 14 – Extracted FDR data related to the left elevator trim tab indication.

The position signal for this trim tab was powered by the AC BUS 1, which, in turn, was supplied by the Static Inverter No. 1. For this reason, this component was also isolated and subjected to examinations and tests.

1.12. Wreckage and impact information.

According to physical evidence at the accident site, the aircraft landed on runway 11 at SBEG. The touchdown (with the landing gear retracted) occurred 410 meters beyond the threshold of runway 11.

The friction marks resulting from the aircraft's contact with the ground extended approximately 540 meters from the initial point of impact until the full stop, which occurred at a distance of 950 meters past the threshold of runway 11 (Figure 15).

Figure 15 - Sketch of the touchdown point and aircraft movement on the runway at SBEG.

The level of damage to the fuselage, caused by abrasive friction against the asphalt surface, indicated that the aircraft had a high horizontal velocity and a low rate of descent at the moment of impact.

The internal and external wing flaps had a deflection of 30°, consistent with the position required for approach and landing. The propellers did not contact the runway due to the high-wing design of the aircraft.

After the landing, the front and rear doors were opened to expedite the evacuation of passengers and crew.

Figure 16 – View of the aircraft after coming to a full stop.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

There was no evidence that issues of physiological order or incapacitation might have affected the crew’s performance.

1.13.2 Ergonomic information.

NIL.

1.13.3. Psychological aspects.

After the accident, interviews were conducted with the aircraft's crew to explore how psychological factors might have influenced their performance during the event.

At these interviews, the pilots reported experiencing some difficulty in clearly identifying the malfunctions due to the successive accumulation of failures, compounded by the concern of maintaining control of the aircraft. This challenge was heightened by the inability to adjust the pitch trim, which remained in the takeoff configuration—slightly nose-up.

Still according to the crew, the decision to return and land after the electrical failure was made with the intent to conclude the flight as quickly as possible, given the challenges in controlling the aircraft.

1.14. Fire.

There was no fire.

1.15. Survival aspects.

After the aircraft came to a complete stop, the pilots initiated the evacuation procedures.

The aircraft doors were not deformed by the impact or the friction caused by the landing with the landing gear retracted.

After the engines were shut down, the cabin crew opened the aircraft's rear door and coordinated the evacuation of the passengers. All the seatbelts and harnesses remained intact following the landing.

Two passengers sustained minor injuries during the evacuation. Initial assistance to the passengers was provided at the very airport.

1.16. Tests and research.

After removal of the aircraft from the runway, several tests and analyses were conducted on the electrical system, as recommended by the manufacturer. The initial tests were performed when the aircraft was in the hangar.

During the initial testing, an instability in the electrical system was observed, with various relays and lights cycling randomly. The system only returned to satisfactory operation after replacement of the 3PA relay (DC ESSENTIAL BUS TRANSFER CONTACTOR) and the 58PA relay (DC EMERGENCY BUS TRANSFER CONTACTOR), and passed the manufacturer-recommended tests. In that context, among the initial non-conformities identified, the intermittent operation of the Bus Tie Contactor (BTC) resulted in the lack of power supply to the DC BUS 2. However, the exact cause of the BTC's malfunction could not be determined.

During the visual inspection of the 58PA relay, it was observed that one of its terminals was loose. It was approximately 5 mm longer than the other terminals (Figure 17).

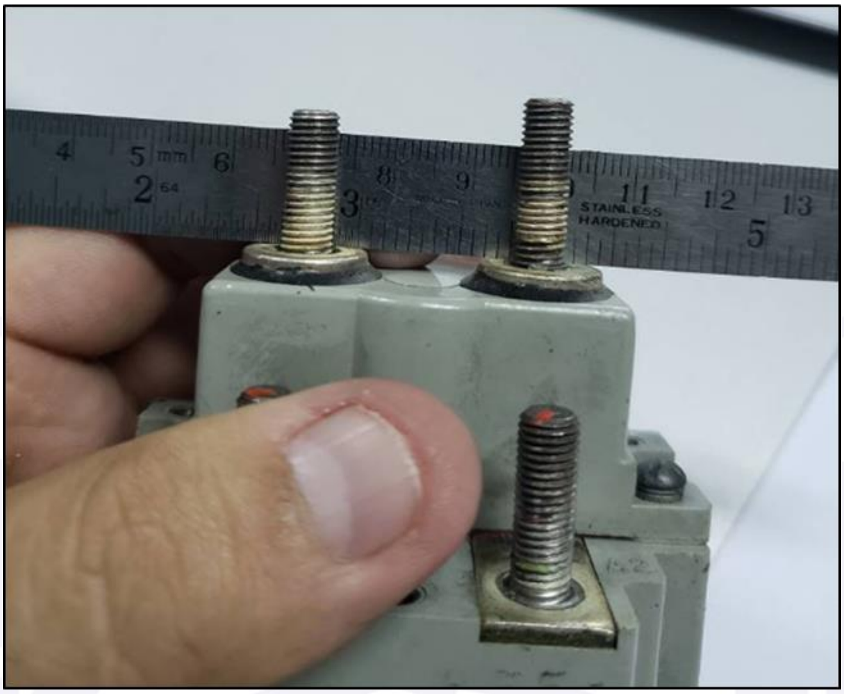


Figure 17 - 58PA relay with height difference in one of the terminals.

For these reasons, the relays were segregated and sent to a specialized facility owned by the component manufacturer for further examinations and testing.

A visual inspection was also conducted on the *Starter-Generator* No. 2, revealing an improperly assembled terminal (A+). One of the contact washers securing the electrical wiring to the terminal exhibited plastic deformation and was out of position (Figure 18).

Figure 18 - Deformation of a contact washer on the terminal A+ of the *Starter-Generator No. 2*.

Due to this issue and considering the failure of the *DC BUS 2*, which was directly powered by the *Starter-Generator* No. 2, this component was also segregated and subjected to examinations and testing in the specialized facility of the component manufacturer.

The bench tests and examinations of the 3PA relay (PN SM150D8, SN MFD 1008) were conducted by the Investigation Committee at the manufacturer's laboratory. No visual or operational abnormalities were identified in the examined relay.

The 58PA relay (PN SM150D8, SN MFD 8551) was also received at the manufacturer's laboratory for compliance examinations and bench testing. During the visual compliance inspection of this component, it was confirmed that one of its contactor terminals was misaligned, with a height differing from the specified value. Analyses indicated that this discrepancy likely resulted from the application of excessive torque during maintenance servicing (Figure 19).

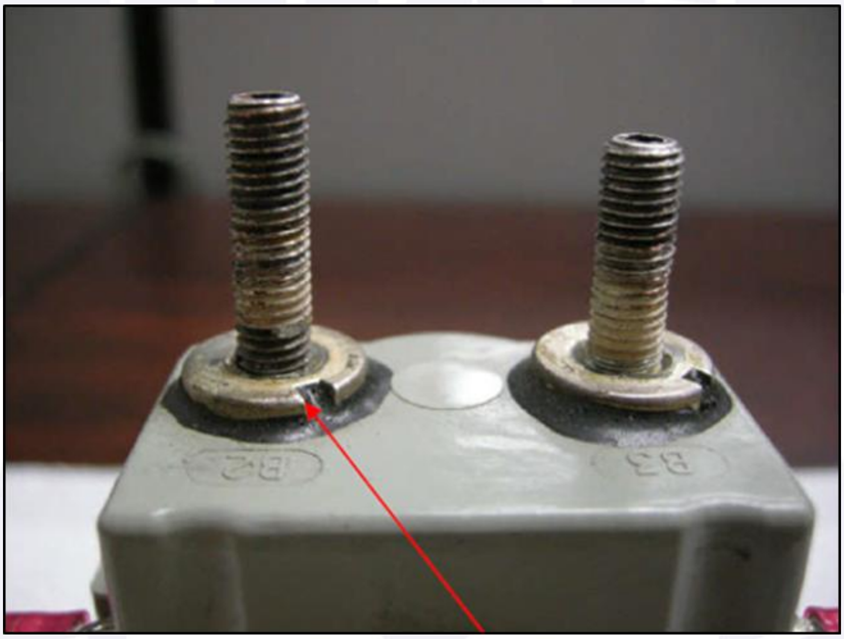


Figure 19 - Visual discrepancy in the 58PA relay:
B2 contact terminal longer than the B3 terminal.

The functional tests concluded that the relay had a non-acceptable condition, failing to meet the minimum operational requirements. The contact terminals B2 and B3, which are of the normally closed type, were also found to be non-functional.

After the relay was disassembled and internally inspected, a discrepancy was identified in one of its actuation buttons, which was in a collapsed position (Figure 20). This condition likely contributed to the relay’s intermittent operation. Such intermittent functioning of the relay could have impacted the proper operation of systems powered by it, including the intermittent activation of the Bus Tie Contactor (BTC).

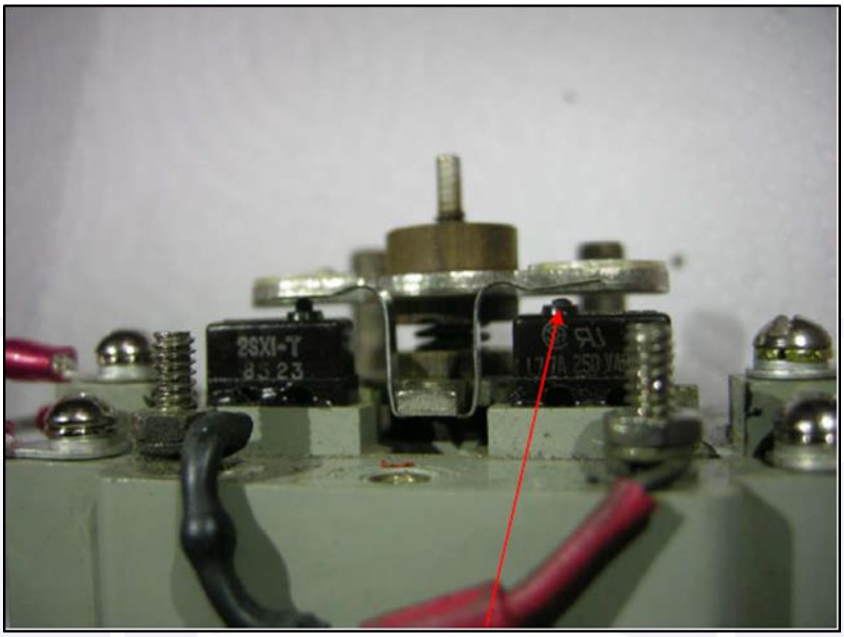


Figure 20 - Collapsed position of the actuation button of the relay 58PA: button related to switch 11/12/13

The *Starter-Generator* No. 2 (PN 8260-123, SN 2394) was received at the manufacturer's laboratory for examination. The compliance inspection revealed that the generator had a sticky surface resulting from an oil spill on its external casing and was in a poor condition of preservation (Figure 21).

Figure 21 - Overview of the *Starter-Generator* No. 2.

There was confirmation of the initial observation relative to the improper assembly at the “A+” terminal contact of this generator, with its insulation coating found to be damaged (Figure 22).

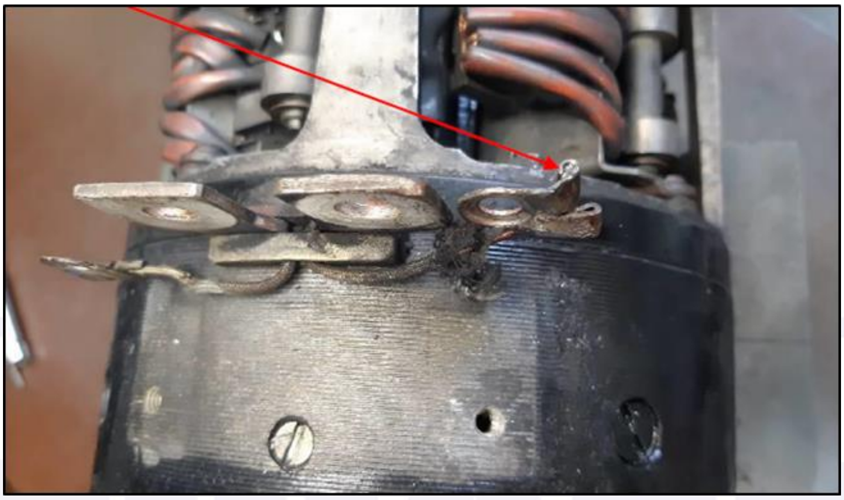


Figure 22 - Detail of the deformation at the fixation point of the wiring connected to the generator’s "A+" terminal and damaged insulation coating.

The incorrect assembly and the plastic deformation induced by excessive tool force on one of the wire contact washers caused this washer (located between the locking nut and the terminal) to become loose and prone to movement. This movement, combined with the deformation, contributed to the development of an abrasive mechanical stress on the wiring insulation layer, wearing it down.

One verified that the speed sensor installed in the *Starter-Generator* was not the model specified by the manufacturer, and the braking mechanism employed was non-compliant. During static testing, it was found that the insulation of the component was outside the prescribed parameters.

Qualitative and quantitative static tests were conducted on the component to evaluate its electrical and mechanical conditions before performing a dynamic test. The following discrepancies were identified in the *Starter-Generator*: insulation measurement below the reference value for the generator, as well as speed sensor installed in a fashion that was different from the specifications required by the generator's manufacturer.

Dynamic bench tests were also conducted on the generator to simulate its operating condition. During these tests, several parameters were found to be outside the reference ranges specified by the manufacturer. Additionally, an electric arc was observed forming between the stator windings and the rotor casing.

The conclusion of the dynamic tests was that the item failed the acceptance test established by the manufacturer for operation in aircraft.

Following the dynamic tests, the *Starter-Generator* No. 2 was disassembled for a comprehensive analysis to examine all its components in detail (*teardown*). Multiple non-conformities were identified in the component:

- improper assembly of the “A+” terminal contact, with a contact washer out of position and exhibiting plastic deformation caused by tool force. The wiring connected to the “A+” terminal, which supplies excitation current to the generator's magnetic field, had its insulation layer damaged;
- speed sensor not listed in the manufacturer’s parts catalog;
- damaged insulation on the generator stator winding;
- screws for fixation of the stator to the generator casing were not as specified in the manufacturer’s parts catalog;
- an abnormal amount of metallic dust was found on the rotor of generator;
- marks of electric arcs present on the hoop of the generator rotor; and

- rotor with physical characteristics differing from those specified by the manufacturer.

The aforementioned discrepancies can be observed in Figures 23, 24, 25, and 26.

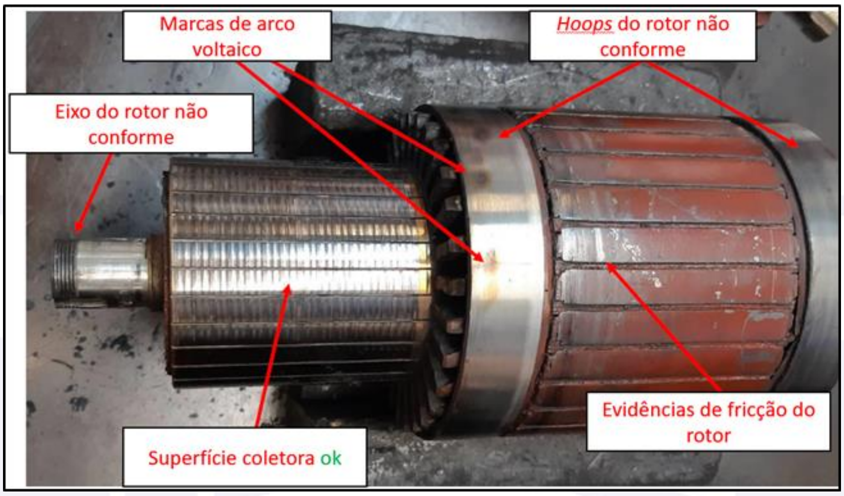


Figure 23 - Evident non-conformities in the rotor of the *Starter-Generator*.

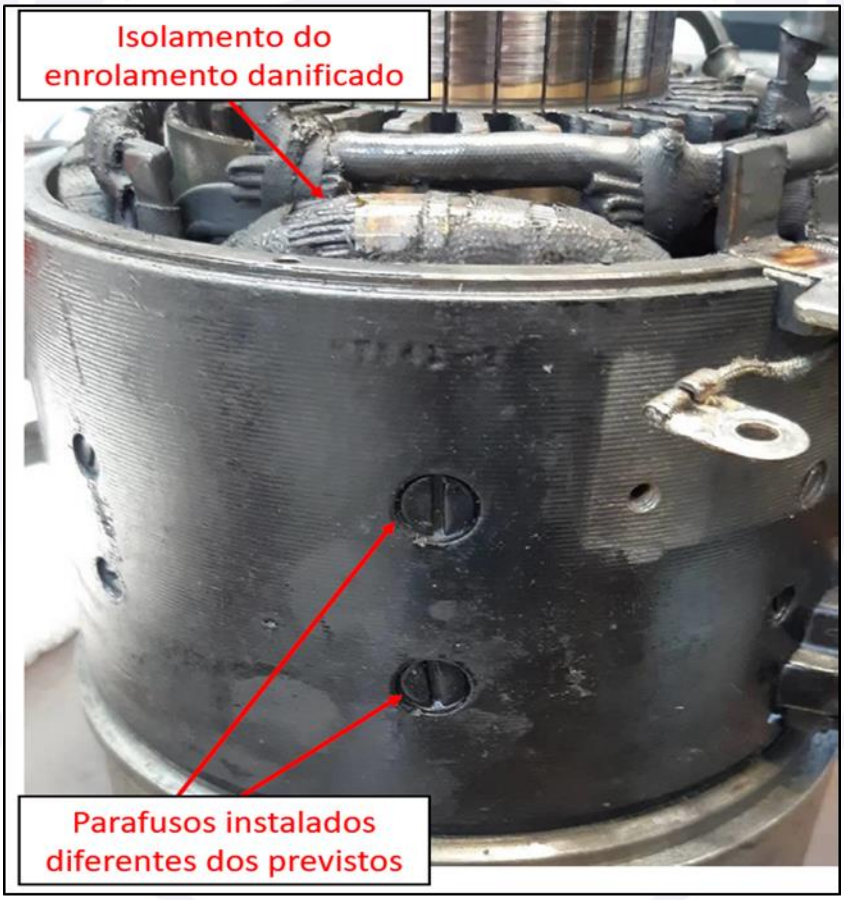


Figure 24 - Evident non-conformities in the casing and winding of the *Starter-Generator*.

Figure 25 - High amount of metallic dust
present on the rotor of the generator.

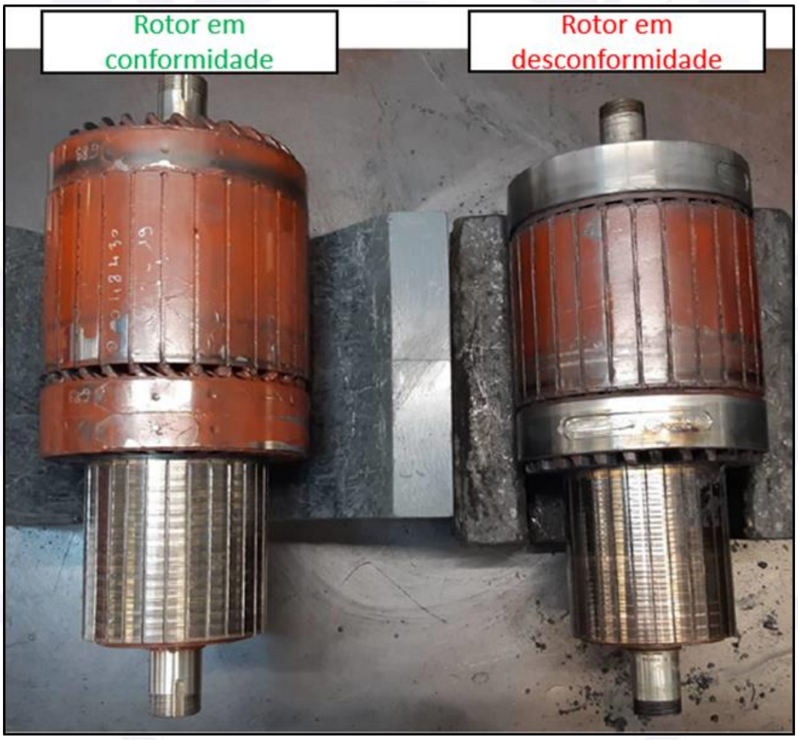


Figure 26 - Comparison between a compliant Starter-Generator rotor (on the left)
and the rotor installed in the PR-MPN aircraft (on the right).

The abnormal amount of metallic dust found in the generator rotor may be associated either with a lack of maintenance, or with a non-compliant execution of maintenance on the component. According to the Component Maintenance Manual, rotor cleaning should be performed during the component's overhauls. The technicians responsible for the overhauls indicated that, based on the quantity of metallic dust found, such cleaning was not performed at the latest overhaul.

The insulation measurement of the generator casing was 5kOhm, compared to the reference value of 20kOhm. This condition was possibly linked to the accumulation of metallic dust on the component, suggesting that the generator was in a worn and aged operational state. The metallic dust contamination increased the electrical conductivity of the generator casing, thereby reducing its insulating capacity.

In summary, the examinations revealed that the generator was not in an operating condition. It was evident that previous maintenance services, which were necessary to restore the component to its reliable operating condition, were possibly not performed in accordance with the manufacturer's specifications.

The *Static Inverter* No. 1 (PN 559-012A, SN 20432) was also subjected to examinations, tests, and analysis at the component manufacturer’s facility.

During the electrical tests, the output voltage measurements were found to be outside the tolerance parameters, indicating a defect in the overvoltage regulation system.

After the electrical tests, the Static Inverter was disassembled for an in-depth analysis. Several non-conformities were identified (Figures 27, 28, and 29):

- power circuit:3 transistors exhibiting signs of overheating.
- control and regulation circuit: two 1-Ohm resistors were used in series instead of a single 2-Ohm resistor, deviating from the manufacturer's specifications for achieving the required 2-Ohm resistance in one of the circuits.
- control and regulation circuit: signs of overheating due to rework, which did not comply with applicable standards; soldering on the circuit was also found to be non-compliant.
- one diode related to overvoltage protection was missing.
- one of the overvoltage protection diodes was in a short-circuit condition; and
- the overvoltage and undervoltage protection settings were incorrectly adjusted.

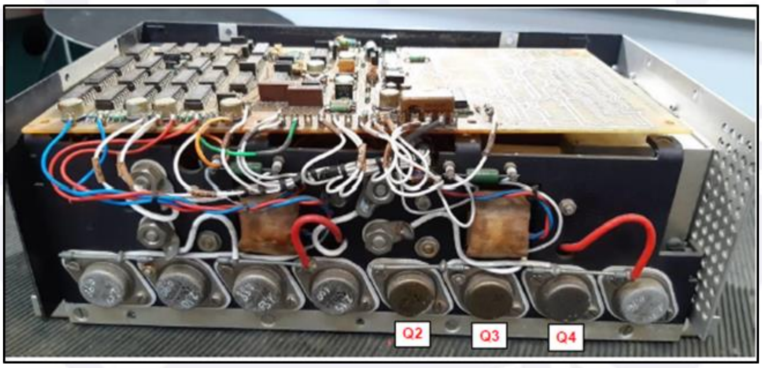


Figure 27 - Transistors Q2, Q3, and Q4 showing discoloration due to overheating.

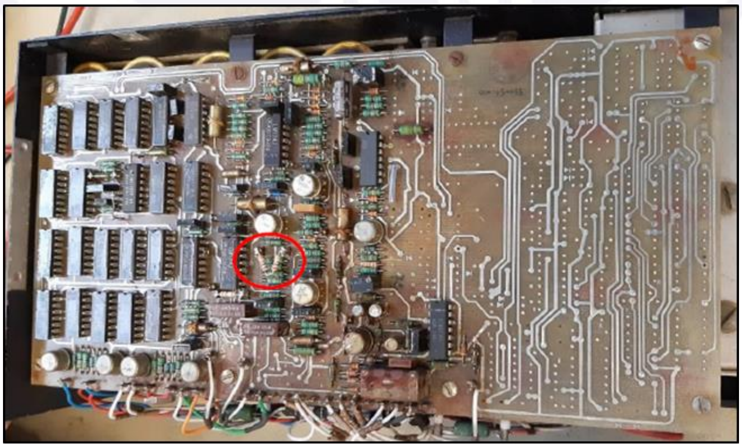


Figure 28 - Use of two 1-Ohm resistors in series
instead of a single 2-Ohm resistor.

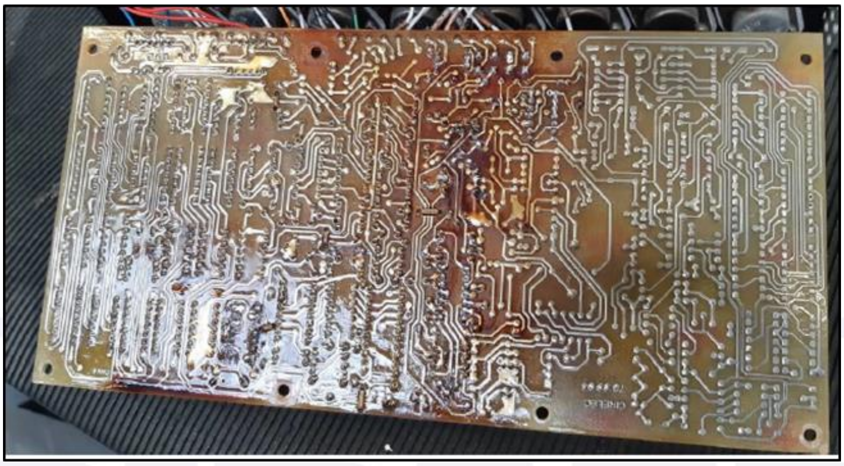


Figure 29 - Signs of overheating due to rework
and soldering performed in non-compliance with standards.

The examinations and tests conducted on the *Static Inverter* No. 1 (INV 1) concluded that this component was not in the operating condition specified by the manufacturer.

Multiple discrepancies contributed to its failure to operate within the minimum technical requirements. These discrepancies were linked to non-compliance in the execution of maintenance procedures.

1.17. Organizational and management information.

Regarding organizational issues, during the course of the investigation, interviews were conducted with company employees, through which it was possible to identify weaknesses in the relationship between the organization and its staff.

It was noted that the operator was undergoing a sales process, and employees were not provided with clear information about the company's actual situation. This lack of communication created an atmosphere of apprehension and uncertainty regarding their employment status.

Following the occurrence, it was verified that the operator did not have a Maintenance Organization certified under the RBAC-145 regulations, which was in effect at the time.

The Operating Specifications of the Airline contained the following information:

> "Part C.2 - Authorized Maintenance Services: Level of maintenance Check A."
>
> "Part C.3 - Authorized Maintenance Service Providers: The operator does not have outsourced providers for line maintenance."** No authorized maintenance providers existed for any other level of maintenance.
>
> "Part C.4 - Domestic Line Stations and Maintenance Bases: Self-maintenance, Check A level, at SBEG."** There were no outsourced maintenance providers for any level at SBEG, the company's headquarters, or at any other aerodrome where the airline operated.

However, the operator's General Maintenance Manual (GMM) read that maintenance was primarily performed by the very company, limited to line maintenance, as approved in the Operating Specification.

Hangar maintenance requiring certification under the RBAC-145 was to be performed by a second company within the same economic group of the aircraft operator. This company was certified under the RBAC-145, and all services carried out were required to comply with its Operating Specification, as well as with the procedures outlined in the operator's GMM and manuals approved by the ANAC.

According to the operator's General Maintenance Manual, line maintenance included Check A, which represented an adaptation of the terminology established by the Regulatory Agency to the company's internal nomenclature.

According to the General Maintenance Manual (GMM) of the operator and the Maintenance Organization Manual (MOM) of the secondary company performing the maintenance services, both organizations shared the same address. During the investigation at the airline's headquarters, it was observed that the two companies shared the same hangars and facilities.

While inspecting the companies' premises, it was not possible to clearly identify the boundaries of responsibilities between the two organizations, concerning either subordination of staff and which sectors were under the responsibility of each individual company.

1.18. Operational information.

The aircraft departed from SBEG en route to SWCA on a scheduled public air transportation flight. Onboard were four crew members and thirty-four passengers. The estimated flight duration was 2 hours.

The aircraft was within the weight and balance limits specified by the manufacturer. The mechanic responsible for conducting the pre-flight inspection reported that no abnormalities were found during the check.

The airline's SOP stipulated that, in the event of an abnormal occurrence, the crew should carefully analyze the situation before taking any action.

The document outlined a sequence of steps for the pilots to follow during such events. The first step was to maintain control of the aircraft, which was to be done concurrently with defining the tasks.

Once aircraft control was maintained and onboard responsibilities were defined, the crew was to proceed with analyzing the available information to determine the situation and decide on the appropriate actions. To aid this process, the SOP emphasized the use of Crew Resource Management (CRM) tools to facilitate the sharing of information, enabling better decision-making.

Regarding the decision-making process, the SOP established that, before making a decision, the impacts on technical aspects (consequences of the failure and compromised systems) and operational aspects (possibility of either continuing the flight or not) should be analyzed. The manual also highlighted that, during the execution of the corrective actions, the PIC ought to command the reading of the QRH and the execution of the procedures corresponding to the SIC.

With regard to communications during urgency or emergency situations, the SOP stipulated that communication should only take place after the PIC made a decision and when the situation allowed.

During the preparation for the flight, the PIC conducted the external inspection while the SIC prepared the cockpit. All checks were carried out as planned, and no abnormalities were noted by the pilots. The procedures for passenger boarding, engine start-up, and taxi were performed uneventfully.

The takeoff parameters were achieved as expected. However, shortly after the landing gear was retracted, the aircraft experienced an electrical failure. At an altitude approximately of 725 ft., the aural "TOO LOW TERRAIN" alarm from the GPWS was triggered, accompanied by the loss of some flight instruments on the panel. According to the flight crew testimony, the only instruments that remained operational were the standby airspeed indicator, the standby artificial horizon, and the standby altimeter. Additionally, the pitch trim control became inoperative in both normal and standby modes, locking in a position consistent with takeoff.

As a result, the aircraft's autopilot ceased functioning, requiring the entire flight to be controlled manually.

The crew initiated a brief discussion about the electrical issue. Initially, the PIC asked the SIC if they had lost the "DC" electrical busbar. The SIC responded that they had lost the "essential" electrical busbar. Following this, the SIC called *Manaus* Approach Control (APP-MN) to report that the aircraft was experiencing an electrical problem, and requested joining the downwind leg for runway 11 at SBEG. However, no emergency was declared by the crew.

The request was accommodated by APP-MN, which instructed the aircraft to make a right turn to join the downwind leg via the southern sector of SBEG. The elapsed time between the activation of the GPWS alarm and the request to join the visual traffic circuit was 55 seconds. There were no further discussions on the part of the crew regarding which busbars were inoperative or what emergency procedures should be executed.

According to pilots' accounts, they chose not to declare an emergency for believing that the situation was under control.

Initially, the flaps were not retracted, and the after-takeoff checklist procedures, as outlined in the QRH, were not performed. One minute and fifty-five seconds after the activation of the GPWS alarm, with the aircraft reaching a speed of 165 kt. at an altitude of approximately 3,300 ft., the flap overspeed warning was triggered. At that time, the flaps were still in the 15º takeoff configuration. After the alarm went off, the flaps were retracted.

The aircraft continued climbing until 2 minutes and 24 seconds after the onset of the emergency, reaching a maximum altitude of 3,779 ft. The climb was interrupted after APP-MN cleared the aircraft to descend to 1,500 ft.

After entering the visual traffic circuit of SBEG, the SIC contacted the chief flight attendant, informing her about the aircraft's electrical problem and their decision to return to SBEG. The flight attendant asked the SIC who would inform the passengers about the situation, and the SIC replied that he would do that. However, no communication to the passengers was identified in the CVR recordings.

Manaus Approach Control (APP-MN) cleared the aircraft to join the base leg of the visual traffic circuit. With the aircraft on the downwind leg, the flaps were set to 15º. Shortly afterward, the SIC initiated the execution of the normal *Approach Checklist* procedures.

Upon completion of the *Approach Checklist*, the PIC instructed the SIC to lower the landing gear. The SIC responded with the callout "*LANDING GEAR DOWN*", two seconds after moving the landing gear lever (4 minutes and 8 seconds after the start of the failure).

According to the company's SOP, the Pilot Monitoring (PM) was required to announce "*GEAR DOWN*" only after confirming the presence of three green lights indicating that the landing gear was locked down. During the accident flight, the SIC did not report any abnormalities in the primary gear indication system, nor was there any mention of verification using the secondary indication system.

Three seconds after the "*GEAR DOWN*" callout (4 minutes and 11 seconds after the failure began), the PIC asked the SIC whether the aircraft's position relative to the runway allowed for entry into the base leg. The SIC confirmed, and the turn to the base leg was initiated.

When the aircraft entered the base leg, the flaps were set to 30º. Four minutes and thirty-two seconds after the failure occurred, the PIC informed the SIC that he had the runway in sight. Shortly thereafter, the SIC called APP-MN to report that they were entering the final approach and was instructed to switch to the TWR-EG frequency. After switching frequencies and making an initial call to TWR-EG, the aircraft was cleared to land on runway 11.

With the aircraft aligned on the final approach to runway 11 at SBEG, the PIC requested the SIC to run the *Before Landing Checklist* (Figure 30).

BEFORE LANDING CHECKLIST

***Checklist* read by PM**	**PF**	**PM**
LDG GEAR .... 3 GREEN	"Down, 3 green"	
FLAPS 30	"Thirty"	
PWR MGT .... TO	"Takeoff"	
TLU .... LO SPD	"Lo speed" (ATR 72)	
CONDITION LEVER 1+2 .... AUTO ou MÁX	"Auto" ou "max"	
ICING AOA LIGHT .... CHECK	"No light / On"	
EXT LIGHTS .... ON	"On"	

Figure 30 - Before Landing Checklist Procedure described in the SOP.

During the execution of this procedure, when the SIC read the item *LDG GEAR - 3 GREEN*, the PIC replied with "*DOWN, 3 GREEN*" in less than one second, without mentioning verification of the gear position using the secondary indication system.

The final approach of the aircraft for landing on runway 11 at SBEG was conducted in a stabilized manner. No unsafe landing gear position alarms were triggered when the aircraft descended below the altitude of 500 ft. AGL.

At an altitude of approximately 360 ft. AGL, the PIC mentioned experiencing difficulty controlling the yoke. Six minutes and four seconds after the onset of the failure, the aircraft touched down on the runway short of the 1,000 ft. marker, with all landing gear legs locked in the up position. Following the aircraft's stop on the runway, the cabin crew initiated evacuation of the passengers through the rear doors, as instructed by the pilots.

At post-accident interviews, the pilots demonstrated a high degree of confidence in identifying a failure in the *Direct Current Bus 2 (DC B*US 2). This assessment was based on the illumination of the amber DC BUS 2 OFF light on the electrical control panel of the *Overhead Panel* and the amber arrow light for the *DC ESS BUS*, indicating that it was being powered by the Main Battery.

The pilots also considered the possibility of a failure in the *DC BUS 1* and in the *Static Inverters 1 and 2 (INV 1 and 2)*. However, they were uncertain about the indications or whether the corresponding lights on the electrical panel had illuminated.

During the flight, no abnormal or emergency procedures outlined in the Quick Reference Handbook (QRH) for electrical failures were requested or executed. Only the normal procedures related to *Approach Preparation*—including the request to lower the landing gear—and the *Before Landing Checklist*, which required verification of the landing gear being locked down (3 green lights illuminated), were performed. According to the pilots, the decision not to execute the QRH procedures was based on their inability to accurately identify the nature of the failure.

Also at those interviews, the pilots reported checking the status of the landing gear being locked down using the secondary indication panel located on the *Overhead Panel*. However, during the execution of the *Before Landing Checklist*, the PIC made the callout "*down 3 green*" less than one second after being prompted by the SIC, without referencing verification via the secondary indication system (Figure 31).

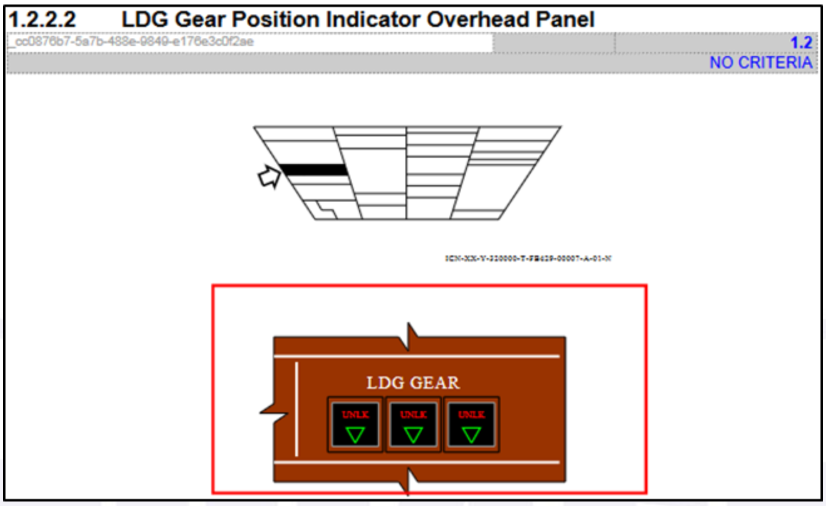
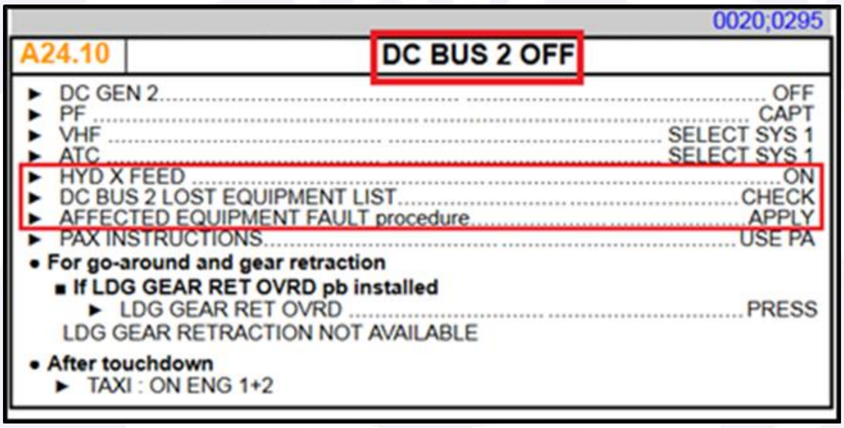


Figure 31 - Location of the landing gear position indicator on the *Overhead Panel*

The aircraft's Quick Reference Handbook (QRH) specified, as the 5th action item for the *DC BUS 2 OFF* failure, the activation of the hydraulic cross-feed valve (*HYD X FEED - ON*) (Figure 32).



0020;0295

A24.10 **DC BUS 2 OFF**

- ▶ DC GEN 2 .... OFF
- ▶ PF .... CAPT
- ▶ VHF .... SELECT SYS 1
- ▶ ATC .... SELECT SYS 1
- ▶ HYD X FEED .... ON
- ▶ DC BUS 2 LOST EQUIPMENT LIST .... CHECK
- ▶ AFFECTED EQUIPMENT FAULT procedure .... APPLY
- ▶ PAX INSTRUCTIONS .... USE PA
- **For go-around and gear retraction**
  - **If LDG GEAR RET OVRD pb installed**
    - ▶ LDG GEAR RET OVRD .... PRESS
  - LDG GEAR RETRACTION NOT AVAILABLE
- **After touchdown**
  - ▶ TAXI : ON ENG 1+2

Figure 32 – QRH's procedures for the "DC BUS 2 OFF" light illumination.

Additionally, the QRH instructed the crew to consult the *DC BUS 2 LOST EQUIPMENT LIST* (Figure 33).

Lost Equipment List

Air
- LANDING ELEVATION indicator

Auto flight
- ADU

Doors
- DOORS **UNLK** Lights
- CDLS

Flight controls
- STBY PITCH TRIM CTL
- CAPT STICK SHAKER

Hydraulic Power
- GREEN PUMP
- HYD PWR AUX PUMP IND
- HYD PWR AUX PUMP AUTO MODE

Ice and Rain protection
- F/O STATIC PORTS ANTI ICING
- F/O SIDE WINDOWS ANTI ICING
- F/O WINDSHIELD HTG indicator
- F/O PROBES indicator
- F/O WIPER

Indicating - Recording Systems
- GPWS FAULT on CAP

Landing Gear
- SECONDARY indicator

Lights
- F/O CHARTHOLDER
- F/O READING Lights
- F/O FLOOD PANELS
- INTEGRATED INSTRUMENTS Lights
- INTEGRATED PANELS Lights
- RH LDG Light
- WING Lights
- PAX SIGNS Lights

Navigation
- F/O EADI/EHSI
- SGU #2
- VOR #2
- ILS #2
- DME #2
- ADF #2
- CAPT RMI
- VHF #2
- HF #2
- ATC #2
- ADC #2
- ALT ALERT #2
- F/O CLOCK
- TCAS
- GPS/GNSS
- GPWS FAULT indicator

Power Plant
- FF/FU #2
- FUEL TEMP #2
- FUEL CLOG #2
- OIL PRESS #2
- OIL TEMP #2
- IDLE GATE CAUTION

Figure 33 - List of inoperative equipment for "DC BUS 2 OFF" failure in the QRH.

The *Green Hydraulic Pump*, responsible for extending and retracting the landing gear, would become inoperative in the event of a *DC BUS 2* failure. Activating the hydraulic cross-feed valve (*HYD X FEED*) would allow the landing gear to be operated using pressure supplied by the other hydraulic pump. However, the hydraulic system cross-feed was not activated, nor was the list of inoperative equipment verified.

The 6th action item outlined in the QRH instructed the crew to verify the equipment rendered inoperative due to the *DC BUS 2* failure. Among the items of equipment listed as inoperative, notable items included, besides the *Green Hydraulic Pump*, the landing gear *Secondary Indicator*, which, according to the pilots, had been utilized for verification of the locking of the landing gear in the down position.

The operator's SOP specified that, during abnormal flight situations, the PIC ought to designate the SIC as the *Pilot Flying* (PF) unless there was a specific reason not to do so.

This procedure aimed to provide the PIC with better situational management capabilities, as he was ultimately responsible for the decision-making process. Still in accordance with the SOP, the PF, during the management of an abnormal situation, would be responsible for controlling the aircraft and maintaining communications with air traffic control, while the PM would be tasked with reading the procedures outlined in the QRH (Figure 34).

PF	PM
Responsável por: • Trajetória de voo e Power levers; • Navegação; • Configuração da aeronave; • Comunicações ATC. ***Obs:*** *O PF é responsável pelas Condition Levers na descida de emergência.*	**Responsável por:** • Leitura de QRH • Executar ações solicitadas pelo PF • Condition Levers e OVHD panel **• Operação dos seguintes itens com o consentimento do PF:** — Condition Lever — Fire EXTG handles — P/B dos geradores DC e ACW

Figure 34 - Task division for abnormal and emergency procedures as per the SOP

Throughout the flight, the PIC remained in the position of Pilot Flying (PF). However, the SIC was responsible for communications with air traffic control, continuing to operate as the Pilot Monitoring (PM). At no point did the PM read the QRH procedures corresponding to the abnormal situation affecting the aircraft, as stipulated in the operator's SOP.

1.19. Additional information.

After the accident, the operator requested the aircraft manufacturer to conduct a *Damage Assessment* to determine the extent of the damage resulting from the landing with the landing gear retracted.

Following the assessment, the manufacturer issued a report that, in addition to the damage to the landing gear, identified multiple instances of corrosion in structures and panels. Among such instances, the ones below should be noted:

- The central section of the rear fuselage, inside the aircraft, near frame 33, where the stringer 20RH was found to be severely corroded, compromising its structural function at that location (Figures 35 and 36**).**

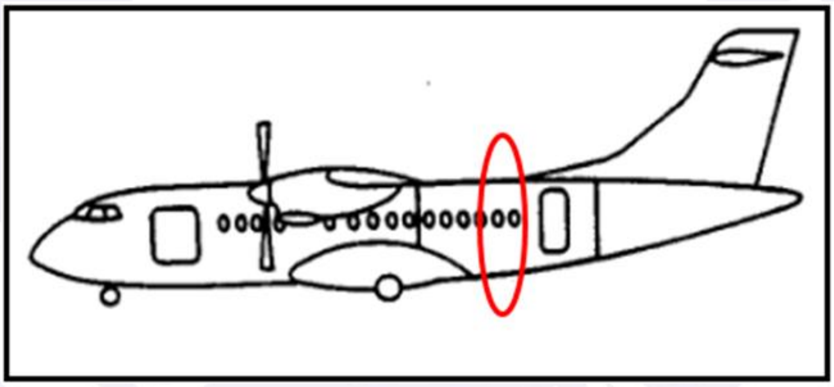


Figure 35 - Approximate location of frame 33.

Figure 36 - Stringer 20RH, near frame 33, showing severe corrosion.

- In the lower part of frame 12, located in the nose section of the fuselage, corrosion was found extending across the entire face of the frame. Additionally, in the same area, a fracture was discovered, spanning over 50% of the frame's face (Figures 37 and 38).

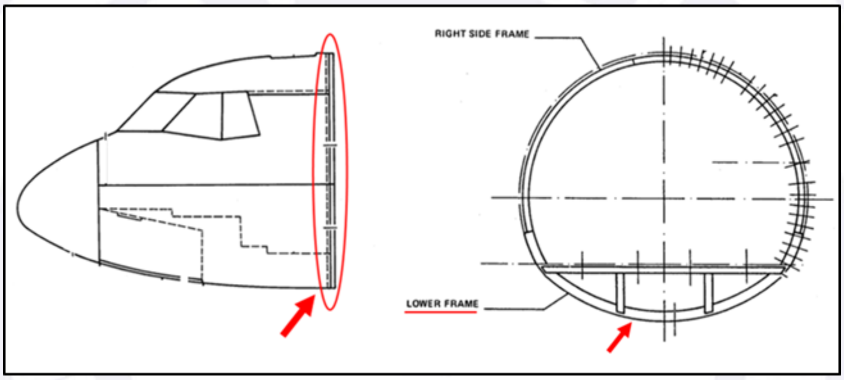


Figure 37 - Location of frame 12 and the corroded/fractured area.

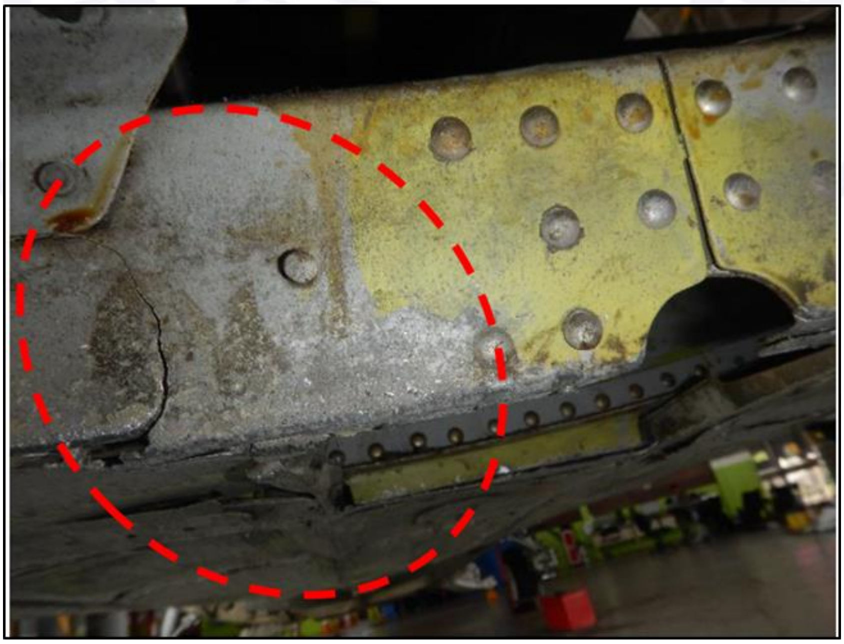


Figure 38 - Lower segment of frame 12, showing corrosion and fracture.

- In the area between frames 36 and 39, multiple instances of corrosion were identified, including passenger seat rails, thresholds of service and passenger doors, as well as floor panels. Specifically, on the structural element where the floor was secured, instances of penetrating corrosion were observed (Figure 39).

Figure 39 - Penetrating corrosion on the structural element securing the floor.

In the documentation referring to the Operator's Maintenance Program, one verified the existence of definitions of corrosion levels, processes for identification of corrosion in aircraft, and protocols related to required repairs. These processes and protocols served as the reference for carrying out tasks aimed at identifying and correcting discrepancies related to aircraft corrosion.

With regard to the documentation for the completion of maintenance tasks, in light of the corrosion identified by the Investigation Committee, the company presented records indicating that the tasks outlined in its Maintenance Program had been carried out.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

The flight was a scheduled public air transport operation from SBEG to SWCA, with an expected duration of two hours.

All pre-flight checks and verifications were completed without detection of any abnormalities. The aircraft was within the prescribed weight and balance limits.

Takeoff was performed uneventfully. However, after retraction of the landing gear, the aircraft experienced an electrical failure. Initially, the aural *TOO LOW TERRAIN* alarm from the GPWS was triggered, followed by the loss of cockpit flight instruments (EADI and EHSI) for both the PIC and SIC, as reported by the crew. According to the pilots, the only instruments remaining operational were the standby airspeed indicator, the standby artificial horizon, and the standby altimeter. Furthermore, the pitch trim control became inoperative, remaining locked in a position corresponding to the takeoff configuration.

The crew requested to return to the aerodrome, executing a visual traffic circuit for runway 11, with a right-hand base turn. The landing occurred with the landing gear legs retracted and locked in the up position.

After the aircraft was removed from the runway and released by the SIPAER Investigation Authority, various tests were conducted in accordance with the manufacturer's recommendations. These tests revealed unstable operation of the electrical system, characterized by multiple relays and indicator lights cycling intermittently and randomly.

The relays of the 3PA (*DC ESSENTIAL BUS TRANSFER CONTACTOR*) and 58PA (*DC EMERGENCY BUS TRANSFER CONTACTOR*) were replaced, and the system recovered satisfactory operation. These relays were segregated for further examinations, tests, and research at a specialized maintenance facility certified by the components' manufacturer.

In the analysis of these components, the 3PA relay showed no abnormalities during bench testing. However, the 58PA relay exhibited multiple discrepancies, indicating that it was not in an operating condition. The issues identified were linked to the execution of improper maintenance procedures.

Based on the analysis of the data recorded by the FDR, the Investigation Board was able to infer that the DC BUS 1 and DC STBY BUS were operational at the time of the event, since some of the equipment powered by these buses remained active. However, it was not possible to identify the cause associated with the loss of the EADI and EHSI indicators on the PIC side (powered by the DC STBY BUS and DC BUS 1, respectively), as reported by the flight crew.

From the analysis of the data recorded by the FDR, a failure of the DC BUS 2 was confirmed.

Since this busbar was normally powered by the *Starter-Generator No. 2*, this component was subjected to examinations and testing.

During the examinations and dynamic tests, several non-conformities were identified, consistent with the malfunction of the component. An abnormal amount of metallic dust was found on the generator's rotor, which could be attributed to inadequate or non-compliant maintenance of the item. According to the Component Maintenance Manual, the rotor cleaning procedure ought to be performed during overhauls of the component.

Based on the analyses conducted, one concluded that, given the amount of metallic dust present, this cleaning was possibly not performed at the last overhaul.

Furthermore, the conformity examinations of the *Starter-Generator No. 2* revealed physical characteristics that differed from those specified in the manufacturer's technical manuals and parts catalog.

These discrepancies were attributed to either non-compliance or improper execution of the tasks outlined in the maintenance plans for both the aircraft and the component.

Additionally, according to FDR data, it was observed that, following the electrical failure, the position parameters of the left pitch trim became inconsistent, showing abrupt variations in indication until the end of the recordings.

Since these parameters were derived from the *AC BUS 1*, which received electrical power from the *Static Inverter No. 1*, this component was also subjected to examinations and testing.

During the examinations, the *Static Inverter No. 1* did not pass the electrical input tests, as the measured output voltage values were outside the tolerance range, and the overvoltage protection did not activate.

The internal inspection revealed that the *Static Inverter No. 1* had been previously repaired but exhibited discrepancies resulting from maintenance procedures that did not comply with the manufacturer's specifications.

Thus, the most likely hypothesis for the power supply failure in *DC BUS 2* is that it was caused by a malfunction of the *Starter-Generator No. 2*, which was not in an operating condition due to inadequate maintenance. As a result, the *Starter-Generator* was not able to supply electrical power to the busbar within the specified parameters.

After the failure of the *Starter-Generator No. 2*, the *DC BUS 2* lost its power supply. At that point, the *Bus Tie Contactor* (BTC) should have activated to allow the *DC BUS 2* to be powered by *DC BUS 1*, using electrical energy supplied by the *Starter-Generator No. 1*, which remained in operation. However, the BTC failed to operate, leaving *DC BUS 2* without electrical power. It was not possible to confirm the exact reason of the BTC malfunction, but a plausible hypothesis is the non-conformity found in the 58PA relay, which was part of the BTC's power supply circuit.

The electrical power failure in *DC BUS 2* prevented the activation of the *Green Pump* in the hydraulic system, thereby eliminating hydraulic pressure for the normal extension of the landing gear, as the crew did not activate the hydraulic cross-feed valve (*X FEED*) of the system.

Due to the loss of power in *DC BUS 2*, the *Inverter No. 2* ceased to operate, as it was connected to this busbar. Consequently, through the operation of the *AC Bus Tie Relay* (ACBTR), the *Inverter No. 1* took over the supply of the *AC BUS 1*, *AC STBY BUS*, and *AC BUS 2*.

It is possible that, when facing a demand higher than normal, when it should only supply the *AC BUS 1* and *AC STBY BUS*, the *Inverter No. 1* may have failed due to not being in the expected operating conditions, as observed in the examination of the item. As a result of this failure, the power supply to the *AC BUS 1* may also have been compromised.

Since the position signal of the left elevator trim tab was provided by a position indicator powered by the *AC BUS 1*, it is plausible that the abrupt variations observed in this parameter's indications were caused by the loss of power in this busbar.

The inconsistencies in the left elevator trim tab indications may have caused a synchronization error with the right elevator trim tab indications, resulting in the inoperability of the trim system in both the "*Normal*" and "*Standby*" modes.

For a better understanding of the aforementioned events, a block diagram was developed (Figure 40).

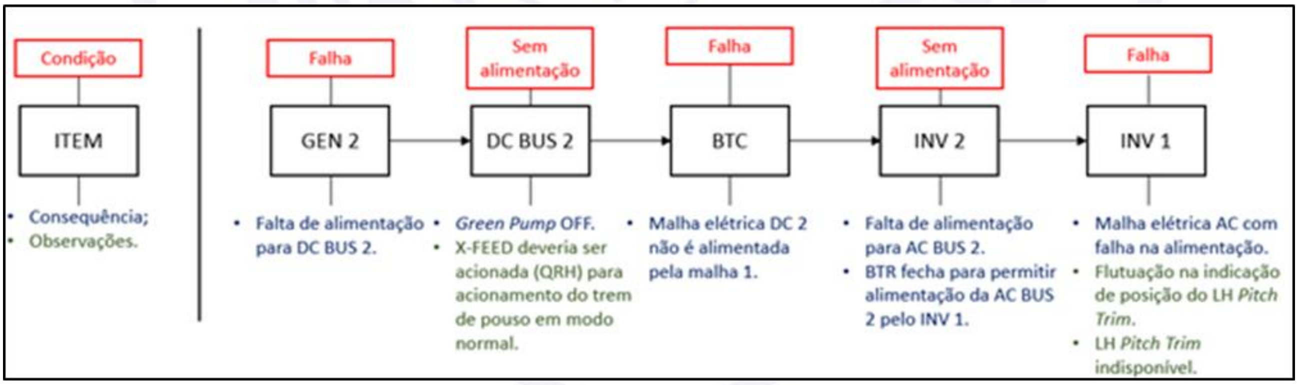


Figure 40 - Block diagram representing the event tree related to the electrical system failures in the PR-MPN aircraft.

Following the occurrence of the electrical failure and the subsequent loss of various flight instruments in the cockpit, the pilots held a brief discussion about the nature of the electrical problem and which busbars had been affected.

Without reaching a consensus on which malfunction was actually occurring, the crew decided to request a return to the departure aerodrome via the visual traffic circuit. From that point on, and once the decision to return to SBEG was made, no further discussions were held regarding the electrical failure or the affected systems.

At interviews conducted after the accident, the pilots told the investigators about their decision to return immediately to SBEG, with the intention of terminating the flight as quickly as possible. They stated that the decision was motivated by the difficulty in piloting the aircraft caused by the inoperability of the pitch trim control.

Once APP-MN authorized their return, the crew did not request or perform the abnormal procedures outlined in the QRH for electrical failures. The pilots justified not following the abnormal procedures by stating they did not clearly understand the nature of the failure affecting the aircraft.

The airline's SOP specified that, in abnormal situations, before any action was taken, the scenario ought to be carefully analyzed based on the available information to assess the technical and operational implications of each action. The manual also emphasized the use of CRM tools during the decision-making process.

The CRM (Crew Resource Management) can be understood as a systematic approach to flight management, in which the crew utilizes all available resources—personnel, procedures, and equipment—to enhance safety and efficiency in air operations.

The short time span between the onset of the malfunction and the request to return to the aerodrome (55 seconds) showed that the decision-making was rushed, with disregard for the prescribed procedures. Utilizing the checklist available in the QRH would have highlighted the overlooked procedures, enhancing the crew's situational awareness and contributing to more effective decision-making for the scenario presented. Furthermore, the implications of the chosen course of action were not considered by the crew members, nor were alternative decisions analyzed, indicating a breakdown in communication between the pilots.

The communication between the crew members was overly concise, considering the complexity of the situation. Their individual understandings of the scenario or the reasoning behind their decisions were neither shared nor discussed.

Despite the pilots' correct understanding of the *DC BUS 2* failure, as observed in the CVR recordings and reported at the interviews, their failure to follow the procedures outlined in the QRH, justified by them as a result of their incomplete understanding of the electrical failure, supports the notion of degraded situational awareness, as well as a decision-making process that was rushed and lacked an analysis of the possible consequences.

By reviewing the procedures for *DC BUS 2* failure outlined in the QRH, the pilots could have identified the need to activate the cross-feed valve (X FEED) of the hydraulic system, something that would have enabled the extension of the landing gear.

The failure to activate the hydraulic cross-feed valve (X FEED)—a step specified in the QRH for managing the *DC BUS 2 OFF* failure—made it impossible to lower the landing gear by means of the normal system. This ultimately resulted in the aircraft landing with the gear locked in the up position.

It is important to highlight that the *DC BUS 2* failure also rendered the secondary landing gear position indicator unavailable. Since this secondary indication system was responsible for sending a signal to the CCAS when any of the landing gear legs were not fully deployed and locked, its inoperability prevented the alarm system from detecting the landing gear's up position. Consequently, the system was unable to trigger the alert related to the landing gear not being down and locked.

Throughout the flight, even after the electrical failure occurred, the PIC remained acting as the Pilot Flying (PF), contrary to the procedure prescribed in the SOP for abnormal situations, which stipulated that the SIC ought to assume the roles of PF and manage the external communications of the aircraft. At no point was there any discussion about the division of tasks between the crew members; the same roles were maintained from takeoff to landing, without adjustments to accommodate the abnormal situation.

Thus, the poor division of tasks between the pilots may have contributed to their becoming overloaded, preventing them from effectively managing the identification of the failure and the necessary procedures to be executed, such as the QRH reading.

During the visual traffic circuit for landing at SBEG, after informing the chief flight attendant to inform her about the aircraft's electrical issue, the SIC stated he would personally communicate the situation to the passengers. However, this communication was not carried out, indicating an inadequate division of tasks among the crew members. This responsibility could have been delegated to the flight attendant, thereby reducing the pilots' workload. The failure to inform the passengers suggests a possible oversight caused by the SIC's overload during the emergency.

During interviews, the pilots stated that they did not declare an urgency condition for believing they had the situation under control. However, this assertion contradicts their own statements that they did not perform the QRH reading because they were unable to accurately understand the nature of the failure.

Failure to declare an urgency condition, despite the aircraft being in an abnormal flight condition, increased risks by preventing the ground crew from implementing potential mitigation actions.

They also attributed their quick decision to return immediately to SBEG to the difficulty in manually piloting the aircraft due to the inoperability of the pitch trim controls. Additionally, with the autopilot system unavailable, the pilots had to execute all maneuvers manually, further increasing the workload and operational challenges during the incident.

The hasty decision to return to SBEG without properly following the prescribed procedures may have been influenced by a condition of anxiety on the part of the PIC.

Furthermore, when analyzing the PIC's operational history prior to joining the airline, it was observed that he had demonstrated difficulties with manual piloting. There were also reports of limited knowledge of aircraft systems, and he had been subjected to a technical review board at his previous employer for these reasons.

Considering that the PIC underwent a reduced initial training program at the current airline, achieving only the minimum passing grade in the segment related to "General Emergencies", it is possible that systematic processes aimed at enhancing his knowledge, skills, and attitudes were not sufficient. This may have resulted in inadequate performance in managing the encountered emergency.

In this context, it is possible that the PIC's apprehension about flying manually—an area where he had a documented history of performance difficulties—negatively impacted the decision-making process. This led to a hasty decision to return without consulting the QRH or declaring urgency.

Once the decision was made, there were no further discussions regarding the electrical failure or which busbars or systems were inoperative. The pilots focused solely on executing the return to SBEG. This persistence in a single course of action, without considering alternative procedures, may indicate a form of cognitive fixation, often referred to as "tunnel vision", which contributed to the crew members' low situational awareness.

During interviews conducted after the accident, the crew reported that, on the occasion of the execution of the *Approach and Before-Landing Checklists*, the landing gear status was verified through the secondary indicator system located on the *Overhead Panel*. However, upon analyzing the CVR transcripts, it was noted that at no point did the pilots mention having observed the landing gear status via the secondary system. It is important to emphasize that this system was inoperative, as previously mentioned.

During the execution of the Before Landing procedure, a two-second interval was observed between the PIC's command to lower the landing gear and the SIC's callout stating: "LANDING GEAR DOWN." Such a short interval between the command and the response suggests a possible automatic response on the part of the SIC, without effective verification of the corresponding lights on the landing gear position indicator.

During the *Before-Landing Checklist*, when the SIC read the item "*LDG GEAR - 3 GREEN*," the PIC responded "*DOWN, 3 GREEN*" in less than a second. This short response time, without any mention of the system used for checking the landing gear, also suggests a possible automatic response from the PIC regarding the landing gear position, without an actual verification of the indicators. As such, it is possible that the pilots ended up forgetting to verify the landing gear status.

This situation may have been caused by the pilots' fixation on the decision to return and land at SBEG as quickly as possible, without conducting a thorough analysis of the situation. This hypothesis underscores the low situational awareness exhibited by the crew during the management of the emergency. It was further compounded by the PIC's difficulty in manual piloting due to the inoperability of the trim system.

Regarding the organizational aspects, it was observed that, contrary to what was established in the airline's Operating Specifications, another organization was performing maintenance services on the aircraft at levels beyond Check A.

Additionally, it was noted that the operator's technical monitoring of the maintenance work conducted by the maintenance organization exceeded the service levels approved in the Operating Specifications.

Another relevant aspect observed was the difficulty in distinguishing the limits of responsibility between the two companies, given that both belonged to the same economic group and shared the same address. Additionally, there was a lack of clear separation regarding which rooms and sectors within the hangars belonged to each individual company.

Thus, it was not possible to confirm that the services performed by the secondary maintenance company were effectively carried out in accordance with the requirements established in the airline's Maintenance Program.

In addition, it was observed that, although the pertinent Certificate of Airworthiness was valid at the time of the accident, the aircraft exhibited significant and advanced corrosion, including on its structural components. This revealed a state of affairs not consistent with the standards established in the operator's Maintenance Program.

This situation, combined with the main hypothesis that the failure of the *DC BUS 2* was caused by the use of a *Starter-Generator* that was not in operating condition, indicates potential deficiencies in the supervision and management processes related to the maintenance of the company's aircraft fleet.

A lack of clear communication was observed between the airline and its personnel in relation to the prevailing situation, taking into account the delicate process of sale and transition of management.

When informal communication replaces formal channels, fostering the spread of assumptions and creating an environment where misinformation gains traction, the workplace becomes susceptible to psychological stress among employees. This stress can manifest as irritability, difficulty concentrating, and excessive worry.

These vulnerabilities can subtly affect the performance of aviation and maintenance activities, even without immediate recognition. Furthermore, they may lead to interpersonal conflicts due to widespread apprehension. When employees operate in an environment perceived as less reliable, operational safety can be compromised, increasing the risk of accidents.

Thus, the lack of clear communication within the airline, particularly amidst its ongoing sale process, may have influenced the performance levels of its personnel. This could have negatively impacted both the operational effectiveness of the crew and the quality of maintenance activities, ultimately compromising safety standards.

3. CONCLUSIONS.

3.1. Findings.

a) the pilots held valid Aeronautical Medical Certificates (CMA);

b) the pilots held valid AT47 aircraft type ratings;

c) the aircraft had a valid Certificate of Airworthiness (CA);

d) the aircraft was within the specified weight and balance limits;

e) the records of the maintenance logbooks were up-to-date;

f) the meteorological conditions were above the minimum requirements for the flight;

g) the maintenance services were periodic but deemed inadequate;

h) the takeoff was uneventful;

i) after takeoff, the aircraft sustained an electrical failure;

j) there was a loss of electrical power supply to the *DC BUS 2*;

k) a failure in the operation of the BTC prevented the *DC BUS 2* from being powered by the *DC BUS 1*;

l) the EADI and EHSI displays in the PIC's and SIC's positions turned off;

m) the pitch trim control became inoperative, leaving the trim tabs in a position corresponding to takeoff configuration;

n) the crew requested to enter the visual traffic pattern for landing at SBEG;

o) the abnormal procedures outlined in the QRH for electrical system failure were not performed;

p) the crew did not declare an urgency condition;

q) the aircraft’s final approach was conducted in a stabilized manner;

r) the landing occurred short of the 1,000-foot mark, with the landing gear legs locked in the retracted position;

s) the aircraft sustained substantial damage;

t) the four crew members and thirty-two passengers emerged uninjured;

u) two passengers sustained minor injuries during the evacuation from the aircraft.

3.2. Contributing factors.

- **Attention – undetermined.**

During the execution of the *Approach* and *Before-Landing* checklists, the landing gear condition was not verified. The pilots' possible automatic response, stating that the landing gear was down and locked without actually checking the corresponding indicator panels, may have been caused by degraded attention resulting from fixation on other tasks at that specific moment of the flight.

- **Attitude – a contributor.**

Improvisation and non-compliance with the procedures outlined in the aircraft's QRH and in the airline's SOP contributed to the inadequate management of the occurrence, leading to the accident.

- **Training – undetermined.**

When analyzing the operational history of the PIC prior to joining the airline, it was observed that he had demonstrated difficulties with manual piloting. There were also reports of a lack of knowledge about the aircraft systems, and he had even been subjected to a technical review board at his previous employer for these reasons.

Considering that the PIC underwent a shortened initial training at the current airline, receiving the minimum passing grade in the General Emergencies segment, it is possible that the systematic processes aimed at enhancing his knowledge, skills, and attitudes were insufficient, resulting in inadequate performance in managing the experienced emergency.

- **Organizational climate – undetermined.**

The sense of insecurity and apprehension among employees during the company's process of sale and management transition, compounded by the lack of formal communication regarding the situation, may have compromised performance in air and maintenance operations. This environment likely degraded operational safety, increasing the risk of accidents.

- **Communication – a contributor.**

Limited communication between the crew members regarding the technical aspects of the abnormal situation experienced during the flight, combined with the difficulty in organizing a clear corrective action plan to address the electrical failure, contributed to the occurrence of the accident.

- **Crew Resource Management – a contributor.**

Inadequate division of tasks between the crew members during the handling of the emergency, where they maintained the same roles corresponding to a normal flight, reflected a disregard for the determinations outlined in the company's SOP for abnormal situations. This contributed to an increased workload for the pilots, ultimately leading them to land the aircraft with the landing gear retracted.

- **Emotional state – undetermined.**

It is possible that manual flying, a condition in which the PIC had a history of difficulties during flight, created a state of tension and anxiety. This may have contributed to a rushed decision-making process, without performing the QRH checklist or declaring an urgency.

- **Aircraft maintenance – a contributor.**

Various technical discrepancies observed during the examinations and tests performed on the *Starter-Generator No. 2* and *Static Inverter No. 1*, as well as the fact that both components were in use on the aircraft despite not being in operating condition, highlighted the inadequacy of the maintenance services performed.

- **Perception – a contributor.**

Conducting the return to SBEG, without considering any alternative procedures, combined with the failure to recognize the actual position of the landing gear, suggests selective perception or "tunnel vision" on the part of the crew. This, coupled with degraded situational awareness, compromised their interpretation of the stimuli and conditions present during the operation, ultimately contributing to the accident.

- **Management planning – a contributor.**

The technical monitoring exercised by the operator over the work performed by the maintenance company, involving service levels exceeding the authorization stated in its Operating Specifications, combined with the difficulty in distinguishing the boundaries of responsibility and supervision between the two companies, revealed inadequacies in the operator's planning related to the allocation of human and material resources for its operational activities, as well as in the definition of the outsourcing of maintenance services.

- **Decision-making process – a contributor.**

Following the electrical failure, the crew promptly decided to return to SBEG without first analyzing other possible alternatives or engaging in a more detailed discussion about the emergency situation and its consequences. As a result, the procedures outlined in the QRH were neither defined nor executed, and the systems affected by the electrical failure were not analyzed.

Thus, the decision-making process by the pilots was carried out prematurely, based on inadequate judgments supported by a low level of situational awareness, contributing to the occurrence of the accident.

- **Managerial oversight – a contributor.**

Several technical discrepancies observed during the examinations and tests performed on the *Starter-Generator No. 2* and *Static Inverter No. 1*, as well as the fact that both pieces of equipment were being utilized on the aircraft despite not being in operational condition, indicate a failure in the managerial oversight exercised by the company with respect to its responsibility to ensure the proper execution of the scheduled maintenance actions and to verify the effectiveness and efficiency of the services performed.

4. SAFETY RECOMMENDATIONS

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of safety, and shall be treated as established in the NSCA 3-13 "Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State".

Recommendations issued prior to the publication of this report:

To Brazil's National Civil Aviation Agency (ANAC):

A-091/CENIPA/2019 - 01 **Issued on: 28/10/2019**

Work with *MAP Linhas Aéreas LTDA.* to ensure the company conducts an extraordinary Corporate Resource Management (CRM) training, covering the entire program outlined in the IAC 060-1002A and ML.DRH.002-16, for all of the airline's flight crew members. Special emphasis should be placed on actions taken during the management of abnormal and emergency situations in flight, considering the types of aircraft in the company's fleet, in accordance with the Operating Specifications.

A-091/CENIPA/2019 - 02 **Issued on: 28/10/2019**

Conduct a follow-up inspection of CRM training at *MAP Linhas Aéreas LTDA.*, in accordance with the terms established by IAC 060-1002A.

A-091/CENIPA/2019 - 03 **Issued on: 28/10/2019**

Work with *MAP Linhas Aéreas LTDA.* to ensure the company conducts refresher courses on the electrical systems of ATR-42 and ATR-72 aircraft for all its pilots. Special attention should be given to the correct understanding of the list of dependent equipment that will be affected by an electrical failure in each aircraft bus.

A-091/CENIPA/2019 - 04 **Issued on: 28/10/2019**

Work with *MAP Linhas Aéreas LTDA.* to ensure that the maintenance services performed on the aircraft operated by the company are in full compliance with the provisions outlined in the Operating Specifications, General Maintenance Manual, and Maintenance Program approved by the Civil Aviation Authority.

A-091/CENIPA/2019 - 05 **Issued on: 28/10/2019**

Work with *MAP Linhas Aéreas LTDA.* to ensure that the company's Maintenance Program complies with the requirements established by the manufacturer, in order to guarantee the proper airworthiness conditions of the aircraft, specifically concerning the Corrosion Prevention and Control Program.

A-091/CENIPA/2019 - 06 **Issued on: 28/10/2019**

Work with *MAP Linhas Aéreas LTDA.* to ensure that the other aircraft in the company's fleet are in proper airworthiness condition, specifically in relation to the Corrosion Prevention and Control Program, considering the conditions identified by ATR during the evaluation of the accident aircraft, which resulted in the issuance of the *DAMAGE ASSESSMENT REPORT*, reference *ES-3495/19-ATR0100625*.

A-091/CENIPA/2019 - 07 **Issued on: 28/10/2019**

Work with *MAP Linhas Aéreas LTDA.* to ensure the company refines its internal communication processes, aiming to stabilize the organizational climate through regular information exchanges with employees, with the objective of keeping them informed about ongoing administrative and operational changes within the organization.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On June 23th, 2025.