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Analysisreliability Of Aircraft Electrical And Pneumatic Monitoring On Boeing 737 Aircraft

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ABSTRACT
This study analyzes the reliability of the electrical and pneumatic monitoring system on the Boeing 737 aircraft, which is a critical component in ensuring the safety and operational efficiency of the aircraft. The electrical system is responsible for supporting various vital functions of the aircraft, such as navigation, communication, and flight control, while the pneumatic system regulates airflow for various subsystems, including the anti-icing system, cabin control, and hydraulic pressure. The purpose of this study is to evaluate the performance of the monitoring system in detecting disturbances or failures in electrical and pneumatic components. The approach used involves direct monitoring, historical data collection, and predictive analysis using statistical methods to assess the level of system reliability. The results of the study indicate that the Boeing 737 monitoring system has high reliability in detecting problems before they become critical, but there are several aspects that need improvement, especially in terms of early detection of failures in the pneumatic system. Improving the reliability of the monitoring system can be done through the integration of more sophisticated sensor technology and artificial intelligence (AI)-based predictive algorithms. Thus, these improvements can improve the operational safety and efficiency of the aircraft.

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INTRODUCTION

The high demand of the public for long-distance transportation makes aviation a very important mode of transportation. This can be seen from the increasing number of passengers, both for domestic and international flights. As expressed by Miru (2004), "A consumer is any person or family who obtains goods for use and not for sale." Based on this definition, it can be concluded that the airline is fully responsible for the safety and service of goods consumed by passengers.

Technological developments play a significant role in global economic growth, including in the aviation industry. Currently, the commercial aircraft market is dominated by two major companies, namely Boeing based in the United States and Airbus based in Europe. These two companies have brought innovation to the world of aviation, influencing the way air transportation operates around the world.

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However, despite the increasing number of international and domestic flights, not everything runs perfectly. Technical failures in aircraft can occur at any time, and this is a serious concern for airline operators. PT. Lion Air Group, one of the largest private airlines in Indonesia founded in 2000, is one of the largest users of Boeing aircraft in Indonesia. They operate a fleet of 178 Boeing B737-800NG and B737-900ER aircraft, which serve flights to various regions throughout Indonesia (https://id.m.wikipedia.org/wiki/Lion_Air).

Boeing aircraft are known as high-tech aircraft equipped with various sensors to detect system failures. Important components such as landing gear, fuselage, engines, wings, and tail require strict maintenance, considering that these aircraft carry passengers on a large scale. One of the important systems on Boeing aircraft is the pneumatic engine, which is tasked with protecting engine components from fatal damage. The air system on this aircraft comes from the engine compressor and APU bleed.

One of the main causes of flight failure is the lack of information received by the flight crew about the problem that occurred, both when the aircraft was on the ground and in the air. The bleed trip system functions as a safety mechanism, where if there is a problem with the bleed air system, the aircraft cannot fly far. However, this problem is often only known to the pilot during the flight.

The reliability of an aircraft's electrical and pneumatic systems is a crucial element in the aviation industry, given its direct impact on safety and operational efficiency. Commercial aircraft such as the Boeing 737 rely on the integration of various advanced technology systems to support performance and safety during flight. Electrical systems provide energy to operate various critical components, such as navigation, communications, and flight controls.

Meanwhile, the pneumatic system plays a role in supporting vital functions such as cabin pressure regulation, air conditioning systems, and de-icing. The Boeing 737, as one of the world's most popular commercial aircraft, has electrical and pneumatic monitoring systems designed to detect, analyze and respond to potential disturbances quickly. However, challenges remain, such as disturbances due to extreme environmental conditions, aging components or failure of early detection by the monitoring system. Disruptions to these two systems can cause performance degradation to the risk of accidents, which not only impact passenger safety but also the image of the airline and the aviation industry as a whole.

This study aims to analyze the reliability of the electrical and pneumatic monitoring system on a Boeing 737 aircraft. The main focus is to evaluate the system's ability to detect disturbances, assess the level of reliability of the hardware and software used, and identify factors that affect system performance. With this analysis, it is expected to provide strategic recommendations to improve system reliability, support flight safety, and minimize the potential for operational failure.

Theoretical Basis

Aircraft

Airplanes are a very profitable invention for mankind because they have a great influence on life. Airplanes are aircraft that are heavier than air, have fixed wings and can fly

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with their own power. The inventors of airplanes are the Wright brothers, Orville Wright and Wilbur Wright, using their own designed aircraft called the Flyer which was launched in 1903 around the United States. In addition to the Wright brothers, there are also several other aircraft inventors, one of which is Samuel F Cody who performed his action in the Farnborough field, England in 1910. Below are the names of the inventors of airplanes;

1. Joseph Montgolfier and Etiene Montgolfier were the French inventors of the hot air balloon in 1782.
2. Samuel F Cody who carried out the airplane introduction action in 1910 which was located at Farnborough Field in England.
3. Ferdinand Von Zeppelin perfected the hot air balloon by modifying the cigar-shaped balloon used to transport passengers and goods in 1900.

After developing from era to era, airplanes have undergone many modifications, both in terms of design, shape and aircraft engines to meet the needs of air transportation, while a larger commercial aircraft was made in 1949, called the Bristol Brabazon.

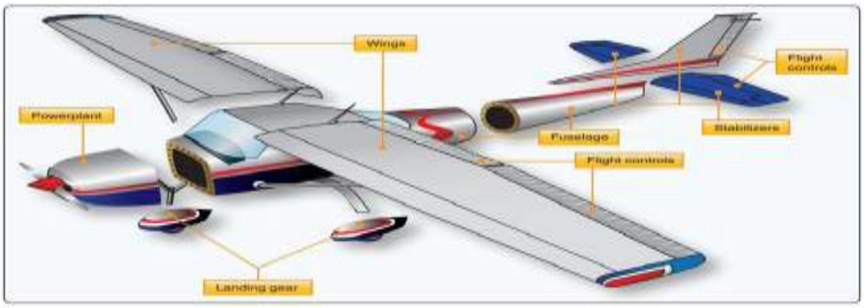

Figure 1. Aircraft and Major Components

The Boeing aircraft itself has experienced developments in each generation, from the B737-300/400/500 series to the latest generation type, namely the B737-600/700/800/900ER, which is currently widely used in the aviation world as a commercial aircraft. The Boeing factory is located in Seattle, Washington, USA, founded in 1916. The founder was William Edward Boeing.

The boeing companyis one of the largest aircraft manufacturers in the world. Boeing factory not only makes aircraft but also designs and even rents aircraft, Boeing company currently not only makes aircraft for commercial use but also makes rotorcraft, rockets and satellites. Fighter aircraft, aircraft used during air warfare. In general, fighter aircraft have a streamlined shape, can move agilely, and are equipped with complete weapons inside.

Figure 2. Fighter Plane Shape

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Wings (wings)

*Wings*is one of the main parts of an airplane that functions to produce lift,

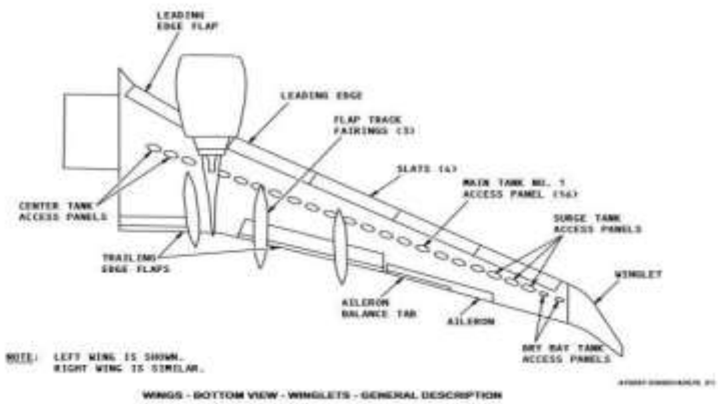

Figure 3. Parts of an Aircraft Wing Component

Figure 3 shows that the wings are used as engine supports, there are 2 parts attached to the wings, namely;

1. Engine nacelle/pylon
   Engine nacelle/pylonis: a place for installing and housing an aircraft engine that is separate from the fuselage that holds the engine, fuel and equipment on the aircraft, which can be round or oval and its shape must be streamlined to the air, and its construction consists of: skin, cowling, structural mamber, fire wall, engine mount
2. Flight control surfaces
   Flight control surfacesis a steering surface in the form of an airfoil designed to change the attitude of the aircraft, which is attached to the wings section and tail section. flight control surfaces are divided into 3 main groups, namely; primary control surface, secondary control surface, auxiliary control surface

How heat energy can be converted into kinetic energy and this is one of the laws of thermodynamics.

In-flight Systems

Airplanes are one of the transportations that have many systems in their control and operation. Airplanes have complex systems which are divided into simple systems that perform their respective functions. The following are the systems in an airplane:

a. Electrical system
b. Hydraulic system
c. Navigation system
d. Flight control system
e. Ice protection (antiicing and deicing) system
f. Cooling System
g. Ice protection (antiicing and deicing) system

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METHOD

This study uses descriptive and quantitative analysis techniques. The research conducted and the collection of data needed for this final assignment were carried out at PT. Lion Air. In order to complete this paper, some data are needed when conducting the research. The data needed are:

a. Regulations governing aircraft backup electricity
b. Battery specification data on Boeing 737 NG aircraft
c. Boeing 737 NG aircraft electrical load analysis data

Literature study is conducted by collecting and searching for information in the form of theories, formulas, and technical data from various sources such as scientific journals, libraries, websites, and manuals of the Boeing 737 NG aircraft. Direct surveys and data collection are conducted by conducting direct observations in the field and directly conducting research. Aviation regulations in Indonesia are regulated in Law Number 1 of 2009. For the implementation of the law, the regulations are stated in the Civil Aviation Safety Regulation (PKPS) or in English called the Civil Aviation Safety Regulation (CASR).

DISCUSSION RESULTS

How it works and the location of components in the Boeing 737 backup electrical system.

The electrical system on the Boeing 737 NG is the last source of electrical power when other sources of electricity are not available during flight. In general, the backup electrical system on the Boeing 737 NG is intended to supply two main standby buses, namely the AC standby bus and the DC standby bus, where these two buses are the main buses that connect or supply selected components that are crucial in their function. The main component that produces electricity for this system is a nickel cadmium battery with a nominal output of 24 VDC with a capacity of 48 AH. To keep the aircraft safe while flying to reach the destination airport or alternative airport when other sources of electricity are not available or damaged, the backup electrical system must be able to supply electricity according to needs. For the Boeing 737 Ng itself, several types of voltage are required to ensure the aircraft operates safely, namely AC and DC voltages. For AC voltage, the Boeing 737 Ng aircraft requires a voltage of 115 VAC for one phase and 200 VAC for 3 phases with a frequency of 400 Hz, while for DC voltage it requires 28 VDC.

The BAT DISCHARGE lamp will usually light up together with the ELEC lamp on the electrical meter and the master caution lamp on the glareshield when any of the above conditions occur, except during the APU start process. The BAT DISCHARGE lamp will go out when the current output drops below the limit for 1 second.

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Figure 4. Battery From Electronic Equipment Compartment

Figure 5. Electrical Meter when the battery is discharging

Figure 6. Battery Charger

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The battery charger has a 115 VAC 400 Hz 3 phase input from another power source (IDG, APU Starter-Generator, External Power) via AC transfer bus 2. The way the battery charger works is the battery charger gets 115 VAC, 400 Hz and 3 phase input then this input is converted by the battery charger into a 27.5 VDC output where this output will be used depending on what mode is operating in the battery charger. When working, the battery charger has 2 modes, namely battery charger mode, where the battery charger operates to charge the battery to the maximum point, and transformer rectifier mode, where the battery charger will supply the buses that are usually supplied by the battery (hot battery bus and switched hot battery bus). The change in battery charger mode is controlled by the SPCU.

Figure 7. Standby Power Switch

On the battery charger there are two green indicator lights that say CHARGER and BATTERY which are called status lights. Normally both of these lights are on. If one or both lights are off, then it is certain that there is damage. Static Inverter is a component of the backup electrical system on the Boeing 737 NG where this component provides AC voltage for the AC standby bus. Static Inverter is located in the EE Compartment in the E2 rack.

The way the static inverter works is by using DC voltage from the battery and then converting it into AC voltage with 115 VAC, 400 Hz and 1 phase to supply the AC standby bus. The AC standby bus itself is normally supplied by AC transfer bus 1. The static inverter will supply the AC standby bus if the AC transfer bus has no power. In addition, if we move the Standby power switch to the BAT position, the static inverter will also supply the AC standby bus even though the AC transfer bus 1 has power. The control of this static inverter is carried out by the SPCU. To find out the voltage and output frequency of the static inverter, it can be seen on the electrical meter in the cockpit.

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*Standby Power Control Unit*or commonly abbreviated as SPCU is the brain of the backup electrical system, where SPCU works together with related components to carry out its duties. SPCU is located in the cockpit, precisely on the P6 panel, behind the first officer (FO) seat in the far right corner

Figure 8. Standby Power Control Unit

SPCU has a crucial function, where SPCU ensures that AC and DC standby buses always get electricity supply. SPCU adjusts the relay position based on the input obtained to determine where the supply will enter the AC standby bus and DC standby bus, in other words SPCU also performs monitoring functions on switches, such as battery switches, standby power switches, etc. Because changes in switch position will also affect where the supply will be given to the AC standby bus and DC standby bus.

Regulations Applicable to Aircraft Electricity in Indonesia

For the electrical regulations applicable in Indonesia, regulated in Civil Aviation Safety Regulation (CASR) Part 23, concerning Airworthiness Standard: Normal, Utility, Acrobatic, and Commuter Category Aircraft, Subpart F – Equipment, explains that aircraft with 10 or more passengers (excluding flight crew) must have a reliable electrical system for continuous operation for 30 minutes after total damage to the electrical generation system. For the Boeing 737 NG aircraft itself, it must follow this regulation, because the Boeing 737 NG aircraft has 215 passengers (all economy seats) with a flight crew of 7 people, with a configuration of 2 pilots and 5 flight attendants. This regulation can be interpreted that the backup electrical system on the aircraft must be able to supply electricity continuously for 30 minutes. In this final assignment, the author conducted a study to obtain evidence whether the backup electrical system in this case is the backup electrical system of the Boeing 737 NG aircraft is able to meet the requirements of the regulation. This is because there has been no research that proves that the Boeing 737 NG backup electrical system can survive for a minimum of 30 minutes when all electrical sources are damaged. To prove

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this, the author conducted research and collected data from one of the Boeing 737 NG aircraft operated by Lion Group, namely aircraft with the code YT766 and YH071. The data taken include battery specifications and the loads on the Boeing 737 NG aircraft's electrical system. After obtaining this data, the author conducted analysis and calculations to prove that the 737NG aircraft that the author took as a sample met the applicable requirements.

Table 1. Source Power rating Boeing 737 NG

Source	Power (KVA)
IDG 1	90KVA
IDG 2	90KVA
APU starter generator	90 KVA (Up to a height of 30,000 foot)
	62 KVA (above 30,000 feet)

During flight, when the three power sources above cannot supply, the power supply will be taken over by the battery as the last backup power system. Where according to regulations, the battery must supply power to certain components for at least 30 minutes.

Table 2. 115 VAC BUS SEC1 (YT766)

Component	KVA	Power Factor
ATC 1	0.064	0.90
Radio Navigation DME 1	0.039	0.90
ADIRU Left AC	0.061	0.89
FMCS Computer 1	0.031	1.00
FMCS MCDU 1	0.067	1.00
Radio Navigation VOR/Marker Beacon 1	0.046	0.62
Radio Navigation Navigation Control Panel	0.009	0.80
Radio Navigation ADF 1	0.043	0.42
Radio Navigation RMI	0.023	0.39
Radio Navigation MMR1	0.051	0.82

AC Standby Bus or 115 VAC STBY BUS is a bus that in stby state is supplied by a battery whose voltage is converted from DC to AC by a static inverter. 115 VAC STBY BUS is divided into three parts, namely 115 VAC STBY BUS Section 1 and Section 2, and 28 VAC STBY BUS which are each used to supply components.

Table 3. 28 VDC STBY BUS SEC 1 (YT766)

Component	Current (Ampere)
Very High Communication 1 (Communication)	1.262
Mach Warning SYS.1	0.159
Engine 1 Thrust Reverser Cont.	0.140
SMYD-1 CMPTR DC	0.341
Engine 1 Thrust Reverser SYNC. Lock	0.193
Display DEU 1 PRI.	4,591
Display Capt. OUTBD	3,661
Display Capt. INBD	3,661
Display Capt. EFIS Cont. Panel	0.075
UPR Display Center.	3,661
Radio Navigation NAV SNSR DC-1	0.128
STICK SHAKER LEFT	0.010
TOTAL	17,882

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From the table above, it is known that the components supplied by 28 VDC STBY BUS SEC 1 consist of several systems. The first is the VHF1 component of the communication system which has been previously explained that this system is crucial for a flight. The second is Mach warn sys. 1 which is a hazard warning system when the aircraft speed is almost exceeding the specified limit. The third is from the Eng 1 Reverser system, this system prevents the thrust reverser from opening when the aircraft is in the air. The fourth is the display and radio navigation systems for navigation purposes required by the pilot. And the last is the stick shaker left which is a warning system that indicates that the condition of the aircraft's angular position (angle of attack) is almost exceeding the specified limit.

Table 4. BAT BUS SEC 3 (YT766)

Component	Current (Ampere)
Landing Gear Latch & PRESS WARN	0.800
Master Caution Annunciator BAT	0.625
Indicator Master DIM DIM/TST CONT	1,399
Control Cabin Lighting STBY Compass	0.047
Landing Gear Aantiskid INBD	0.265
Control Cabin Lighting Dome White	0.937
DIM BAT Master Indicator	1,346
Fuel QTY 2	1,250
Landing Gear Aural WARN	0.116
MISC Clock Display	0.023
Master Caution Annunciator CONT 1	0.184
Master Caution Annunciator CONT 2	0.184
Master Caution Annunciator CONT 3	0.184
Master Caution Annunciator CONT 4	0.184
Engine Fuel Engine 1 HPSOV IND	0.035
Engine Fuel Engine 1 HPSOV IND	0.035

For Battery Bus Section 3, just like the buses, this bus will distribute electricity from the battery to crucial components and systems, namely warning indicators for the aircraft wheels, master caution, which functions as a marker if there is damage to a system, clock, and fuel valve for engine number 1.

Loads When Electricity is Supplied by Battery on Aircraft with Block Number YT766 (737-8GP) (Standby Mode)

As explained earlier, when electricity is supplied only by the battery or can be called standby mode, not all components are supplied. This is because not all buses are supplied due to the limited capacity of the battery. The buses that are supplied during standby mode. AC Standby Bus or 115 VAC STBY BUS is a bus that in stby state is supplied by a battery whose voltage is converted from DC to AC by a static inverter. 115 VAC STBY BUS is divided into three parts, namely 115 VAC STBY BUS Section 1 and Section 2, and 28 VAC STBY BUS which are each used to supply components. For this AC Standby Bus, because the voltage source is in the form of DC voltage from the battery, the DC voltage from the battery must be converted to AC voltage through the Static Inverter. To calculate the length of time that can be held by the battery, the input current from the static inverter is sought, and it is obtained 26,107 Ampere. Dc Standby Bus or 28 VDC STBY BUS is a bus that in

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stby state is supplied by a battery through the STBY DC ALT relay. 28 VDC STBY BUS is divided into two parts, namely 28 VDC STBY BUS Section 1 and Section 2, each of which supplies components. Battery Bus is a bus that is in standby condition supplied by the battery through the BAT BUS ALT relay. Similar to the previous buses that have been discussed, the Battery bus or 28 VDC BAT bus is also divided into several parts, namely Battery bus section 1, 2, and 3, BUS which are each used to supply components. For Bat Bus Sec 1, this bus will distribute voltage from the battery to several components, the first for the control system for anti-ice for the wing and engine number 1 or the left, which is a crucial system when the aircraft is flying in icing conditions, which can cause ice on the wings and aircraft engines. The next for Engine 1 Start Lever channels A and B, this system functions to provide power for the start lever to open and close the valve for aircraft fuel. And the last is ISFD or Integrated Standby Flight Director, this component is very important when all displays cannot function, data for the position, speed and altitude of the aircraft can be seen on the ISFD. For Battery Bus Section 3, just like the buses, this bus will distribute electricity from the battery to crucial components and systems, namely warning indicators for aircraft wheels, master caution, which functions as a marker if there is damage to a system, clock, and fuel valve for engine number 1. Switch Hot Battery Bus or 28VDC SW HOT BAT BUS is a bus that is supplied directly by the battery when the battery switch is in the on position. The Hot Battery Bus switch is divided into three buses, namely sections 1, 2, and 3, but for section 3 it is not used. The components supplied by 28VDC SW.

CONCLUSION

Based on the results of the analysis of the reliability of the electrical and pneumatic monitoring system on: The electrical monitoring system on the Boeing 737 aircraft has a high level of reliability in detecting anomalies in the aircraft's electrical network. However, several weaknesses were detected, especially in components that were approaching their service life, which could potentially reduce detection accuracy. Therefore, routine maintenance and component updates are important steps to maintain system performance. Pneumatic monitoring systems have proven effective in ensuring cabin pressure remains within safe limits and supporting critical functions such as de-icing and actuator drive. However, extreme temperature fluctuations at certain altitudes can affect the accuracy of pneumatic sensors. This indicates the need to develop sensors with better temperature tolerance.The integration between electrical and pneumatic systems shows a fairly good level of synergy, which allows for early detection of potential system failures in a more comprehensive manner. However, there is still room for improving the data analysis algorithm so that the system can provide earlier warnings.The electrical and pneumatic monitoring system on the Boeing 737 aircraft is currently quite reliable in supporting flight operations. However, with the implementation of more advanced technology and repair strategies, the reliability and efficiency of the system can be further improved, which ultimately supports global aviation safety standards.

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