



AEROSPACE INFORMATION REPORT

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Assessment of Electric Engine Failures Leading to LOPC

RATIONALE

Civil aviation authorities have published Special Conditions for the airworthiness and type design of aircraft electric and hybrid engines which include requirements for the tolerance of engine control systems to single failure leading to loss of power or thrust control events. While there is a common industry-wide understanding of the scope of applicability of such requirements for traditional propulsion technologies, this is not the case for electric and hybrid engines. Furthermore, the means to accommodate loss of thrust or power control applicable to traditional propulsion technologies may not be suitable for electric and hybrid engines and some of the aircraft applications they are intended to be integrated into. The intent of this document is to provide and propose the adoption of alternative criteria to this historical approach in the context of electric and hybrid technologies based on propulsion power loss levels, their effects at the aircraft level, and acceptable failure rates.

INTRODUCTION

This aerospace information report provides guidance to assess the tolerance of an aircraft electric engine design to electrical and electronic failures leading to Loss of Power Control (LOPC) or Loss of Thrust Control (LOTC) events. Its intent is to provide a means to demonstrate compliance with certification requirements. At issue 1, this document has been developed to address fully electric engine configurations targeting single engine aircraft applications with conventional engine installation. Information, guidance, and recommendations from this document may also be relied upon by applicants to develop compliance demonstration strategies for other types of engines and aircraft.

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1. SCOPE

This document proposes a method to demonstrate compliance to engine certification rules requiring tolerance of the control system to single failures leading to Loss of Power Control (LOPC) or Loss of Thrust Control (LOTC) for electric or hybrid engines. At issue 1, the document was developed to address only fully electric engine configurations targeting single engine CS/part 23 level 1 and 2 aircraft applications.

The methodology proposed herein is based on an alternative definition of Loss of Power Control (LOPC) proposed by EASA, the FAA, TCCA, and ANAC in a joint Decision Document. It is therefore only applicable to projects which elect to implement this authority-proposed alternative definition. Other approaches for the demonstration of compliance of electric engines to control system single fault tolerance requirements, including approaches based on legacy practices applicable to piston engines, remain possible. They are, however, outside of the scope of this document.

Future issues of this report are expected to provide additional guidance for the application of the proposed method to other engine and aircraft applications.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR8678	Architecture Examples for Electrified Propulsion Aircraft
ARP4761	Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Sysems, and Equipment
ARP5107	Guidelines for Time-Limited-Dispatch (TLD) Analysis for Electronic Engine Control Systems
ARP8676	Nomenclature and Definitions for Electrified Propulsion Aircraft

2.1.2 ANAC-EASA-FAA-TCCA Certification Management Team Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

This chapter refers to the document version available at the date of the publication. It is recommended to refer to the EASA website and use the latest amendment available.

Certification Management Team Decision Document entitled "Single Fault Tolerance and LOPC in Electric Engines: Level 1 and 2 Normal-Category Aeroplanes in General Aviation," dated October 12th, 2023, and henceforth called "CMT Decision Document."

<https://www.easa.europa.eu/en/document-library/bilateral-agreements/cmts-tst-certification-management-team-secretariat-task-specific-team>

2.1.3 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

14 CFR Part 23 Airworthiness Standards: Normal Category Airplanes

14 CFR Part 33 Airworthiness Standards: Aircraft Engines

2.1.4 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

This chapter refers to the document version available at the date of the publication. It is recommended to refer to the EASA website and use the latest amendment available.

CS-E Amendment 7 - Certification Specifications and Acceptable Means of Compliance for Engines

CS-23 Normal, Utility, Aerobatic and Commuter Aeroplanes

SC E-19 Issue 1 - Special Condition Electric/Hybrid Propulsion System

AMC 20-3B Certification of Engines Equipped with Electronic Engine Control Systems

2.1.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

This chapter refers to the document version available at the date of the publication. It is recommended to refer to the FAA website and use the latest amendment available.

Special Condition 33-022-SC Special Conditions: magniX USA, Inc., magni350 and magni650 Model Engines; Electric Engine Airworthiness Standards

AC 33.28-3 Guidance Material for 14 CFR § 33.28, Engine Control Systems

2.1.6 U.S. Military Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-STD-1629 Procedures for Performing a Failure Mode, Effects and Criticality Analysis

2.2 Terms, Definitions, and Abbreviations

Term	Source of Definition	Proposed Definition
AA	This document	Airworthiness Authority
Cooling System	ARP8676	A system that may be used to cool the electric engine to a manageable temperature range. The cooling system working fluid could be liquid or gaseous.
DC Link Capacitor	This document	Electric energy storage element (capacitor) acting as a buffer between a high voltage DC (HVDC) electrical source and an inverter.
Digital Controller	This document	Processing unit based on one or more digital processing components such as a digital signal processor, programmable logic device, or microcontroller that implements the control laws required to control a system.
Electric/Hybrid Propulsion System (EHPS)	ARP8676	An electric/hybrid propulsion system may include, but is not limited to, electric motors, inverters, turbine engines, piston engines, generators, electrical wiring interconnection systems, electric power generation, energy storage systems, integrated fans, cooling systems, and power management system. An EHPS is intended to produce lift, thrust, or power for flight. Refer to AIR8678 for example of architectures.
EHPS Control System	EASA SC E-19	A system or device that controls, limits, monitors, or protects the operation of the EHPS or a subsystem of the EHPS.
Electric Engine	ARP8676	The Electric Engine is composed of a minimum of components including the electric motor, associated electronic controllers, disconnects, wiring, and sensors that provide propulsion to the aircraft. The main function supported by an Electric Engine is to transform electrical power to mechanical power.
Electric Motor	ARP8676	An electric machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current to generate force in the form of shaft rotation.
Electric Motor Windings	This document	Arrangement of electrical conductors used to transform an AC current controlled by an inverter into a rotating magnetic field that generates the motion of the rotor. Motor windings are usually installed in a metallic envelope intended to guide and concentrate the magnetic flux generated.
Engine Control System (ECS)	FAA AC 33.28-3 2-1 (a) FAA Special Condition 33-022-SC	Any system or device that is part of engine type design, that controls, limits, or monitors engine operation, and is necessary for the continued airworthiness of the engine.

Term	Source of Definition	Proposed Definition
Emergency Short Duration Power (ESDP)	CMT Decision Document	Declared rating that defines the short-term power capability of the electric engine in the event of a single electrical or electronic failure other than LOPC-E.
Emergency Continuous Duration Power (ECDP)	CMT Decision Document	Declared rating that defines the continuous power capability of the electric engine in the event of a single electrical or electronic failure other than LOPC-E.
Fault Tolerance	This document	A property of a system or function that allows proper functional operation even if components fail.
Inverter	ARP8676	A power converter is an electronic circuit or electromechanical device that converts electric energy from one form to another. There are various power converter types: AC to AC, AC to DC, DC to AC, and DC to DC. Power converters can convert voltages and/or currents. An inverter is a synonym for a DC to AC power converter. In the context of this document, this term designates the function which converts HV DC power to AC power to feed the electrical motor.
Loss of Power Control for Electric Engines (LOPC-E)	CMT Decision Document	An LOPC-E event is defined as an event where: • An electric engine has lost the capability of modulating power between Minimum Power* and Single Fault Ratings (e.g., ESDP and ECDP) at applicable operating conditions, or • An electric engine suffers a Fault which results in unacceptable power oscillations, or • Has lost the capability to govern the Engine in a manner which allows compliance with its operability specifications. * Minimum Power: A minimum controllable power setting, as defined by the manufacturer, otherwise use zero.

Term	Source of Definition	Proposed Definition
Loss of Power Control for Reciprocating Engines (LOPC-R)	EASA AMC 20-3B FAA AC 33.28-3	AC 33.28: For reciprocating engines intended for part 23 Class I., II., and III. Aircraft, an LOPC event occurs when the engine control system: (a) Has lost the capability to modulate power between idle and 85% of maximum rated power at all operating conditions, or (b) Suffers a fault that results in a power oscillation greater than the levels given in Paragraph 6-2 c. of this AC 33.28, or (c) Has lost the capability to govern the engine in a manner that allows compliance with the operability regulations in § 33.51. AMC 20-3: An LOPC event is defined as an event where the Engine Control System: - has lost the capability of modulating power between idle and 85% of maximum rated power at all operating conditions, or - suffers a Fault which results in a power oscillation greater than the levels given in paragraph (7)(c) of this AMC 20-3, or - has lost the capability to govern the Engine in a manner which allows compliance with the operability specifications given in CS-E 390. In this document, these legacy definitions of LOPC are referred to as "LOPC-R" in order to distinguish them from the novel "LOPC-E" definition applicable to electric engines only.
Loss of Power (LOP)	This document	Within the context of this AIR, loss of power below Single Fault Ratings (SFR), including total loss of power. The LOP event may result from Engine Control System and/or mechanical parts failures.
Minor Power Loss (MPL)	FAA AC 33.28-3	A reciprocating engine control system failure event resulting in the ability to attain less than 95%, but still greater than 85% of rated power. This definition also applies to electric engines.

Term	Source of Definition	Proposed Definition
Motor Controller	This document	Electronic unit or group of units composed of: - Digital controller(s) hosting: - Engine control software/firmware - Engine monitoring software/firmware - Low voltage power supply unit(s), fed from aircraft low voltage network or from internal high voltage DC (HVDC) bus - Aircraft engine controls input/output circuits (digital, discrete, analog) - Inverter interfaces (including gate drivers if applicable) - Integrated sensing/health monitoring means (temperature, ...) - Any filtering means that may be required for EMC and lightning protection - Signal connectors NOTE: The motor controller may be integrated with the motor power electronics.
Motor Power Electronics	This document	Electronic unit or group units composed of: - Inverter (power switches, gate drivers if applicable) - Sensing means (temperature, voltage, current) - High voltage DC Link capacitor - Any filtering means that may be required for EMC and lightning protection - Power connectors
No Take-off (NTO)	This document	No Take-off (no dispatch)
PPL (Partial Power Loss)	CMT Decision Document	An electric engine control system failure event resulting in a loss of power such that the remaining available power is below 85% of rated power but still equal to or greater than Single Fault Ratings.
Redundancy	ARP4761	Multiple independent means incorporated to accomplish a given function.
Sensor	This document	Device used to measure a physical parameter of the electrical engine, such as: - Shaft angular position - Temperature - Current - Voltage
Single Fault Ratings (SFR)	CMT Decision Document	Emergency ratings that specify the power available following a single electronic or electrical fault.
Time-Limited Dispatch (TLD)	ARP5107	Predetermined durations when a fully functional fault-tolerant system is allowed to operate with faults present in the redundant elements of the system, before repairs are required.