

Electrical Load Analysis

2 August 2016

General

Civil Aviation Authority advisory circulars contain guidance and information about standards, practices, and procedures that the Director has found to be an acceptable means of compliance with the associated rules and legislation.

However, the information in the advisory circular does not replace the requirement for participants to comply with their obligations under the Civil Aviation Rules, the Civil Aviation Act 1990 and other legislation.

An advisory circular reflects the Director's view on the rules and legislation. It expresses CAA policy on the relevant matter. It is not intended to be definitive. Consideration will be given to other methods of compliance that may be presented to the Director. When new standards, practices, or procedures are found to be acceptable they will be added to the appropriate advisory circular. Should there be any inconsistency between this information and the rules or legislation, the rules and legislation take precedence.

An advisory circular may also include **guidance material** generally, including guidance on best practice as well as guidance to facilitate compliance with the rule requirements. However guidance material must not be regarded as an acceptable means of compliance.

An advisory circular may also include **technical information** that is relevant to the rule standards or requirements.

Purpose

This advisory circular provides guidance material for the preparation of an Electrical Load Analysis (ELA).

Related Rules

This advisory circular relates specifically to Civil Aviation Rules Part 91 *General Operating and Flight Rules* and Part 21 *Certification of Products and Parts*.

Change Notice

This is the initial release of this advisory circular.

Table of Contents

1. Introduction	3
2. Applicability	3
3. Definitions	3
4. General Requirements	3
5. Basic Principles	4
6. Content	4
7. Test Regime	6
Appendix 1— Sample Template	7
Example Template- ELA (DC)	7
Example Template- ELA (AC)	9
Appendix 2—Electrical Definitions	11

1. Introduction

An Electrical Loads Analysis (ELA) is a fundamental document verifying the airworthiness of an aircraft by providing evidence that the aircraft electrical generation, storage and distribution systems have sufficient capacity to power all installed electrically-powered equipment in both normal and emergency flight conditions. As such, an ELA has two main purposes—

- (a) to ensure generating capacity is sufficient to supply the greatest demand of the equipment; and,
- (b) to ensure the battery has sufficient capacity to power the required systems in the event of an emergency.

From a regulatory perspective, there are two areas where the required performance may be stipulated—

- (a) the original design basis for the aircraft; or
- (b) the operating rule under which the aircraft operates.

An ELA provides a means of showing compliance against these requirements.

This AC has been generated with reference to MIL-E-7016F and ASTM F2490-05.

The initial ELA generated for type certification provides the baseline for subsequent changes and this should be kept updated with all future configuration changes. Where role equipment is to be used, the impact of this equipment should be immediately available so the operator can determine safety, suitability and any operating limitations prior to departure.

2. Applicability

This advisory circular is applicable to all aircraft and is specific to the actual configuration of the aircraft. If any stage avionics equipment is added or removed, or the generating/ storage devices altered, the ELA should be revised accordingly.

In the absence of an ELA, practical testing is a suitable method of verifying loads.

3. Definitions

The definitions specifically pertaining to an ELA are included in Appendix 2 of this advisory circular.

4. General Requirements

An ELA does not compensate or cover design or installation. These still need to be done in accordance with the required design standards and specifications pertaining to the aircraft type and operation.

The ELA is a living document and should stay with the aircraft and be updated to constantly reflect the aircraft configuration. Where role equipment is permissible for the aircraft, the effect of

installing that role equipment should be readily summarised and be able to be applied to the overall aircraft ELA.

This advisory circular has been generated at a high level to provide an overview and means of compliance. In some instances it may be necessary to provide greater detail and determine more specific details of the aircraft's electrical system, such as the discharge and recharge characteristics of the battery. In these instances or where a greater level of understanding is desired by the designer/person generating the ELA, reference to MIL-E-7016F and ASTM F2490-05 should be made.

5. Basic Principles

A loads analysis is essentially a summation of the electrical loads applied to the electrical system during specified operating conditions and then the demand analysed with respect to the supply. The ELA requires the listing of each item of equipment or system, the power requirement for that system/ equipment and identification of when the item is used during the phases of flight.

To determine the overall evaluation of power requirements, it is necessary to consider the transient demands of equipment and determine whether these require inclusion. The in-rush currents on motors and momentary/ intermittent operation of relays are not included unless considered significant by the person compiling the ELA.

6. Content

ELA should contain the following information as a minimum.

Introduction

- A brief overview of the aircraft, the intended operating role of the aircraft, the electrical system and its function.
- An electrical schematic and bus wiring diagram can be included to assist in establishing this overview.

Assumptions and criteria

- All the assumptions and design criteria used as the basis for the ELA.
- This should include a description of the operating conditions (including worst case loading- night, ice, cruise) and the equipment that is operating in each scenario- including duty cycles and details of the non-standard operating cycles.
- Unless otherwise stated, radios are considered to be transmitting 10% and receiving 90% of the operating time.

Table of values (an example is included in Appendix 1 of this advisory circular)

- The starting point with any ELA is the generation/ distribution network. As such the capacity of the generator(s) and battery (ies) is identified.
- For each bus, identify the equipment (by system- e.g. VHF radio, fuel, etc.) and its rated current draw.

- For each system, identify the operating time, or annotate C for continuous, and identify the phase of flight it is used in. For each load, for each phase of flight, an ampere hour figure should be derived.
- Additionally, if the system or component is used in the situation of a generator failure, annotate that in the separate column for emergency.

Note: Momentary / intermittent loads (such as valves and relays) are not included. *In-rush currents on motors are not included. The overload design ratings of the sources should however be adequate to cope with these.*

- For those aircraft with AC generation and distribution systems, additional requirements need to be considered such as—
 - phase balance/ loading per phase
 - connection architecture (star/ delta)
 - power factor
 - reactive power, true power and apparent power.

Emergency and standby operations

Where standby power is provided by a non-time limited source- such as RAT, APU or pneumatic/ hydraulic motor, the emergency loads should be listed and evaluated to ensure that demand does not exceed capacity.

Calculations and results

Once the results have been tabulated, the following calculations can be completed.

- System capacity. This is derived by accumulating the highest demand load at any point in time and ensuring that it is within the required rated capacity. Unless stipulated elsewhere, the standard guide is that loading should be less than 85% of rated generating capacity.
- Duration on emergency power. This is duration in minutes and is derived by calculating the time that the equipment connected to the emergency bus can operate before the battery voltages drops to the point that the equipment cannot be relied on. This figure is calculated based on industry wide assumptions¹ made about the condition and type of the battery, the time it takes to disconnect the non-emergency buses (this factor changes if auto-load shedding occurs), the load required for landing and the load drawn by the emergency equipment². The standard duration required on emergency power is 30 minutes however this may vary with design or operating rule requirements.

Summary and conclusion

The summary should provide evidence that for each operating condition the available power can meet the loading requirements, with adequate margin for both peak loads and maximum continuous loads under normal and abnormal conditions. For AC systems these summaries should include power factor and phase loadings.

¹ The assumptions made are particular to the battery conditions and drop off points. These have been captured in the underlying specifications.

The conclusion should include statements confirming that the power sources can satisfactorily supply electrical power to necessary equipment during abnormal/ emergency operations under the highest demand conditions.

7. Test Regime

In the absence of sufficient data to enable a comprehensive analysis, when validation of data is required or when it is considered more desirable by the operator to decide, testing is a suitable alternative to analysis. The principle of the testing is the same as the analysis. To prove that the aircraft's generation system can supply the equipment needs and to ensure that sufficient emergency capacity exists in the event of generator failure.

To conduct the test, the participant needs to develop a similar table as per the template in Appendix 1 of this advisory circular, in which they identify the equipment that will be operating during each phase of flight. Rather than calculate the individual loading per system, it is sufficient to determine the current draw for each operating condition. The rest of the process can then be followed as per an ELA by analysis.

To measure the current draw, it is important to ensure that the currents being measured are purely related to the equipment current draw. As such, the battery needs to either be isolated (if testing with generator) or current draw assessed purely off battery. It is preferable to use external current measuring and where possible, verify this against the aircraft ammeter.

If it is considered that in-flight forces will affect the current draw on the system (eg. control surfaces), a factor may be applied to the measured result and this needs to be identified and explained in the assumptions that accompany the test results.

Appendix 1— Sample Template

Example Template- ELA (DC)

Generator _____ Amps

Battery _____ Amp minutes

	Connected Load	Operating Time (C-continuous)	Normal Operation						Emergency	
			Takeoff		Night, Ice, Cruise		Land		Ampere	Ampere Min
			Ampere	Ampere Min	Ampere	Ampere Min	Ampere	Ampere Min		
Bus										
Item										
Total										
Bus										
Item										
Total										

Battery Duration Calculation – Emergency

Battery capacity (A/min)=	_____	Amp-min	(1)
Derated battery capacity ((1) * 0.75)=	_____	Amp-min	(2)
Preload shed (5min * night, ice, cruise load) =	_____	Amp-min	(3)*
Emergency Load =	_____	Amp	(4)
Landing load (5min * landing load)=	_____	Amp-min	(5)

Duration= $\frac{\text{Derated Battery Capacity} - \text{Pre Load shed} - \text{Landing Load}}{\text{Emergency Load}} = \frac{(2)-(3)-(5)}{(4)}$ minutes (6)

Total Duration= Pre load shed time (5min)+ Landing Time (5 min) + Duration (6) minutes

*Where pre-load shed current draw is greater than twice the 1 hour rating of the battery this is to be increased by 20%.

Example Template- ELA (AC)

Generator _____ Amps

Generator _____ Amps

Battery _____ Amp minutes

	Connected Load	Power Factor	Operating Time (C-continuous)	Normal Operations						Emergency	
				Takeoff		Night, Ice, Cruise		Land		Ampere	Ampere Min
				Ampere	Ampere Min	Ampere	Ampere Min	Ampere	Ampere Min		
Bus Phase A											
Item											
Total											
Bus Phase B											
Item											
Total											
Bus Phase C											
Item											
Total											

Battery Duration Calculation - Emergency

Battery capacity (A/min)=	_____	Amp-min	(1)
Derated battery capacity ((1) * 0.75)=	_____	Amp-min	(2)
Preload shed (5min * night, ice, cruise load) =	_____	Amp-min	(3)*
Emergency Load =	_____	Amp	(4)
Landing load (5min * landing load)=	_____	Amp-min	(5)

$$\text{Duration} = \frac{\text{Derated Battery Capacity} - \text{Pre Load shed} - \text{Landing Load}}{\text{Emergency Load}} = \frac{(2)-(3)-(5)}{(4)} \text{ minutes} \quad (6)$$

Total Duration= Pre load shed time (5min)+ Landing Time (5 min) + Duration (6) minutes

*Where pre-load shed current draw is greater than twice the 1 hour rating of the battery this is to be increased by 20%.

Appendix 2—Electrical Definitions

Electrical system consists of an electrical power source, its power distribution system and the electrical load connected to that system.

Electrical source is the electrical equipment which produces converts or transforms electrical power. Some common AC sources are identified as follows: AC alternators, inverters, transformers and frequency changers. Some common DC sources are DC generators, converters and batteries. In practice an electrical source could be a combination of these units connected in parallel e.g. a typical AC bus may have both AC alternators and inverters connected in parallel.

Primary source is equipment that generates electrical power from energy other than electrical, and is independent of any other electrical source. For example, the primary source of an AC electric system may be the main engine-driven alternators (s) or Auxiliary Power Unit (APU) driven-alternators (s). The primary source of a DC electrical system may be a battery, main engine-driven generator(s) or APU driven-generator(s). There may be both AC and DC primary power sources in the same aircraft.

Secondary source is equipment that transforms and/or converts primary source power to supply electrical power to either AC or DC powered equipment. A secondary source is entirely dependent upon the primary source and is considered part of the load of the primary source. There may be both an AC and DC secondary source in the same aircraft.

Normal source is that source which provides electrical power throughout the routine aircraft operation.

Alternate source is a second power source, which may be used in lieu of the normal source, usually upon failure of the normal source. The use of alternate sources creates a new load and power configuration, and therefore a new electrical system, which may require separate source capacity analysis.

Nominal rating of a unit power source is its nameplate rating. This rating is usually a continuous duty rating for specified operating conditions.

Growth capacity is a measure of the power source capacity available to the aircraft electrical system to supply future load equipment. This value is expressed in terms of percent of source capacity.

Take-off is that condition commencing with the take-off run, including the climb and ending with the aircraft levelled-off and set for cruising.

Landing is that condition commencing with the operation of navigational and indication equipment specific to the landing approach and following to the completion of the rollout.

Night, Ice, Cruise is that condition during which the aircraft is in level flight, at night with full anti-icing equipment (including pitot heat) selected. This is considered the highest demand situation during normal flight.

Normal electrical power operation (or normal operation) conditions assume that all of the available electrical power system is functioning correctly within Master Minimum Equipment List (MMEL) limitations (e.g. AC and/or DC generators, transformer rectifier units, inverters, main batteries, APU etc.).

Emergency electrical power operation (or emergency operation) is a condition that occurs following a loss of all normal electrical generating power sources or other malfunction that results in operation on standby power (batteries and or other emergency generating source such as an APU or Ram Air Turbine (RAT)) only.

Power factor is the ratio of real power (measured in watts) to apparent power (measured in volt-amperes).