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Standard Guide for Aircraft Electrical Load and Power Source Capacity Analysis[1]

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1. Scope

1.1 This guide covers how to prepare an electrical load analysis (ELA) to meet Federal Aviation Administration (FAA) requirements.

1.2 The values given in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *FAA Aeronautics and Space Airworthiness Standards:*[2]

14 CFR 23.1309 Normal, Utility, Acrobatic, and Commuter Category Airplanes—Equipment, Systems, and Installations

14 CFR 23.1351 Normal, Utility, Acrobatic, and Commuter Category Airplanes—General

14 CFR 23.1353 Normal, Utility, Acrobatic, and Commuter Category Airplanes—Storage Battery Design and Installation

14 CFR 23.1419 Normal, Utility, Acrobatic, and Commuter Category Airplanes—Ice Protection

14 CFR 23.1529 Normal, Utility, Acrobatic, and Commuter Category Airplanes—Instructions for Continued Airworthiness

14 CFR 91 General Operating and Flight Rules

14 CFR 135.163 Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons on Board Such Aircraft—Equipment Requirements: Aircraft Carrying Passengers under IFR

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *abnormal electrical power operation (or abnormal operation), n*—occurs when a malfunction or failure in the electric system has taken place and the protective devices of the system are operating to remove the malfunction or failure from the remainder of the system before the limits of abnormal operation are exceeded.

3.1.1.1 *Discussion*—The power source may operate in a degraded mode on a continuous basis when the power characteristics supplied to the using equipment exceed normal operation limits but remain within the limits for abnormal operation.

3.1.2 *alternate source, n*—second power source that may be used instead of the normal source, usually on failure of the normal source.

3.1.2.1 *Discussion*—The use of alternate sources creates a new load and power configuration and, therefore, a new electrical system that may require separate source capacity analysis.

3.1.3 *cruise, n*—condition during which the aircraft is in level flight.

3.1.4 *electrical source, n*—electrical equipment that produces, converts, or transforms electrical power.

3.1.5 *electrical system, n*—consists of an electrical power source, the electrical wiring interconnection system, and the electrical load(s) connected to that system.

3.1.6 *emergency electrical power operation (or emergency operation), n*—condition that occurs following a loss of all normal electrical generating power sources or another malfunction that results in operation on standby power (batteries or other emergency generating source such as an auxiliary power unit (APU) or ram air turbine (RAT)) only, or both).

3.1.7 *ground operation and loading, n*—time spent in preparing the aircraft before the aircraft engine starts.

3.1.7.1 *Discussion*—During this period, the APU, internal batteries, or an external power source supplies electrical power.

3.1.8 *landing, n*—condition starting with the operation of navigational and indication equipment specific to the landing approach and following until the completion of the rollout.

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[2] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

3.1.9 *nominal rating, n*—this rating of a unit power source is its nameplate rating and is usually a continuous duty rating for specified operating conditions.

3.1.10 *normal ambient conditions, n*—typical operating conditions such as temperature and pressure as defined by the manufacturer's technical documentation.

3.1.11 *normal electrical power operation (or normal operation) , n*—assumes that all the available electrical power system is functioning correctly with no failures or within the Master Minimum Equipment List (MMEL) limitations, if a MMEL has been approved (for example, direct current (DC) generators, transformer rectifier units, inverters, main batteries, APU, and so forth).

3.1.12 *normal source, n*—provides electrical power throughout the routine aircraft operation.

3.1.13 *takeoff and climb, n*—condition starting with the takeoff run and ending with the aircraft leveled off and set for cruising.

3.1.14 *taxi, n*—condition from the aircraft's first movement under its own power to the start of the takeoff run and from completion of landing rollout to engine shutdown.

4. Significance and Use

4.1 To show compliance with 14 CFR 23.1351, you must determine the electrical system capacity.

4.2 14 CFR 23.1351(a)(2) states that:

4.2.1 For normal, utility, and acrobatic category airplanes, by an electrical load analysis or by electrical measurements that account for the electrical loads applied to the electrical system in probable combinations and for probable durations; and

4.2.2 For commuter category airplanes, by an electrical load analysis that accounts for the electrical loads applied to the electrical system in probable combinations and for probable durations.

4.3 The primary purpose of the electrical load analysis (ELA) is to determine electrical system capacity (including generating sources, converters, contactors, bus bars, and so forth) needed to supply the worst-case combinations of electrical loads. This is achieved by evaluating the average demand and maximum demands under all applicable flight conditions. A summary can then be used to relate the ELA to the system capacity and can establish the adequacy of the power sources under normal, abnormal, and emergency conditions.

NOTE 1—The ELA should be maintained throughout the life of the aircraft to record changes to the electrical system, which may add or remove electrical loads to the system.

4.4 The ELA that is produced for aircraft-type certification should be used as the baseline document for any subsequent changes. When possible, the basic format of the original ELA should be followed to ensure consistency in the methodology and approach.

4.5 The original ELA may be lacking in certain information, for instance, time available on emergency battery. It may be necessary to update the ELA using the guidance material contained in this guide.

5. Basic Principles

5.1 A load analysis is essentially a summation of the electric loads applied to the electrical system during specified operating conditions of the aircraft. The ELA requires the listing of each item or circuit of electrically powered equipment and the associated power requirement. Note that the power requirement for an item may have several values, depending on the utilization for each phase of aircraft operation.

5.2 To arrive at an overall evaluation of electrical power requirement, it is necessary to give adequate consideration to transient demand requirements, which are of orders of magnitude or duration to impair system voltage or frequency stability, or both, or to exceed short-time ratings of power sources, that is, intermittent/momentary and cyclic loads. This is essential, since the ultimate use of an aircraft's ELA is for the proper selection of characteristics and capacity of power-source components and the resulting assurance of satisfactory performance of equipment under normal, abnormal, and emergency operating power conditions.

5.3 A large majority of general aviation aircraft uses only DC power. If an aircraft also uses AC power, the ELA will have to include the AC loads as well.

6. Procedure for Preparation of Electrical Load Analysis

6.1 *Content*—The load and power source capacity analysis report should include the following sections:

6.1.1 Introduction,

6.1.2 Assumptions and Criteria,

6.1.3 Load Analysis—Tabulation of Values,

6.1.4 Emergency and Standby Power Operation, and

6.1.5 Summary and Conclusions.

6.2 *Introduction:*

6.2.1 The introduction to the ELA report should include information to assist the reader in understanding the function of the electrical system with respect to the operational phases of the aircraft.

6.2.2 Typically, the introduction to the ELA should contain the following:

6.2.2.1 Brief description of aircraft type, which may also include the expected operating role for the aircraft;

6.2.2.2 Electrical system operation, which describes normal, abnormal, and emergency operations, bus configuration with circuit breakers, and connected loads for each bus. A copy of the bus wiring diagram or electrical schematic should also be included in the report;

6.2.2.3 Generator, alternator, and other power source description and related data (including such items as battery discharge curves, inverter, emergency battery, and so forth). Typical data supplied for power sources would be as shown in Table 1;

6.2.2.4 Operating logic of system (for example, automatic switching, loading shedding, and so forth); and

6.2.2.5 List of installed equipment.

6.3 *Assumptions and Criteria*—All assumptions and design criteria used for the analysis should be stated in this section of the ELA. For example, typical assumptions for the analysis may be identified as follows:

TABLE 1 Typical Data for Power Sources

Identification	1	2	3
Item	DC Generator	Inverter	Battery
Number of units	2	1	1
Continuous rating	250 A	300 VA (total)	35 Ah
(Nameplate)	. . .	. . .	. . .
5-s rating	400 A	. . .	. . .
2-min rating	300 A	. . .	. . .
Voltage	30 V	115 VAC	24 VDC
Frequency	. . .	400 Hz	. . .
Power factor	. . .	0.8	. . .
Manufacturer	ABC	XYZ	ABC
Model number	123	456	789
Voltage regulation	±0.6 V	±2 %	. . .
Frequency regulation	. . .	400 Hz ± 1 %	. . .

6.3.1 Most severe loading conditions and operational environment in which the airplane will be expected to operate are assumed to be night and in icing conditions;

6.3.2 Momentary/intermittent loads, such as electrically operated valves, that open and close in a few seconds are not included in the calculations;

6.3.3 Motor load demands are shown for steady-state operation and do not include starting inrush power. The overload ratings of the power sources should be shown to be adequate to provide motor starting inrush requirements;

6.3.4 Intermittent loads such as communications equipment (radios, for example, VHF/HF communication systems) that may have different current consumption depending on operating mode (that is, transmit or receive);

6.3.5 Maximum continuous demand of the electrical power system must not exceed 100 % of the load limits of the alternator(s) or generator(s) that are equipped with current monitoring capability;

6.3.6 Cyclic loads such as heaters, pumps, and so forth (duty cycle); and

6.3.7 Estimation of load current, assuming a voltage drop between bus bar and load.

6.4 *Load Analysis—Tabulation of Values*—A typical load and power source analysis would identify the following details in tabular form:

6.4.1 *Connected Load Table*—See Appendix X1.

6.4.1.1 *Aircraft Bus*—Identify the appropriate electrical bus being evaluated. In a multiple bus configuration, there will be a set of tables for each bus (that is, DC Bus 1, DC Bus 2, AC Bus 1, Battery Bus, and so forth).

6.4.1.2 *Condition of Power Sources*—Normal, abnormal (abnormal conditions to be specified, for example, one generator inoperative, two generators inoperative, and so forth), and emergency.

6.4.1.3 *Aircraft Operating Phases*—The following aircraft operating phases should be considered for the ELA. Assume "night" conditions as the worst-case scenario.

NOTE 2—Icing conditions should be considered for worst-case scenarios if the aircraft is approved for flight into known icing in accordance with 14 CFR 23.1419. However, in some cases, the icing system is deactivated or not installed, so icing may not always be the worst-case.

6.4.1.4 *Permissible Nonserviceable Conditions*—The analysis should also identify permissible nonserviceable conditions likely to be authorized in the MMEL, if approved, during the certification of the airplane and should include calculations appropriate to these cases. All MMEL items must be accounted for in the load analysis to ensure that the electrical system capacity is not exceeded when all items are functional.

6.4.1.5 *Circuit Breaker*—Identify each circuit breaker by circuit name or identification number.

6.4.1.6 *Load at Circuit Breaker*—The ampere loading for each circuit.

6.4.1.7 *Operating Time:*

(1) The operating time is usually expressed as a period of time (seconds/minutes) or may be continuous, as appropriate. Equipment operating time is often related to the average operating time of the aircraft. If the "on" time of the equipment is the same or close to the average operating time of the aircraft, then it could be considered that the equipment is operating continuously for all flight phases.

(2) In such cases in which suitable provisions have been made to ensure that certain loads cannot operate simultaneously, or there is reason for assuming certain combinations of load will not occur, appropriate allowances may be made. Adequate explanation should be given in the summary.

(3) In some instances, it may be useful to tabulate the data using a specified range for equipment operating times, such as follows:

5-s Analysis	All loads that last longer than 0.3 s should be entered in this column.
5-min Analysis	All loads that last longer than 5 s should be entered in this column.
Continuous Analysis	All loads that last longer than 5 min should be entered in this column.

(4) Alternatively, the equipment operating times could be expressed as actual operating time of equipment in seconds or minutes or as continuous operation. In the example given in Appendix X1, the approach taken is to show either continuous operation or to identify a specific operating time in seconds/ minutes.

6.4.1.8 *Condition of Aircraft Operation*—Phase of preflight and flight (such as ground operation and loading, taxi, takeoff, cruise, and land). For aircraft, the conditions in Table 2 could be considered.

6.4.2 *Calculations:*

6.4.2.1 The following equations can be used to estimate total current, total current rate, and average demand for each of the aircraft operating phases (ground operation and loading, engine start, taxi, takeoff and climb, cruise, and landing):

$$\text{Total Current (A)} = \text{Sum of All Current Loads} \tag{1}$$

$$\text{Operating at a Given Time}$$

TABLE 2 Condition of Aircraft Operation

Ground operations and loading	15 min typically
Engine start	5 min typically
Taxi	10 min typically
Takeoff and climb	20 min typically
Cruise	as appropriate for aircraft type
Landing	20 min typically