SAE The Engineering Society For Advancing Mobility Land Sea Air and Space

400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

Submitted for recognition as an American National Standard

AEROSPACE STANDARD

AS 1831

Issued June 1987

ELECTRICAL POWER, HIGH VOLTAGE DIRECT CURRENT, AIRCRAFT, CHARACTERISTICS AND UTILIZATION OF

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1. GENERAL:

1.1 Scope: This standard establishes the characteristics and utilization of 270-VDC electric power at the utilization equipment interface and the constraints on the utilization equipment. These characteristics shall be applicable for both airborne and ground support power systems. This standard also defines the related distribution and installation considerations. Utilization equipment designed for a specific aircraft application may not deviate from these requirements without the approval of the procuring activity.

1.2 Purpose: The purpose of this standard is to assure compatibility between aircraft electric systems or ground support electric systems and airborne utilization equipment.

2. REFERENCED DOCUMENTS: The following specifications, standards, and publications of the issue in effect form a part of this standard to the extent specified herein:

MIL-P-81653, "Power Controller, Solid State, General Specification for."

MIL-STD-461, "Electromagnetic and Susceptibility Requirements for the Control of Electromagnetic Interference."

MIL-STD-704, "Electric Power, Aircraft, Characteristics."

MIL-E-6051, "Electromagnetic Compatibility Requirements, Systems."

3. DEFINITIONS:

3.1 Abnormal Electric System Operation: Abnormal operation is that condition of the electric system wherein electric power characteristics exceed normal limits.

The initiating action of the abnormal condition is uncontrolled and the occurrence is not anticipated.

System protective functions shall prevent system characteristics from exceeding the abnormal limits.

3.2 Abnormal Limits: Abnormal limits are those bands of operation beyond the normal limits but within the limits which would activate system protective functions.

3.3 High Voltage Direct Current System: "The 270-VDC Electric Power System" is that group of connected generation, distribution, controlling, and conversion equipment active in supplying 270-VDC electric power to utilization equipment.

3.4 HVDC Electric Power System Voltage: System Voltage is the voltage at the point of regulation, which is compatible with the specified limits.

3.5 Alternate Power Source: Alternate Power Sources are power sources such as auxiliary power units, emergency power units and batteries.

3.6 Current Limiting: The characteristic of a device which limits its current to a specified value.

3.7 Differential Fault Current: The difference between the positive and return currents in a two-wire distribution system.

3.8 Distribution System: The part of the electrical system used for conveying energy to the point of utilization from the 270-VDC source.

3.9 Electromagnetic Compatibility: The capability of systems and associated equipment to perform within required levels in the specified electromagnetic environment.

3.10 Electrical Load Management Center (ELMC): Equipment which contains localized power buses and utilizes power controllers for protection and remote control of branch and load circuits. An ELMC may utilize a remote terminal processor and data bus for system communication, providing for automated load management and system monitoring.

3.11 Emergency Mode: The Emergency Mode is that condition of the electric system whereby the emergency system (independent of the main generating equipment) is used to power a selected, reduced complement of distribution and utilization equipment.

3.12 Emergency Power Characteristics: The Emergency Power Characteristics are those existing at the utilization equipment terminals during operation in the emergency mode.

3.13 Emergency Power System: An independent reserve source of electrical energy which, upon failure or outage of the normal source, automatically provides reliable electric power within a specified time to critical devices and equipment whose failure to operate satisfactorily would jeopardize the safety of personnel and the safe return of the vehicle.

3.14 Fault Sensor: Devices used to detect ground faults in the HVDC generation and distribution system.

3.15 Fault Time: The built-in delay in a fault detection device before it initiates corrective action.

3.16 Feeder Drop: The total voltage drop in the feeders including both the positive and return feeder drop between the power source terminals and point of regulation.

3.17 Ground: Ground may or may not be the return bus in the 270-VDC system. Ground may be isolated from aircraft structure by a single high impedance path.

3.18 Ground Fault: An abnormally low impedance between the positive bus, the negative bus, and/or the ground return.

3.19 Hybrid Power Controller: A device utilizing solid state components in conjunction with electromechanical switching contactors to perform a power control function.

3.20 Integral Control Power: Independent power source provided by each generator (independent of the HVDC) to be used for system control.

3.21 Interrupt Capacity: The current which a device is designed to interrupt at rated voltage.

3.22 Load Voltage: The voltage between the power input terminal of the utilization equipment and the return bus.

3.23 Main Power Generation Unit: The source of high voltage DC power.

3.24 Multiplex: A method or system of transmitting information on time shared data lines.

3.25 Normal Electric System Operation: Operation of the primary electric system which includes all the functional electric system operations required for aircraft operation and mission support. These operations occur at any given instant and any number of times during flight preparation, takeoff, airborne conditions, landing, and anchoring. Examples of such operations are switching of utilization equipment loads, engine speed changes, bus switching and synchronization, and paralleling of electric power sources. It includes all system functions required by all phases of aircraft operation except during the electric starting of the propulsion engine when required. Switching of utilization equipment loads is a type of system operation which occurs very often.

3.26 Overshoot: The instantaneous value of a parameter that exceeds the specified average value during a transient condition.

3.27 Overvoltage and Undervoltage: Overvoltage and undervoltage are those voltages which exceed the combined steady state and surge limits and are usually terminated by the action of protective devices.

3.28 Point of Regulation (POR): That point in the system where voltage is sensed for voltage regulation.

3.29 Power Controller (PC): An electrical system component that provides circuit protection and switching control of a branch circuit. It is designed to allow complete remote control via a low level interface to an automatic control system.

3.30 Ripple: A cyclic voltage variation above and below the average level of DC voltage.

3.31 Rupture Capacity: The maximum current for which a device is designed to provide protection under fault condition.

3.32 Rupture Current: The value of current in a circuit which reflects the capabilities of power source without the effects of the power controller.

3.33 Short Circuit: An abnormally low resistance between the positive and negative conductors.

3.34 Spikes: A variation from the controlled steady-state level of a characteristic which occurs for an extremely short duration.

3.35 Steady State: A condition that shows only negligible change throughout an arbitrary long period of time.

3.36 Source Voltage: The voltage available at the generator terminals.

3.37 Transients: A short term changing condition of a characteristic beyond the steady-state limits, returning to the steady-state limits within the specified time period.

4. GENERAL REQUIREMENTS:

4.1 Power Systems: Characteristics of aircraft power at the input terminals of utilization equipment shall be within the limits specified in Sections 5 and 6 under the conditions of power utilization specified in Section 7. The electric power system shall be so designed as to ensure that the characteristics of electric power at the utilization equipment terminals conform to the requirements specified herein, and shall be so installed and protected that the failure of any power source and its disconnection from the system will not result in subsequent impaired performance of the remaining power sources.

4.1.1 HVDC Power: The HVDC power system shall be a 2-wire system having characteristics defined in paragraph 5.1.

4.1.2 LVDC Power: For detail characteristics, see MIL-STD-704.

4.1.3 AC Power: For detail characteristics, see MIL-STD-704.

4.1.4 Power Source Impedance: The electric power system source impedance looking into the electric power system from the terminals of utilization equipment shall be characterized. Typical characterization is shown in Figure 4.1-1.

4.2 Distribution Systems: The distribution system shall be designed to furnish power in accordance with Figure 5.1-1.

4.3 Utilization Equipment: Utilization equipment shall maintain specified performance when using power with characteristics which are specified in Section 5.

4.4 Equipment Polarity: All equipment interfaces shall provide mechanical protection against polarity reversal.

5. DETAILED REQUIREMENTS - AIRCRAFT ELECTRICAL POWER SYSTEM:

5.1 HVDC Power System Characteristics:

5.1.1 Steady-State Voltage: The steady-state voltage shall be within the limits specified in Figure 5.1-1.

5.1.2 Ripple: The ripple voltage under normal operating conditions shall be within the limits as specified in Figure 5.1-2.

5.1.2.1 Frequency Characteristics: The frequency components of the ripple shall be within the limits of Figure 5.1-2.

5.1.3 Transient Voltage: Transient voltages shall be within the limits of Figure 5.1-1 for all operations of the aircraft electric system.

5.1.3.1 Normal Electric System Operation: For normal system operations, the dc voltage shall be within the normal limits of Figure 5.1-1. Under conditions of normal bus transfer, switching and paralleling, no interruption of the dc supply shall occur. During the transfer, the dc voltage transients shall be within the limits of Figure 5.1-1.

5.1.3.2 Abnormal Electric System Operation: For abnormal system operations, the dc voltage shall be within the abnormal limits of Figure 5.1-1.

5.1.4 Spikes: Subsequent to the application of the spike waveforms, as specified below, to the power - input terminals of utilization equipment functioning according to corresponding detail specifications, this equipment shall meet the specified requirements. The spike waveform, produced by a generator with a source impedance of 50 ohms ±5, shall satisfy the following requirements:

Open circuit voltage: ±600 volts peak
Risetime: 0.9 microseconds +0.2
Falltime: 10.0 microseconds ±1.0
Pulsewidth (50% amplitude points) 5.0 microseconds +0.1
Repetition rate (aperiodic): not greater than 50 HZ
Source energy capability: not less than 0.01j
See attached Figure 5.1-3 for spike waveform example.

5.1.5 Emergency Power: Emergency power characteristics shall meet the same requirements as primary power characteristics, however, the emergency power source is usually of lesser capacity and may have limited operating time.

5.1.6 Engine Start: Equipment which is required to operate or be left switched on during engine starting shall be so identified by the detailed specification which shall also define the applicable electrical system characteristics.

6. DETAIL REQUIREMENTS - DISTRIBUTION SYSTEM:

6.1 Detailed Distribution: The distribution system is the interface between the vehicle utilization equipment and the electrical power system. The distribution system consists of feeders from the main bus(es) (or POR), PC's or other means of controlling application of power lines connecting each piece of utilization equipment and the associated distribution system control and protection elements. If used, ELMC's will house most if not all of the PC's, the remote terminal (to interface with multiplex bus), the means to select one of several feeders, and the means to interface distribution system analog and discrete signals.

6.2 Multiplex Interface: If a multiplex system is incorporated, the generator system shall provide an interface to the multiplex system to accommodate status interrogation by the multiplex system. This interface shall not interfere in any way with the critical protective and control functions of the generator system. Typical generator system parameters capable of being interrogated are as follows: temperatures, AC generator voltage and current to rectifier bridge, ripple, bus voltage, bus current, bus contactor position, and bus status.

6.2.1 Multiplex Interface Electrical Characteristics: The multiplex interface can exist as either an impedance level, a voltage level, or a switch. Interfaces different than described will be specified in the detail specification.

a. If an impedance level is used to establish normal and abnormal operating levels, the following levels shall be provided within 20 microseconds after being interrogated by a 10 ma, 50 microsecond pulse (interrogation rate is one hundred pulses per second):

NORMAL: = 720 ohms ± 72
ABNORMAL = 420 ohms ∓ 42
FAULT = 1100 ohms ∓ 110

b. If a voltage level is used to establish normal and abnormal operating conditions, the following levels shall be provided:

NORMAL: 8 volts or more
ABNORMAL: 4 volts or less

c. If a switch is used to establish normal and abnormal operating conditions, it shall have the following characteristics:

NORMAL = 2.5 V max drop with 10 ma max current
ABNORMAL = 0.5 ma max leakage at 30 V dc.

6.2.2 Multiplex Interface Isolation: The multiplex interface circuit common when electrically isolated from the generator system return shall be 100 megohms minimum at 500 Vdc.

6.3 ELMC Feeder Protection: Feeder from the main buses to the ELMCs shall be protected as necessary so that fault or overload on the feeder or in the distribution system in or beyond the ELMC will not result in loss of power at the main bus or on any other feeders supplied from the main bus and not directly involved in the fault or overload.

6.4 Power Source Isolation: If individual ELMCs are supplied from multiple main buses simultaneously, means shall be provided to assure that a fault on a feeder from one source does not result in a fault on the feeders from the other sources. If diodes are used for power source isolation, means shall be provided for detection of diode passive or latent failures.

6.5 Personnel Shock Prevention: Switching and protection devices at the main busses or in the ELMCs shall incorporate means of limiting leakage current to a maximum value of 2 milli-amperes.

6.6 Converter Protection: When using converters, fault protection shall be provided. Protection shall be provided on the output such that a fault in one feeder or piece of utilization equipment shall not affect any other feed or equipment connected to the output of the converter. Likewise, the fault protection shall be coordinated such that the input protection shall not be operated prior to an output protection when the output protection should isolate the fault.

6.7 Sub-Bus Distribution: Certain portions of the distribution system may be capable of being separated from the main distribution system for special purposes. In case of an all primary power outage, some emergency loads may still require power to provide safe flight and landing conditions. These loads could be connected to a portion of the main bus which may be switchable to another emergency power source (either time-limited or non-time-limited). These loads, the bus and the power source, as well as all connecting wiring shall be installed in such a manner that maximum integrity and reliability are achieved to assure that this power is provided to these loads with the maximum probability of success.

7. LOAD DEMAND CONSTRAINTS:

7.1 User Equipment Constraints: The interface characteristics of the HVDC Electric Power System impose the following constraints on the design of equipment utilizing dc electric power.

7.1.1 EMI Limits: EMI limits for users and power system are specified in MIL-STD-461, and/or MIL-E-6051.

7.1.2 DC Ripple Current Demand: When energized from a low impedance voltage source free of ripple, the load equipment shall draw a continuous current flow with a total ripple content not exceeding an equivalent value of 2000 ampere-Hertz. The total ripple content defined as

$$\sqrt{(I_1 \cdot F_1)^2 + (I_2 \cdot F_2)^2 \cdots (I_n \cdot F_n)^2} = 2000$$

amperes-Hertz maximum. (Where I_n = amplitude of individual ripple, i.e. Peak-Peak Amperes; and $\frac{F_n}{2\sqrt{2}}$ equals the effective frequencies of the individual harmonic frequencies.)

7.1.3 User Input Current Inrush/Initialization: Unless specified otherwise in the equipment specification, the instantaneous input current shall not exceed 4 times user equipment normal input current, returning to equal or less than normal input current within 10 msec.

7.1.4 User Load Inrush Demand Rate: All user equipment shall be designed to control load current rate such that its magnitude does not exceed 150% of the user equipment connected load current and the rate of change does not exceed 60 amps per millisecond.

7.1.5 User Equipment DC Ground Isolation: Each user equipment DC input power and return line at the interface shall be isolated from aircraft ground by a dc resistance of 10 megohms at 500 VDC.

7.1.6 User Equipment AC Ground Isolation: The leakage capacitance to ground at the user interface shall not exceed the lower of 0.005 uF/kW of connected load or 0.1 uF measured at 1kHz for each 270 VDC input line.

7.1.7 User Equipment Input/Output Isolation: The input 270 VDC lines shall be isolated from power conversion equipment outputs by 10 megohms minimum at 500 VDC.

7.1.8 Protection of User Equipment:

7.1.8.1 Built-In Protection: Designers of user equipment shall provide protection within their equipment from power input limits defined in Sections 5 and 8.

7.1.8.2 Other Circumstances: The equipment shall be designed so that it will not sustain damage as a result of:

a) 500-volt insulation resistance tests across mutually insulated parts (terminals).

b) Spike voltages in accordance with paragraph 5.1.4.

c) Momentary voltage drop below the transient limits specified but not necessarily to zero due to interruption and restoration of power. Equipment considered flight critical is required to operate in this region.

7.2 Other Electric-System Operation: If the electric-system operates in regions of characteristics other than as specified in section 5 and 8, then these requirements shall be stated in the detail equipment specification.

7.3 Voltage Spikes: Transient voltage spikes generated by utilization equipment shall not exceed the limits of Figure 5.1-3. Amplitude shall be defined in the detail specification.

7.4 Power Requirements Data: Power requirements data shall be specified for 5 seconds maximum, 2-minute maximum and 15-minute average.

8. GROUND SUPPORT EQUIPMENT CHARACTERISTICS:

8.1 Electric DC Power System Description:

8.1.1 Type of Power: The ground support HVDC power shall be a two-wire ungrounded system.

8.1.2 Voltage Sensing: The ground support power generation equipment shall have provision to sense and regulate its output voltage at the aircraft ground power connector.

8.2 Power System Interface Characteristics: The HVDC Ground Support power system/user characteristics shall be as defined in Section 5.

8.3 Interface: The interface characteristics of paragraph 8.2 shall be maintained at the aircraft ground power connector.

8.4 Ground Source Requirements:

8.4.1 Power System Source Ripple: The total RMS ripple voltage generated by the source shall not exceed 4.5 V.

8.4.2 DC Ground Isolation: The leakage resistance between both the power line and the power return as measured to ground shall be greater than 10 megohms at 500 VDC.

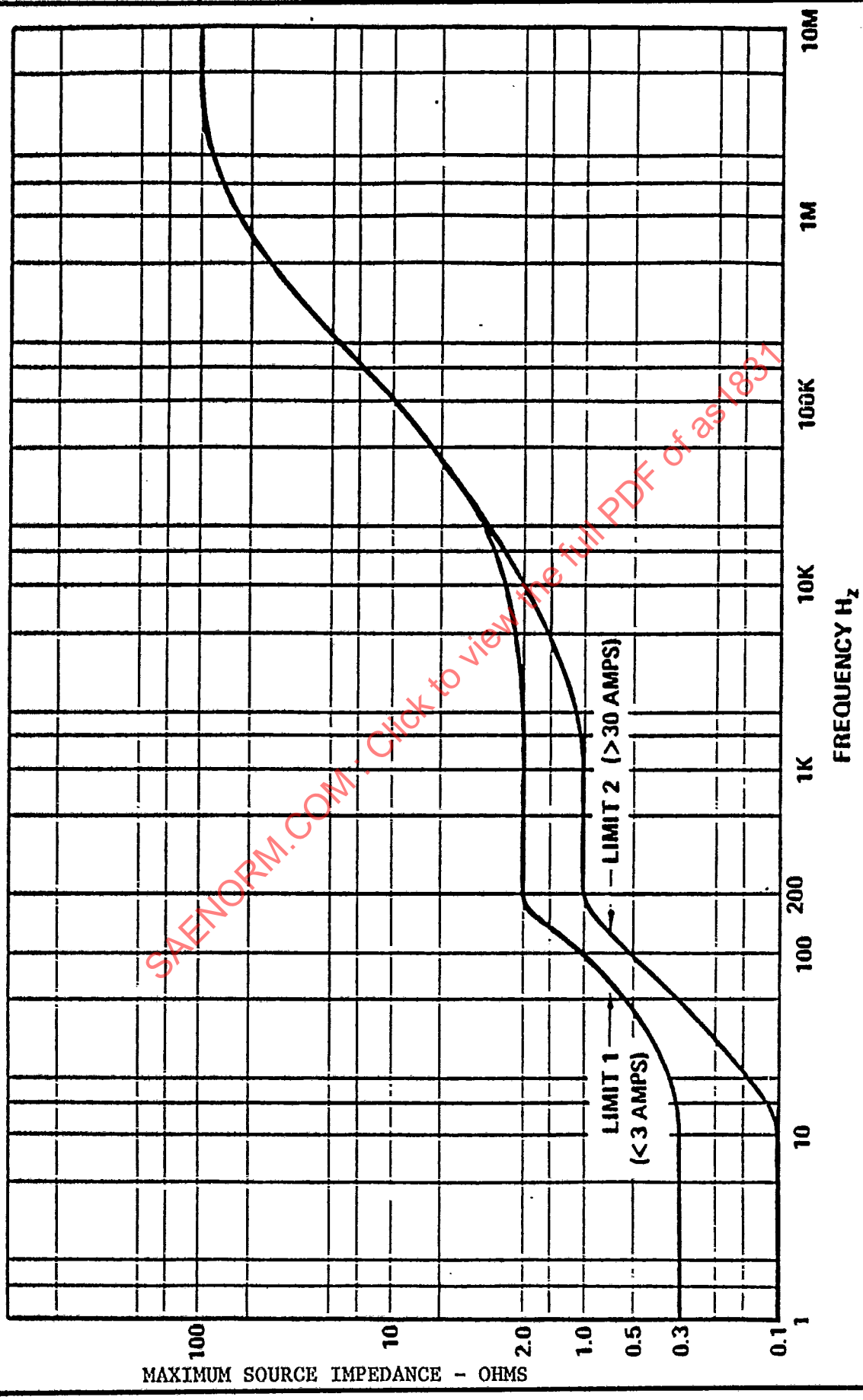

FIGURE 4.1-1 POWER SOURCE IMPEDANCES AT ELECTRIC POWER INPUT TERMINALS OF UTILIZATION EQUIPMENT