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Document for 270 Voltage Direct Current (270 V DC) System

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

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FOREWORD

This document was prepared by the panel members of the AE-7C Systems High Voltage Direct Current (HVDC) Panel under the overall direction of the SAE-AE7 Aerospace Electrical Power and Equipment Committee. The document is in accordance with the SAE Technical Report Style Manual, dated May 1992.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides technical design and application information related to the generation, distribution, control, and utilization of aircraft 270 V DC electrical power systems and support equipment. This document also provides references and definitions to permit comparisons of various electrical systems and components.

1.1 Purpose:

The purpose of this document is to consolidate industry recommended practices for 270 V DC systems and equipment to enable a common understanding of their specification, design, and use.

2. APPLICABLE DOCUMENTS:

Specific 270 V DC requirements will be contained within the governing procurement specification; however, all or part of the following documents may form a part of that specification. A working knowledge of their scope, purpose, and use is recommended. Where applicable, these documents are referenced within specific sections of this document. Selection of specifications and standards for necessary commodities and services not specified herein should be selected in accordance with MIL-STD-143.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS486	Aircraft Circuit Breaker and Fuse Arrangement
ARP926	Fault/Failure Analysis Procedure
ARP935	Suggested electromagnetic interference (EMI) Control Plan Outline
AS1212	Electric Power, Aircraft, Characteristics Utilization of
AIR1221	Electromagnetic Compatibility System Design Checklist
AIR1277	Cooling of Modern Electronic Equipment
AIR1406	Lightning Protection and Static Electrification
AS1831	Electrical Power, High Voltage Direct Current, Aircraft, Characteristics and Utilization of
ARP1870	Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety

2.2 Military Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-143B	Military Standards and Specification, Order of Precedence for the Selection
MIL-STD-210C	Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment
MIL-STD-454K	Standard General Requirements for Electronic Equipment
MIL-STD-461C	Electromagnetic and Susceptibility Requirements for the Control of Electromagnetic interference
MIL-STD-462	EMI Characteristics, Measurements of

2.2 (Continued):

MIL-STD-704E	Electric Power, Aircraft, Characteristics
MIL-STD-785	Reliability Program for Systems and Equipment, Development and Production
MIL-STD-810D	Environmental Test Methods
MIL-STD-1553	Aircraft Internal Time Division Command/Response Multiplex Data Base
MIL-STD-1629A	Procedures for Performing a Failure Modes, Effects and Criticality Analysis
MIL-STD-2073	Packaging Requirements
MIL-B-5087B	Bonding, Electrical, and Lightning Protection, Aerospace Systems
MIL-C-7115E	Military Specification Converters, Aircraft, General Specification
MIL-C-81991	Converters, Aircraft, dc to dc, Boost, General Specification for
MIL-E-5400T	Electronic Equipment, Airborne
MIL-E-6051D	Electromagnetic Compatibility Requirements, Systems
MIL-E-7016F	Military Specification Electric Load and Power Source Capacity, Aircraft, Analysis
MIL-E-25499C	Military Specification Electrical Systems, Aircraft, Design and Installation of, General Specification
MIL-E-81910A(AS)	Military Specification Electrical Power Generating and Control Equipment, Aircraft, Testing, General Specification
MIL-G-21480A	Military Specification Generator System 400 Hertz, Alternating Current, Aircraft General Specification
MIL-I-8500D	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles
MIL-I-27273	Military Specification Inverter, Power, Static, General Specification
MIL-P-81653C(AS)	Military Specification Power Controller, Solid State, General Specification
MIL-R-6106J	Military Specification Relays, Electromagnetic (including Established Reliability (ER) Types), General Specification
MIL-T-23103A(AS)	Military Specification Thermal Performance Evaluation, Airborne Electronic Equipment and Systems, General Requirement
MIL-Q-9858	Quality Program Requirements

2.3 OTHER PUBLICATIONS:

DOD-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment
NADC-60-TS-7803	Generator System, 270 Vdc, Oil Cooled, Aircraft, General Specification for
NASA CR-1205	Compendium of Human Responses to the Aerospace Environment, Volume 1, Section 5

3. 270 V DC SYSTEM:

3.1 Generic Description:

270 V DC aircraft systems typically consist of a variety of electrical power and control equipment that have been selected and integrated to meet the specific design application requirements.

Such requirements include electrical performance, power/control and source/load redundancy, component/system reliability, and maintainability. A generic presentation of a 270 V DC system is shown in Figure 1. The system and component arrangement is intended to show typical power flow and interconnections, not a specific recommended configuration. The components or elements and their characteristics are discussed in subsequent sections of this document and include the following:

- a. Generators and generator control units (GCU)
- b. 270 V DC power conditioning
- c. 270 V DC distribution (load management panel and bus structure)
- d. Power switching devices (contactors, circuit breakers, and power controllers)
- e. 270 V DC utilization (direct, direct current converters and inverters)
- f. Power control processor (system/element monitoring and built-in test capabilities)

3.2 Performance:

This section should contain all the requirements for establishing the overall 270 V DC system as well as the specific power generation, conditioning, distribution, control, and utilization equipment designs. This should be based on the electrical power interface in accordance with MIL-STD-704 and the methodology for establishing the electrical load in accordance with MIL-E-7016.

- 3.2.1 Duty Cycle: A descriptive of the loads and their duration should be specified so that the heat-sensitive 270 V DC equipment/components can be sized to handle the resulting thermal loads. This duty cycle specification is particularly important for electronic power equipment as opposed to hydromechanical counterparts. It is recommended that the duty cycle be specified for a typical and worst case mission in terms of consecutive time intervals for identifiable mission segments such as takeoff, cruise, special maneuvers (if applicable), and landing. The time duration of each segment should be specifically indicated. If the typical mission is likely to be repeated according to a predictable schedule (such as for commercial aircraft), the ground time between mission cycles should be included in the duty cycle specifications.

In some cases, the worst-case loading occurs on the ground during training or maintenance exercises during which the amplitude of the steady state and/or dynamic loading can be set artificially high compared to in-flight values. If such conditions are expected, the nature and duration of such ground-based loading should be specified.

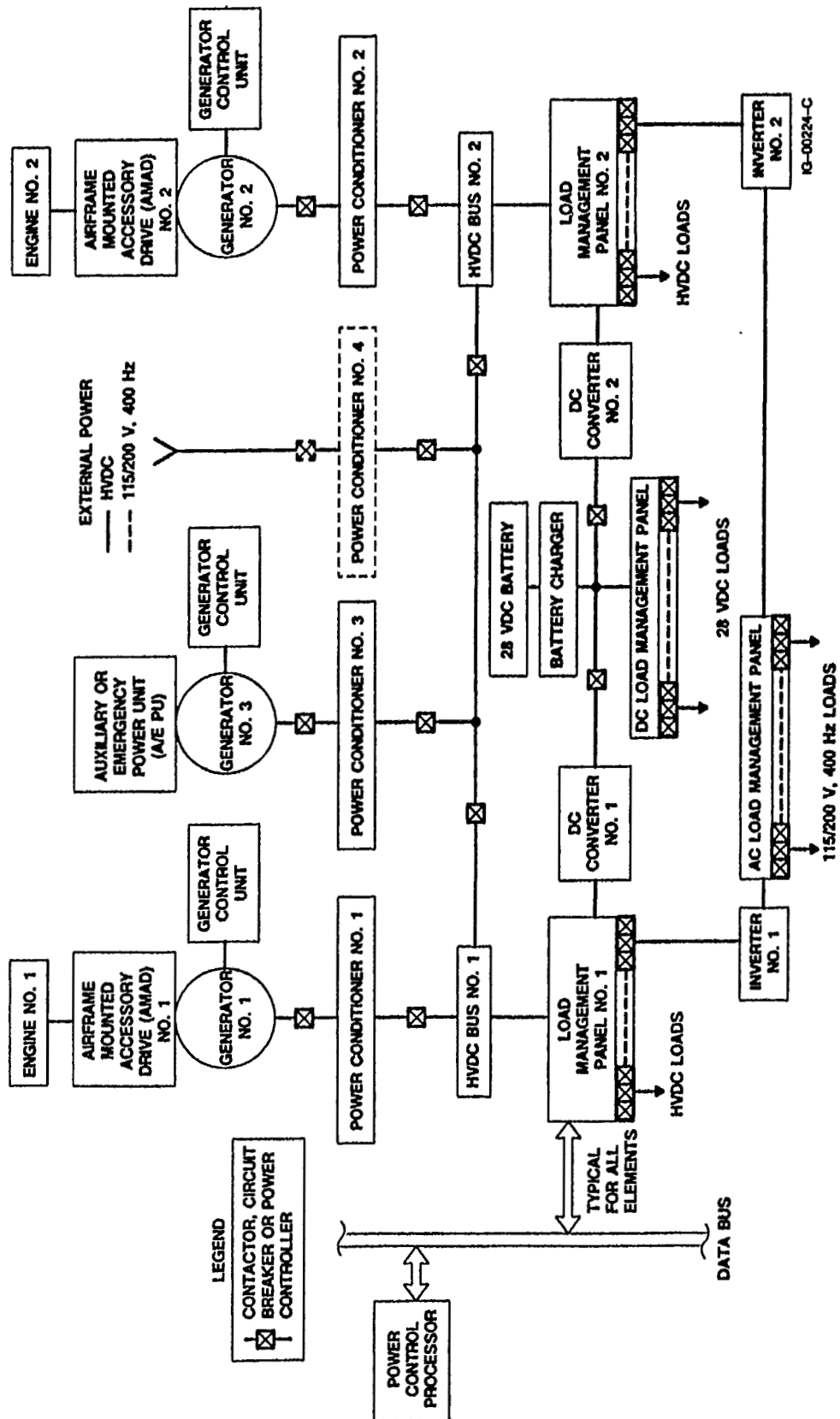


FIGURE 1 - Generic 270 Vdc High Voltage Direct (HVDC) System Diagram

- 3.2.2 Reliability: The mean time between failure (MTBF) for the 270 V DC system when operating within the loading and environmental levels specified should be defined. The analysis using a mathematical model should be performed in accordance with MIL-STD-785. The failure mode, effect, and criticality analysis (FMECA) should be in accordance with ARP926 and MIL-STD-1629.
- 3.2.2.1 Redundancy: Based on the results of the FMECA and/or the MTBF, some systems will require full or partial redundancy in order to meet mission reliability. Both the philosophy and degree of redundancy required should be specified.
- 3.2.2.2 Fault Tolerance: The degree of fault tolerance and resultant 270 V DC system performance under fault conditions should be defined.
- 3.2.3 Electromagnetic Interference and Compatibility: Unless otherwise specified in the procurement specification, the generation and susceptibility to EMI for all electrical and electronic equipment should be evaluated early in the design phase in accordance with ARP935 with control and testing in accordance with MIL-STD-461 and MIL-STD-462, respectively. Special attention should be given to the 270 V DC waveform distortion specified in MIL-STD-704E and the allowable MIL-STD-461 limits.
- 3.3 Interface Requirements:
- 3.3.1 Electrical Power Interface: The electrical input power, both direct current and/or alternating current, to the system should be defined. This definition should include the normal range which the system will see, for the majority of the time, the abnormal or transient range of short time duration and if applicable the emergency input power range. If there is a maximum permissible power draw limit for any circuit, it should also be specified. The input power definition can be specified as MIL-STD-704 or a similar electrical power specification that has been developed for the industry, such as AS1212 or AS1831.
- 3.3.1.1 Regenerated Power: The utilization loads, such as electric actuation, will represent significant aiding loads during portions of their operation. This regenerated power should be recognized and its method of disposal specified. The probable choices are either to put the power back into the aircraft electrical system for other load demands or dissipate it across a load resistor.
- 3.3.2 Control Signal Interface: The control signal interface should be defined as all signals, mechanical, fluidic, electrical or optical but excluding input electrical power, that are either input to or output from the 270 V DC system.

The definition of this interface shall include but not be limited to:

- a. Number and types of interfaces
- b. Data or control content of each interface
- c. Ranges, scales, resolutions, frequencies
- d. Voltages, impedances, currents, bit rate
- e. Applicable specifications, such as MIL-STD-1553 and DOD-STD-1686

- 3.3.3 Mechanical Interface:** The mounting configuration for the 270 V DC system should be specified. This should include airframe attachment points and desired location of electrical connections. If there is a particular location for mounting a specific 270 V DC equipment, this should also be shown along with access distances.

The information for this paragraph is best provided with a written requirement paragraph referring to a figure elsewhere in the specification or to a specification drawing.

- 3.3.3.1 Bonding and Grounding:** Bonding of electrical and electronic components should be in accordance with MIL-B-5087. Each electrical or electronic assembly other than sensors should have a ground return isolated from the power return lead or connector pin.

- 3.3.4 Envelope:** The maximum envelope available for the 270 V DC equipment should be shown as a figure in the specification or on a separate specification drawing. If the center of gravity of a particular 270 V DC equipment is required, it can be shown as a to be determined requirement of this paragraph.

The envelope may be specified as "The equipment shall be as small as practical using good design practices and shall be within the envelope(s) shown in Figure 1."

NOTE: It may be practical to provide "mechanical interface" and "envelope" information in one figure or specification drawing.

- 3.3.5 Thermal Interface:** The 270 V DC system contains electrical and electronic components that generate heat and the performance, reliability, and life of these components depend on dissipating this heat and maintaining critical components within their operating temperature range. The vehicle thermal interface greatly affects the process of removing this heat and, therefore, it is necessary to describe the thermal environment as it pertains to the 270 V DC system and equipment. The evaluation criteria for the above should be in accordance with MIL-T-23103.

This description should include the following minimum information:

- a. The ambient temperature range at each 270 V DC equipment location for operating and nonoperative conditions.
 - b. The ambient temperature of surrounding structure including maximum temperature limits and, if applicable, mass and thermal conductivity of material.
 - c. A description of any air or other gas available for cooling including temperature range, mass flow rate, and thermal characteristics.
- 3.3.6 Operator Interface:** The interface between an operator and the 270 V DC system should be considered in order to allow for manual operation of switches and levers, installation of hardware, visual observance of critical parameters, and normal maintenance or ground operations.

3.4 Design and Construction:

- 3.4.1 General: The 270 V DC system and equipment shall be of the optimum design and construction to meet the proposed use in the detail specification. The following should be used as a guide in specifying requirements for the design and construction using criteria in accordance with MIL-E-25499.
- 3.4.1.1 Workmanship: Workmanship standards for the 270 V DC system and equipment should be in compliance with requirement 9 of MIL-STD-454.
- 3.4.1.2 Quality: The procurement specification should require that a quality control system per MIL-Q-9858, or equivalent, be in place to insure the continuing quality of the 270 V DC system and equipment.
- 3.4.1.3 Electrical Requirements: All assembly or processes involving electrical or electronic components and/or assemblies should be controlled by government specifications or other applicable industry specifications unless otherwise specifically authorized by the procuring activity.
- 3.4.1.4 Interchangeability: Interchangeability of the 270 V DC equipment should be in accordance with requirement 7 of MIL-STD-454 and/or MIL-STD-8500.
- 3.4.1.5 Weight: Design and materials used in the 270 V DC equipment should be chosen to minimize weight while still meeting all the requirements of the procurement specification.
- 3.4.1.6 Life: The required life of the system shall be specified. Life is defined as that period during which the system shall meet a given set of specified parameters.

It is important that only those parameters that are truly salient to the life of the system be included. In addition, any specified parameter must be measurable, preferably while installed.

The units of life may be expressed in terms of aircraft flight hours, system operational hours, system operational cycles, or others. Whichever units are chosen, it is important that full account of the specified duty cycle is taken in order that the units used during qualification testing and verification of life are commensurate with those units used by the system's end user.

- 3.4.2 Generators and GCU: The specification for the power generator and GCU should be based on MIL-G-21480. While this specification is intended for 115/200 V, 400 Hz, 3 phase, 4 wire electrical power generation, it can be extended to 270 V DC power generation at higher generator frequency or speed allowed in the rectification process. Alternatively, the generator and GCU can be specified based on the Naval Air Development Center (NADC) document NADC-60-TS-7803, specifically for 270 V DC generator systems.

3.4.3 Protection and Control Devices: The specification for 270 V DC system protection and control devices include circuit breakers, relays/contactors, and power controllers. While each of these devices need specific characteristics to properly perform in 270 V DC systems, the 28 V DC and/or 115/200 V, 400 Hz specification for each is MIL-C-5809, MIL-R-6106, and MIL-P-81653, respectively. For 270 V DC relay and contactor applications, Aerospace Resource Document (ARD) 50031 should be used.

3.4.4 Power Conditioning and 270 V DC Utilization Equipment: In general, electrical and electronic equipment should be designed to meet the applicable sections of MIL-E-5400 and MIL-STD-454.

Specific power conditioning equipment, i.e., the rectification of the generator alternating current voltage to 270 V DC can be based on MIL-C-7115. The primary changes are those associated with the input power frequency, other than 400 Hz, and the output voltage, 270 in lieu of 28 V DC. Based primarily on thermal requirements, packaging of this equipment integral with the generator should be considered. Direct current converter 270 V DC utilization equipment can be based on MIL-C-81991 and inverter 270 V DC utilization equipment can be based on MIL-I-27273.

3.5 Environmental Requirements:

The 270 V DC system and equipment should be capable of meeting the requirements of the procurement specification when subjected to an environmental condition or any natural or unnatural combination of environmental conditions listed in the procurement specification.

Unless otherwise specified, 270 V DC equipment components should use the specified environmental requirements as a design guide but they must meet the environmental requirements specified when they are assembled as a part of the end equipment.

The following is a list of environmental requirements normally specified in aerospace systems. Specifications may be added or subtracted from this list depending on the application. The specific requirements and test methods should be per MIL-STD-210, MIL-STD-810, and/or MIL-E-81910.

- a. Low temperature
- b. High temperature
- c. Temperature cycling
- d. High altitude
- e. Vibration
- f. Shock
- g. Salt fog atmosphere
- h. Humidity
- i. Sand and dust
- j. Fungus growth
- k. Explosive atmosphere