



AEROSPACE INFORMATION REPORT

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High-Voltage DC Electromechanical,
Solid State, and Hybrid Switching Devices
in Aerospace Applications

RATIONALE

Future aircraft programs employ high-voltage direct current (HVDC) as primary sources of electric power. In these conditions, electromechanical, solid state, and hybrid switching devices will be exposed to new electrical dynamic behavior and switching energy during nominal operation and fault conditions.

The intent of this SAE Information Report (AIR) is to define electrical switching characteristic to consider for proper selection of switching devices among available technologies for safe operation and electrical installation integrity considering that traditional low-voltage switching devices are not compatible with high-voltage switching expectation.

INTRODUCTION

High voltage in aerospace application is defined in AIR7502, which defines four different HV voltage levels above usual legacy voltage ranges. Considering power sources characteristics and environment, such as altitude with dielectric influence on materials associated with energy density, switching devices have to be designed to operate safely first and compatible with operational life on aircraft during its operation.

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1. SCOPE

The scope of this SAE Aerospace Information Report (AIR) is first to establish applicable definitions and terms prior to considering the application domain and use cases in HVDC applications. Then it will identify commanded switching technologies to be considered for aerospace applications and provide rationale for their selection.

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.

AIR6127	Managing Higher Voltages in Aerospace Electrical Systems
AIR6139	Ways of Dealing with Power Regeneration onto an Aircraft Electrical Power System Bus
AIR7502	Aircraft Electrical Voltage Level Definitions
AIR7506	Impact of High Voltage on Wiring
AIR8678	Architecture Examples for Electrified Propulsion Aircraft
ARP4754	Guidelines for Development of Civil Aircraft and Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP8676	Nomenclature and Definitions for Electrified Propulsion Aircraft

2.1.2 U.S. Government Publications

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

AFWAL-TR-82-2057	High-Voltage Design Guide: Spacecraft
DO-160	Environmental Condition and Test Procedures for Airborne Equipment
DO-178	Software Considerations in Airborne Systems and Equipment Certification
DO-254	Design Assurance Guidance for Airborne Electronic Hardware
MIL-PRF-6106	Performance Specification - Relays, Electromagnetic, General Specification for

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 60664-1 Insulation Coordination for Equipment within Low-Voltage Supply Systems - Part 1: Principles, Requirements and Tests

2.1.4 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

Bilodeau, T.M., Dunbar, W., and Sarjeant, W. (1989). High-voltage and partial discharge testing techniques for space power systems. *Electrical Insulation Magazine*, IEEE, 5, p. 12, 1989.

2.2 Definitions

Major definitions for electrified propulsion aircraft can be found in ARP8676

2.3 Abbreviations

AC	Alternating current
CTOL	Conventional take-off and landing
DC	Direct current
eCTOL	Electric conventional take-off and landing
EM	Electromechanical
EMC	Electromagnetic compatibility
EMPC	Electromechanical power controller
ES	Equipment sealed
EU	Equipment unsealed
eVTOL	Electric vertical take-off and landing
FMEA	Failure mode and effect analysis
HVDC	High-voltage direct current
kA	Kiloampere
kft	Kilofoot
L/R	Time constant due to inductance and resistance
PDU	Power distribution unit
SD	Switching device
SSPC	Solid state power controller

SSR	Solid state relay
UAM	Urban air mobility
UAS	Unmanned aircraft systems
VAC	Volts AC
VDC	Volts DC
VTOL	Vertical take-off and landing

3. USE CASES AND APPLICATION DOMAIN IN HV APPLICATION

This section describes several simplified architecture to illustrate the use case of switching devices in their electrical power system application in HVDC aerospace flying platforms.

The intent of a switching component is to remotely allow electrical energy transfer from one electrical source to a load or a group of loads.

Some architectural examples where switching devices are used for high-voltage electrified propulsion aircraft are mentioned in AIR8678.

Simplified use cases of switching devices are shown in the following figures as examples; note that use cases are not limited to the examples shown here.

On a small vehicle such as flight training aircraft with short duration mission, a single battery pack can be used to supply one electric motor. This architecture ([Figure 1](#)) may require only one switching device to protect the installation and allow disconnection of the load from the source. In this case, it is understood that safety analysis have been conducted per ARP4761 and that this switching device SD-a is not a single point of failure in this design. This can be resolved at system level either with other protective device at source level or with internal protection at load level, but this is beyond the scope of this document.



Figure 1 - Full electrical architecture simplified example, single source/single load

In another application, a single battery pack may be used to supply several electrical motors. In this case ([Figure 2](#)), switching devices are used to perform source connection/disconnection on one hand and load connection/disconnection on the other hand.

In this case again, it is understood that safety analysis have been conducted per ARP4761 and that this switching device SD-a is not a single point of failure in this design.

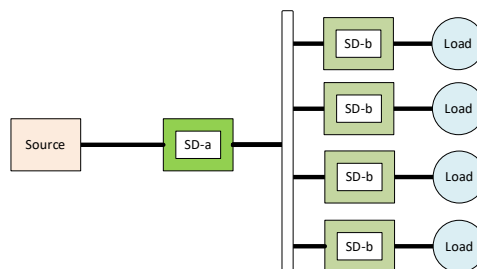


Figure 2 - Full electrical architecture simplified example, single source/multiple loads

A third configuration employs several sources connected in parallel on a single bus bar to supply several electric motors ([Figure 3](#)). The same type of switching devices may be required for single source configuration.

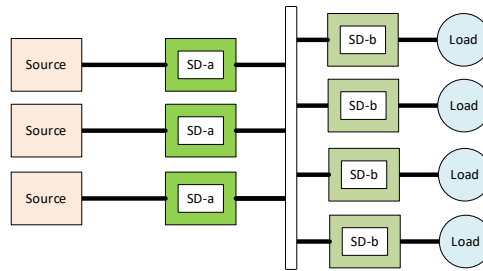


Figure 3 - Full electrical architecture simplified example, multiple sources/multiple load/single channel

A fourth configuration, for a more complex platform that includes multiple sources, multiple loads, and several channels (at least two), is shown in [Figure 4](#).

In this case, it is understood that safety analysis have been conducted per ARP4761 and that this switching device SD-c is not a single point of failure in this design.

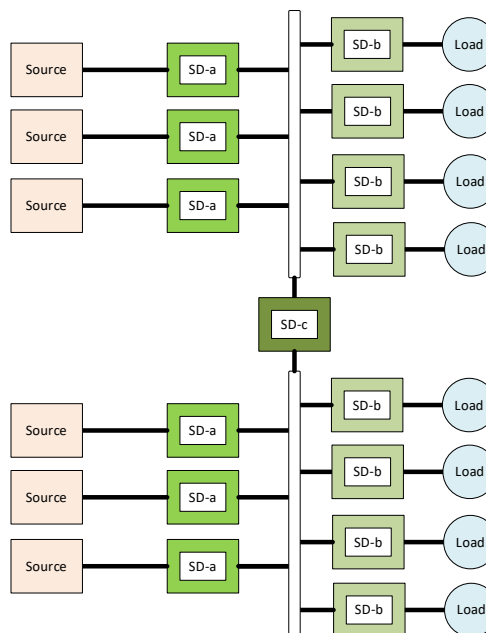


Figure 4 - Full electrical architecture example, multiple source/multiple loads/multiple channels

From these electrical architectures and applications, different types of switching devices can be identified—for example:

- One associated with electrical power source SD-a.
- One associated with loads, likely active loads SD-b.
- One to interconnect channels each composed of sources and loads SD-c.