Electric Power in Airplane

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Power sources on aircraft

- engine driven AC generators,
- auxiliary power units (APUs),
- external power and ram air turbines.

Voltages in airplane

Aircraft electrical components operate on many different voltages both AC and DC. The most of the aircraft systems use:

-115 volts (V) AC at 400 hertz (Hz)

- 28 volts DC

DC power is generally provided by “self-exciting” generators containing electromagnetics, where the power is generated by a commutator which regulates the output voltage of 28 volts DC. AC power, normally at a phase voltage of 115 V, is generated by an alternator, generally in a three-phase system and at a frequency of 400 Hz.

Why use two different generators (AC & DC)?

REDUNDANCY!!!

The Airplanes have both transformer rectifiers to turn the 400 *HZ* voltage into DC for the 28 volt buss, and they also have a static inverter to create the *AC* 400HZ in case the airplane is down to battery power only (meaning you have lost engine generators, APU generators etc.).

The aircraft *battery offers a short-term power storage capability.

So there are other methods used for providing back-up power:

1. Ram Air Turbine(RAT)
2. Back-Up Converters
3. Permanent Magnet Generators (PMGs)

*battery- From [7] nominal values are:

|Vn=24V |Cn=53Ah |m=96lbs |len.=13in. |wid.=11in. |height=11in.|

Emergency power generation

1. Ram Air Turbine(RAT)- air driven turbine stowed in aircraft ventral or nose section. Gen. Sizing varies between 5 and 15kVA. Rat is intended to furnish the crew with sufficient power while attempting to restore primary generators
2. Back-Up Converters- The back-up generators are VF. This supply is fed into back-up converter which converts the AC power to DC and then generates three phase 115 VAC 400Hz
3. Permanent Magnet Generators are used to generate 28VDC emergency power for high-integrity systems. In case of Boeing 777 there are 13 PMGs across the aircraft critical control systems- flight control, engine control and electrical system

Why not just use DC generation?

DC systems are limited to around 400A or 12 kW for two reasons:

1. The size of conductors and switchgear to carry necessary current becomes prohibitive
2. The brush wear on brushed DC generators becomes excessive with resulting maintenance costs if levels are exceeded.

Main advantage of AC power is that it operates at a higher voltage

Pro:

1.Higher voltages are important in the transmission of power.

Higher voltage→Lower current→Lower loses

2.Current conductors are generally heavy. So reduction of current saves weight, a very important consideration for aircraft system

Con: Higher voltages require better standards of insulation

DC and AC generator sizes- comparison

AC generators are typically oversized to handle starting and to provide light enough engine loads to facilitate speed regulation (Fig 1).

DC generators are smaller in size (Fig 2) . (Generated much less power though)

Pictures are taken from[8]

Why 400 Hz?

Universal emf equation says: $E = 4.44*f*n*a*B$

So for a given voltage and number of turns, increasing the frequency allows for decreasing the cross-sectional area of the core without bringing the core into saturation.

Pro: The advantage of running an electrical system at 400 Hz rather than 60 Hz is that the power supplies are smaller and lighter.

Con: This reduction in weight comes at a price, since high-frequency electrical systems are less efficient, because transformer losses increase with frequency (mostly due to increased hysteresis losses, eddy currents, skin effect, etc.).

So, the 400Hz figure represents an optimal trade-off between efficiency and compactness

Electrical Loads

- Motors and actuation - are used to drive a valve or an actuator

  1.DC motors are usually used for linear and rotary, fuel valve actuation and starter functions

  2.AC motors are usually used for continuous operations during flight
- Lightening services - are powered by 28VDC or by 26VAC provided by auto transformer from the main AC buses. Usually filament bulbs are used for lighting. They vary from 600W for lending lights to few watts for minor internal illumination uses.

Electrical Loads

- Heating services are used extensively.

  - anti-icing and de-icing systems can consume tens of kVAs

    This power does not have to be frequency stable and can be variable frequency which makes it much easier and cheaper

  - windscreen heating

- Subsystem controllers and avionics system

  - Line replaceable units (LRUs) are used for control, communication and navigation functions. They may require DC or AC power depending upon their function and modes of operation. Usually they have internal power supply units to convert aircraft power to electronic voltages (+-15 and +-5)VDC

Using Laptop in airplane

PC power is available in First and Business on all international B747-400 and A330-300 aircraft. This system provides 110V AC (60 Hz) power and accepts most household power plugs including: Australian 2 or 3 pin, European 2 pin, Japanese 2 or 3 pin and USA 2 or 3 pin. Customers using UK 2 or 3 pin plugs need to use an adaptor.

PC power supply 115 volts (V) AC is converted from main AC source on 400Hz to 60Hz using frequency converters

In case of power outlets 75 Watts of power draw per seat is available

Using Laptop in airplane

In some situations power outlets in aircraft 115 volts (V) AC on 400 Hz are available and then passenger has to use adapters that are either acquired in airplane or are personal.

Adapter [5]:

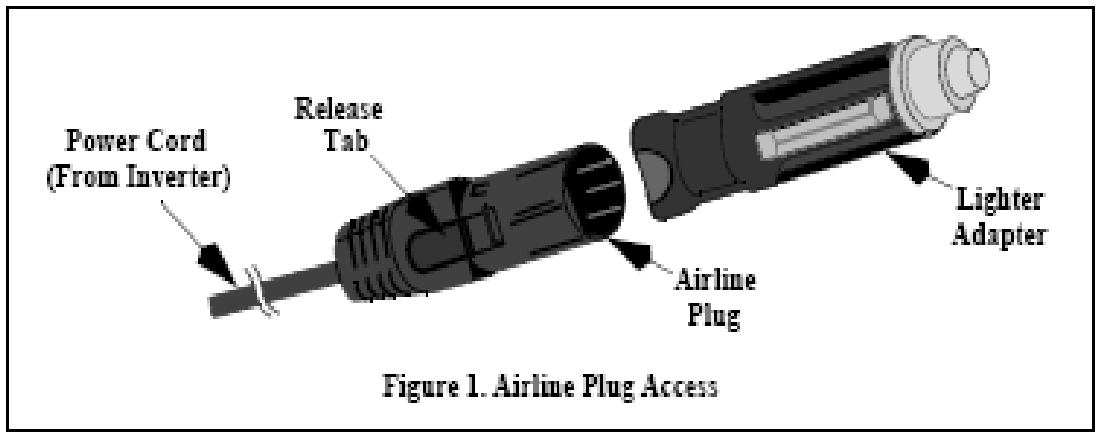

Figure 1. Airline Plug Access

Power Transmission

Lines are sized according to voltage drop and other considerations. Main generator feeders on a 12OkVA/channel civil system **(B777** and **B767-400)** require **2 x** 0 gauge wire per phase for the **main** generator feeders.

The present sensible rated current limit is - 400 Amps for power switching; equivalent to around **12kW** for dc and **12OkVA** for ac power. Practical limitations are based upon **surviving** fault conditions with several times rated current values as well as switching normal rated currents.

The contactors may therefore have to survive fault currents of several thousand amperes

References

- [1]Aircraft electrical systems and why they operate at 400 Hz frequency by Aspi Wadia of GE Aircraft Engines: http://www.wonderquest.com/expounding-aircraft-electrical-systems.htm
- [2] http://www.qantas.com.au/info/flying/inTheAir/communications
- [3] http://www.aerospaceweb.org/question/electronics/q0219.shtml
- [4] http://www.pcworld.com/article/id,111982-page,1/article.html
- [5] In-flight Power Manual http://www.walkabouttravelgear.com/graphics/invert.pdf
- [6] I. Moir,A. Seabridge,"Aircraft systems: Mechanical, Electrical and avionics subsystem integration", AIAA Education Series, Ohio, 2001
- [7] http://www.saftbatteries.com/020-MS_Aviation/20-20-10_Engine_starting.asp
- [8] http://www.power.goodrich.com/products/ac.shtml

More details needed

- Detailed load characteristics, during steady state operation, during start up.
- Detailed ratings on all generators, backups and regular ones.
- Monitoring and control details of when to kick in emergency operations.