U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – AVIATION & MISSILE CENTER

Design of circuits using AS50881, MIL E 7016 and other standards

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17 JULY 2024

AGENDA

- ❑ Requirements of an example circuit
- ❑ Where to start design
- ❑ ELA considerations – power source
- ❑ AS50881 ampacity review
- ❑ Circuit protection
- ❑ Select wire and analyze
- ❑ Questions
- ❑ Back Up

EXAMPLE CIRCUIT

Example LRU = fan
Power type = 28 Volts DC
Continuous power draw = 210 watts or 28VDC x 7.5 amps
Max power draw – typical at start up = 294 watts or 28VDC x 10.5 amps. Max power is held a max of 1 sec at start up.
Simple connection of power and ground

Utilizing AS50881 and other appropriate standards, design and substantiate the circuit to support this install.

What standards?
AS50881 Rev H Wiring Aerospace Vehicle (2023) – Overall design guidance but for this example looking for ampacity calculations (current carrying capacity). Charts and formulas Pages 53-58.
MIL-E-7016 Electric load and power source capacity, Aircraft, analysis of (1976) – looking at 5 sec, 5 min, continuous analysis for the power source.
Others – **MIL-STD-704** Aircraft Electric Power Characteristics; **MIL-STD-7080** Selection and Installation of Aircraft Electrical Equipment; **MIL-STD-11991** Department of defense Standard practice General standard for parts, materials, and Processes; **NAVAIR 01-1A-505-1** Organizational, intermediate, and depot Level maintenance Installation and repair practices Volume 1 Aircraft electric and Electronic wiring Volume

WHERE TO START DESIGN

Upstream = Power Source of the aircraft – in this case assume non emergency DC and assume DC#2 bus (e.g. Utility helo #2 DC Primary from the #2 converter)
Characteristics of the #2 converter are:
The 28 volt power source for each DC Primary Bus is an AC to DC unregulated converter (transformer-rectifier). It has a continuous rating of 400 amperes. Each DC converter is powered by its respective AC Primary Bus and both DC Converters are powered should one (1) AC Gen malfunction.

Will our load function under the established Operating conditions:

- G-1 GND MAINT, External Ground Power, Hot Day
- G-3 Loading and Preparation, Utilizing APU Generator Power, Hot Day
- G-4 Start and Warm-up, Hot Day
- G-5 Taxi, Cold Day
- G-6 Take-off and Climb, Cold Day
- G-7 Cruise, Cold Day
- G-8 Cruise Combat, Cold Day
- G-9 Landing, Cold Day
- G-10 Emergency - Single Converter Failure, Cold Day
- G-11 Emergency - Single Generator Failure, Cold Day, APU Online
- G-12 Emergency - Single Hydraulic Pump Failure, Cold Day
- G-13 APU Load - Dual Generator Failure, Cold Day, APU Online
- G-14 Emergency - Single Generator and Dual Hydraulic Pump Failure, Cold Day, APU Online
- G-15 Hover, Cold Day
- G-16 APU Load - Dual Generator Failure, Hot

HOW TO CHARACTERIZE USING THE ELA

We know we are using the #2 DC Primary and we will NOT use the #1 or #2 battery or #1 #2 essential busses. How does the ELA characterize the load?

Item #	FCT	Load EQPT	TOT UNITS	AMPS DC	NOTES	Time (in min)
11	Z	Fan	1	7.5	10.5 for 1sec	C

- ❑ Reference MIL-E-7016, the aircraft specific ELA, AS 50881 (Table B1)for circuit function category – we choose Z for experimental circuits or R,S,U for types of miscellaneous

Now that we characterize, how do we plug into ELA conditions

Item	G1			G3			G4-16		
	5sec	5 min	cont	5sec	5 min	cont	5sec	5min	cont
11	8.1	7.5	7.5	8.1	7.5	7.5	8.1	7.5	7.5

NOTE: For 5 sec calculation G1 use 1/5 X 10.5 + 4/5 X 7.5

DC PWR SOURCE CALCULATION

Do we have enough capacity for the load? Example only

Source rating	1000	600	400	1000	600	400	1000	600	400
OpCond	G1			G11			G15		
Interval	**5sec**	**5 min**	**cont**	**5sec**	**5 min**	**cont**	**5sec**	**5min**	**Cont**
Load before	190.0	160.0	140.0	280.0	240.0	220.0	290.0	255.0	230.0
Exc Cap Before	81.0%	73.3%	65.0%	72.0%	60.0%	45.0%	71.0%	57.5%	42.5%
FAN	8.1	7.5	7.5	8.1	7.5	7.5	8.1	7.5	7.5
Load after	198.1	167.5	147.5	288.1	247.5	227.5	298.1	262.5	237.5
Exc Cap after	80.2%	72.1%	63.1%	71.2%	58.8%	43.1%	70.2%	56.3%	40.6%

SUMMARY ELA

We have shown by quick analysis that we have sufficient power capacity for the load using the #2 DC Primary bus

Things to consider…

- ELA analysis using 22 VDC instead of 28…a technique some vendors use.
- Converters do reflect on AC Pwr and technically according to the format recommended in MIL-E 7016, this should be displayed first.

Example reflected load– under the #1AC Generator is a line item for the #1 converter 100 P NO. 1 CONVERTER - the reflected load is

- VA = (VDC x IDC)/(h x PF) Watts = (VDC x IDC)/ h
- h and PF are characterized by the actual loading on the converter (e.g. 200 amps 27.92 VDC 90.6% eff (h) and 0.99 PF

Example summary

- No. 1 AC Generator 21.30% (G-9, 5 sec.)
- b. No. 2 AC Generator 15.90% (G-15, 5 min.)
- c. APU AC Generator 4.90% (G-3, 5 sec.)
- d. No. 1 DC Converter 81.20% (G-15, Cont.)
- e. No. 2 DC Converter 45.60% (G-15, Cont.)
- f. Emergency AC System 1.80% (No. 1 Generator, G-11, 5 min.)
- g. Emergency DC System 33.00% (Converter No. 1, G-10, Cont.)

AS50881 AMPACITY DESIGN

- General rules we follow at TDD (Fort Eustis)…
  - Use MIL STD Aviation grade parts – if its not approved in 50881, try to find something that is
  - Match the aircraft but beware of standards changes and the “locked in” contract…OEM can do things we may not…look out for the “proprietary”.
  - 200 C wire at a minimum – typically go higher to match the aircraft – some aircraft use 260 degree in power distribution centers
  - Most conservative approach is typically applied – consider that something will be on for the life of the aircraft, even if its not planned to be. Sometimes a balance is needed.
  - Just because a commercial vendor brings non aviation grade parts, doesn’t mean we have to integrate that way
  - Vendors can be wrong and we should check to see if they are – we have dictated redesign because of a bad ampacity calculation on their part as well as a congested connector and current dividing
  - One LRU – one circuit with its own circuit protective device (CPD)
  - We have made mistakes (know thyself) but so has SRD and OEM and mission equipment vendors. Cross checking each other is a necessary function.
  - If an error is found report it and make the report clear (don’t hide catastrophe on slide 22 and obfuscate the words so it doesn’t mean what it says)
  - Communicate lessons learned across the enterprise, train them and and enforce them – world class teams act that way
  - We have a color code for expressing design issues. Red – fails to meet the standard – must re-engineer and if you can’t reengineer, a deliberate mitigation strategy must be put in place and enforced (typically for experimental only). Yellow – standard is met but less than 25% safety margin – reengineer if able but identify as a risk and explain/mitigate as necessary – engineering judgement allowed. GREEN – exceeds standard 25% or more.

SELECT THE CURRENT PROTECTION

- MIL-STD-7080 - Circuit protective devices shall be installed to prevent damage to aircraft wiring, wire insulation, and electric power distribution equipment from overloads and faults. They shall be installed at the power source end (both ends of bidirectional bus tie feeders) of circuits with no more than one foot of wire between the point of power takeoff and the circuit protective device. Circuits shall be individually protected.
- Circuit breakers shall not be used as switches unless they have been designed for use as switches.
- MIL-STD-11991 - General Standard for Parts, Materials, and Processes Derating standards for circuit breakers show 0.75 for resistive loads.

- At 7.5 amps continuous load, we show we can use a 10 amp CB (AS33201) and still meet 11991 derating which matches our own TDD design criteria for safety margin at 25%.

- What about 10.5 amps for one second inrush? If you assume AS33201 trip curves you typically see the ability to handle 200% for 1.5 seconds or more.
- Some designers may consider going to 15 amps

SELECT THE WIRE

Initially we would consider 200C wire. AS50881 walks us through several derating steps.

Step 1. AS50881 use figure 2 single copper wire in free air. 20 gauge wire is the minimum recommended power wire size. Note this may be dictated by the ICD. 200C-70C (71) = 130C (129). The chart leads you to 21 amps.

Note: 70C is a heat soaked aircraft

Step 2. Bundle derating. #wires in a bundle and how many carry power? Use Figure 4 and use 2 wires at 100% load. The derating is 0.825.

Step 3. Altitude derating. Utilize service ceiling for aircraft (e.g. Utility Helo 20,000 ft). Derating 0.905.

Apply deratings: 21 x .825 x .905 = 15.68 amps.
Analyze: 15.68 > 10 meets at least yellow condition. Safety margin 15.68/10 = 1.57 > 1.25 so this is green.
CB value to wire ampacity, load to CB, load to wire all green.

OTHER CONSIDERATIONS FOR CIRCUITS

Can we use 150C wire? Yes if the math works out. Not recommended in our organization.

Accidental attachment to an existing circuit.? (Low impedance)

Use of current limiters and fuses.

Do we ONLY care about the wire ampacity? Short answer is NO.

HISTORY OF INTEREST REF AMPACITY

Who are Preece and Onderdunk? In the 1880's Sir William Henry Preece worked as a consulting engineer for British General Post Office – lightning strikes on telegraph wires led him to work on ampacity.

Onderdunk more obscure but may have been researching conditions where a short circuit that occurs between a high-voltage transmission line and the copper wires attached to the insulators or poles supporting the line – needed to determine sizes. Their calculations are where we derive our charts and equations today.

*It is important to understand what constitutes the melting of a copper wire. When we apply heat to a wire (or any solid for that matter), there are two stages we can consider. The first is that the wire heats up from the initial temperature to the melting temperature. The second when it goes from solid to liquid.

Questions?