Power Dissipation Optimization Process in Aircraft Secondary Power Distribution Systems

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PROPOSED AGENDA

• Introduction, Aircraft Electrical Power History and Concepts
• Power Distribution Units, Configurations and Characteristics
• Problems, Challenges and Constrains
• Solution, Tools and Methods
• During the WWI era, radio communication was introduced and 12 volt lead acid battery and air or engine driven DC generators were used.

• 28 V dc aircraft system voltage was established during WW II era (then sometimes called a 24 volt, or 27 volt or 30 volt system).

• In the early 1940s the decision was made to adopt 400 Hz, 3-phase, 115/200 volt system as future aircraft electrical power system.
AIRCRAFT ELECTRICAL POWER GENERATION HISTORY

AIRCRAFT AC POWER GENERATION

POWER RATING [KVA]


B787  A380  B747  A340  B757  DC-9
SECONDARY POWER DISTRIBUTION WITH COCKPIT CIRCUIT BREAKERS CONCEPT

115 V AC BUS

TRU

28 V DC BUS

AC ELECTRICAL LOADS

DC ELECTRICAL LOADS

COCKPIT CIRCUIT BREAKER PANEL

TRIP CURVE - Approximate Time, Current Characteristics At 77°F (25°C)
SECONDARY POWER DISTRIBUTION CONCEPT WITH INTEGRATED PDUs

COCKPIT MULYT FUNCTIONAL DISPLAYS

28 V DC

115 V AC

AVIONICS AND INTERFACE CONTROL

PDU

PDU

PDU

PDU

28 V DC

115 V AC
Each PDU contains up to n AC and/or DC power modules with Solid State Power Controllers (SSPCs) designed to switch power ON and OFF to aircraft electrical loads in response to commands from dedicated system controllers.
DC POWER MODULE ARCHITECTURE

POWER FEED
+28 V DC

DATA AND CONFIGURATION CONTROL BUS

POWER MODULE

INPUT FILTER

INTERFACE

BOARD CONTROLLER

SSPC 1

SSPC 2

SSPC 3

SSPC K

LOAD #1

LOAD #2

LOAD #3

LOAD #K

POWER RETURN
CHALLENGES AND CONSTRAINS

• Total system equipment weight.

• Architecture driven by minimal distance between power source and electrical load.

• Bus power and load segregation.

• Load shed pattern.

• System hardware limitations.
PHYSICS OF HARDWARE AND SYSTEM LIMITATIONS

1. Limit on AC and DC input feed current.

2. Limit on power dissipation on SSPC components.

3. Limit on internal control power dissipation.
For each Power Module at position X, total power dissipation can be defined as a sum of all individual SSPC channel power dissipations:

\[ PD_{MX} = R_{ON} \sum_{1}^{K} I^2 \quad [W] \]

were

\[ I = I(\varepsilon) \quad [A] \]

\[ R_{on} = R_{on}(Temp) \quad [\Omega] \]

\( I \) is a continuous load current through SSPC channel, which depends on aircraft configuration \( \varepsilon \),

and \( R_{on} \) is SSPC channel ON resistance, as a function of ambient operating temperature \( Temp \),
• Load currents of the electrical and electronic equipment are dependant on aircraft configuration.

• For the purpose of this analysis, the aircraft configuration parameter $\varepsilon$, can be tied to a different aircraft designated flight phases, listed in the following order:

- Ground Loading
- Engine Start
- Taxi
- Takeoff
- Climb $\varepsilon$
- Cruise
- Descent
- Landing
SSPC channel ON resistance $R_{on}$ includes MOSFET ON drain-source resistance, current sensing resistance, and some other elements relevant to specific hardware configuration.
• PDU total power consumption can be calculated as a sum of Power Supply power consumption, and all $n$ Power Modules power dissipations:

$$\text{PDU}_\text{TPC} = \text{PS\_Power\_Consumption} + \sum_{1}^{n} \text{PD\_MX} \quad [\text{W}]$$

were

Power Supply power consumption includes:

- Processor power
- Power Supply efficiency, and
- Control Switching power losses.
POWER ANALYSIS NUMERIC ALGORITHM

PDU CONFIGURATION

\[
\begin{pmatrix}
M_{1,1} & M_{1,2} \\
M_{2,1} & M_{2,2} \\
M_{n,1} & M_{n,2}
\end{pmatrix}
\]

CONFIG :=

\[
\begin{pmatrix}
\vdots \\
\vdots \\
\vdots \\
\vdots
\end{pmatrix}
\]

\[
:\Rightarrow
\]

MODULE 1

MODULE 2

\[
\gamma = n
\]

\[
\sum_{i=1}^{n} DC_i
\]

\[
\Rightarrow
\]

DC\text{int}\epsilon

LOAD DATABASE

AIRCRAFT LOADS CONFIGURATION

THREE DIMENSIONAL CURRENT MATRIX

\[
\begin{pmatrix}
TDCM_{1\epsilon,1} & TDCM_{1\epsilon,2} & \cdots & TDCM_{1\epsilon,k} \\
TDCM_{2\epsilon,1} & TDCM_{2\epsilon,2} & \cdots & TDCM_{2\epsilon,k} \\
TDCM_{n\epsilon,1} & TDCM_{n\epsilon,2} & \cdots & TDCM_{n\epsilon,k}
\end{pmatrix}
\]

\[
\begin{pmatrix}
\vdots \\
\vdots \\
\vdots \\
\vdots
\end{pmatrix}
\]

\[
\Rightarrow
\]

\[
\epsilon
\]

\[
K
\]

\[
n
\]

\[
\epsilon
\]

\[
\Rightarrow
\]

\[
\epsilon
\]

\[
\Rightarrow
\]

\[
\epsilon
\]
POWER ANALYSIS BLOCK DIAGRAM

PDU HARDWARE CHARACTERISTICS
AND SPECIFIC LOAD CURRENT VALUES

AIRCRAFT CONFIGURATION
\( \varepsilon \)

AMBIENT TEMPERATURE
\( \text{Temp} \)

PDU POWER ANALYSIS NUMERIC ALGORITHM

\( \text{PDU}_\text{TPC}(\text{Temp}, \varepsilon) \)
\( \text{PD}_\text{M1}(\text{Temp}, \varepsilon) \)
\( \text{PD}_\text{M2}(\text{Temp}, \varepsilon) \)
\( \ldots \)
\( \text{PD}_\text{Mn}(\text{Temp}, \varepsilon) \)
PDU POWER ANALYSIS RESULTS

![Graph 1: Total Power Consumption vs Ambient Temperature](#)

- Phase Of Flight(ε) = "CLIMB"

![Graph 2: Power Dissipation vs Ambient Temperature](#)

- PD_M1(Temp, ε)
- PD_M2(Temp, ε)
- PD_M3(Temp, ε)
- PD_M5(Temp, ε)
- Dissipation Limit

Phase Of Flight(ε) = "CLIMB"
POWER DISTRIBUTION OPTIMIZATION PROCESS

1. POWER ANALYSIS NUMERIC ALGORITHM
2. AMBIENT CONDITIONS CHANGE
3. ELECTRIC INTERFACE CHANGE
4. LOAD POWER CHARACTERISTICS CHANGE
5. AIRCRAFT LOADS CONFIGURATION
6. POWER ANALYSIS RESULTS
REFERENCES


• “MOSFET Power Losses Calculation Using the Data-Sheet Parameters” by Dr. Dusan Graovac, Marco Pörschel, Andreas Kiep, Application Note, V 1.1 July 2006, INFINEON.


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