More Electric Aircraft Forum

Standardizing solid state electric distribution components for a greener and cheaper aircraft

Author
Dominique-Robert Meux business engineer for CROUZET Aerospace

Co-Author
Dominique Girot project manager for CROUZET Aerospace

ABSTRACT

Through its role in MOET, Crouzet has approached the problem of electric distribution in the More Electric Aircraft with a bottom up approach.

This bottom up approach has led us to develop stand alone power distribution units (SPDU), a modular approach to the solid state power distribution standardization problem.

INTRODUCTION

What is the standardization problem ? With MOSFET electronics getting cooler and cooler, it is possible to replace traditional circuit breakers with their electronic counterparts ; (ie solid state circuit breakers with ratings up to 25 amps). To take full advantage of this, a solid state solution must be cost effective (standardized) and this is in contradiction to specific system & aircraft needs.

Solid state distribution is in the heart of the greener aircraft because it brings

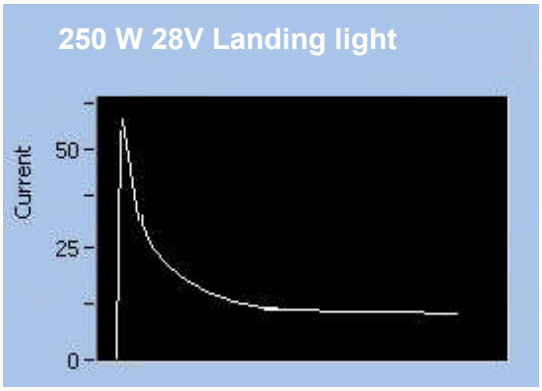
- inrush current reduction
- energy multiplexing ability
- wire rationalization

The MOET Project Steering Committee has approved this paper for publication. The author is solely responsible for the content of the paper.

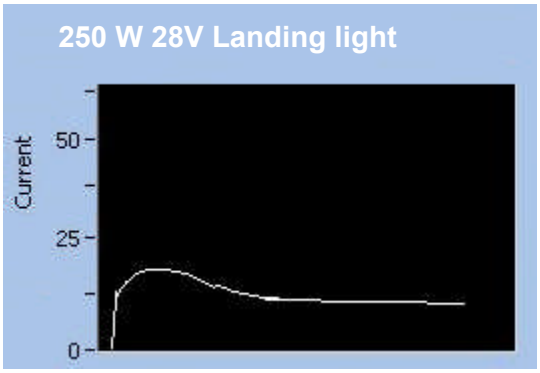
WHY A GREENER AIRCRAFT ?

Greener with inrush current reduction

The soft start feature available on all solid state protection lines illustrates the contribution of electronics to generator size reduction ; an illustration is given below with the recording of an incandescent light powering on :



traditional power on

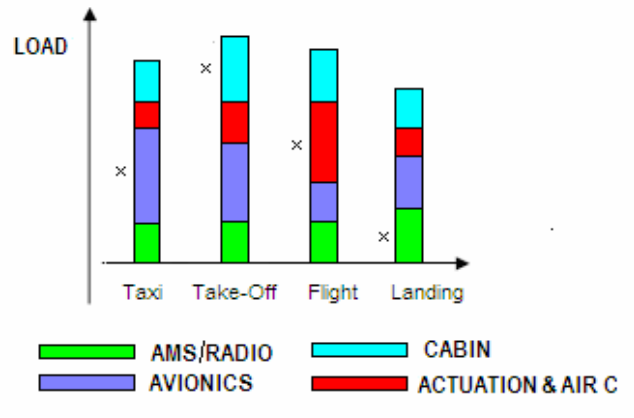


power on with soft start

The application of the above feature in conjunction with a sequential power on of loads contributes to reducing generator size thus weight and operator possession cost.

Greener with flight phase management

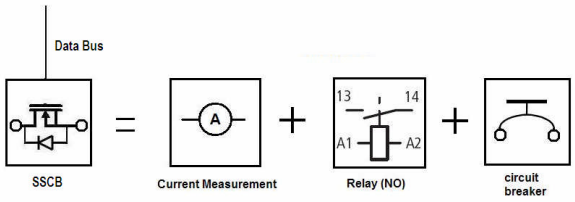
More gains in cost and weight appear when a load management unit is used in conjunction with flight phases.



energized loads vs flight phase

Without multiplexing, the wire feeders must cope with the worst case (here marked with an x).

Multiplexing is possible because a communicating Solid State Circuit Breaker (SSCB) is a switch, a relay and a current sensor at the same time:



With these 3 intrinsic features an SSCB gives to the system energy multiplexing ability.

Greener through modular architecture

This has been of one the goals of MOET and is the standard now for large aircrafts [3].

"SOLID COSTS" CONSIDERATIONS

Because of the lack of a standard, solid state power distribution systems are generally taylorized and adapted. Because of this, the ratio between the cost of an SSCB line inside a solid state protection and the cost of an electromechanically protected line is 4:1. This is also illustrated in [2].

The above ratio (4:1) is prohibitive when your SSCB line performs only a thermal protection (ie is just used as a circuit breaker).

But as soon as an SSCB is used as a relay the ratio comes down to (1,5:1) because with your SSCB, you remove an LRU relay costing 100 to 200 USD.

Hidden gains appear when weight and wiring simplification come into the equation. Some studies show that weight gains of 20Kg can be possible on business jets [1]. For larger aircrafts, the wire simplification is preponderant [3] bringing the ratio to (1:1) or even lower.

ACHIEVEMENTS THROUGH MOET

Inside the MOET large aircraft 100m test rig Crouzet was assigned to 3 tasks :

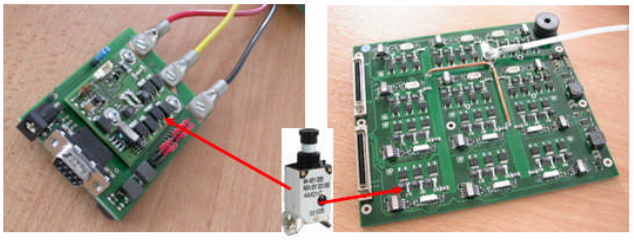
- adapt and support an SEPDC cabinet from the MODERNE project

- develop two Stand Alone Power Distribution Units **(SPDU)** (28VDC and 115VAC 400Hz).

- implement GFI and arc fault protection on the AC solid state devices

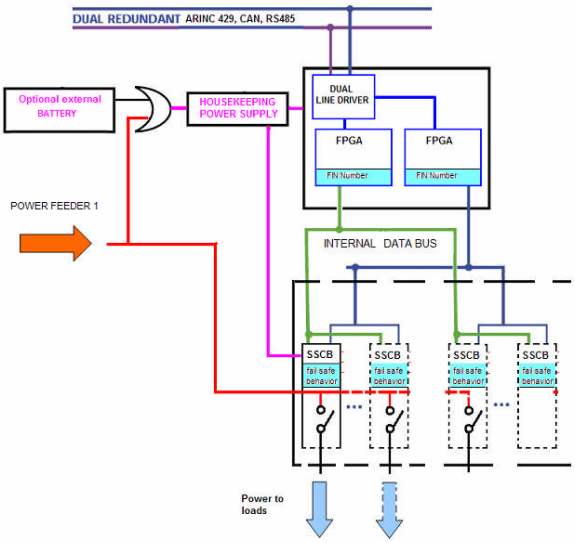
Secondary Power distribution Cabinet

In order to mutualise thermal sink, power supplies and communication SSCB are clustered on power board :



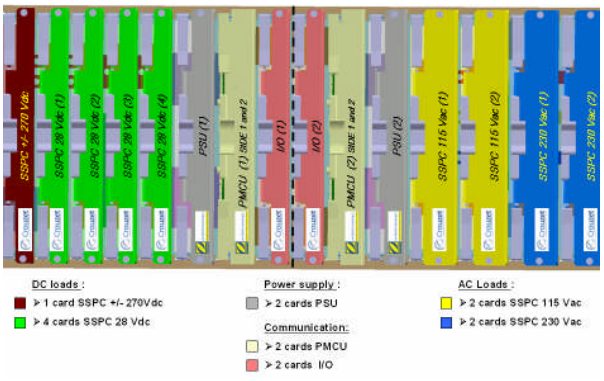
Solid State circuit breaker =SSCB cluster of SSCB = POWER BOARD

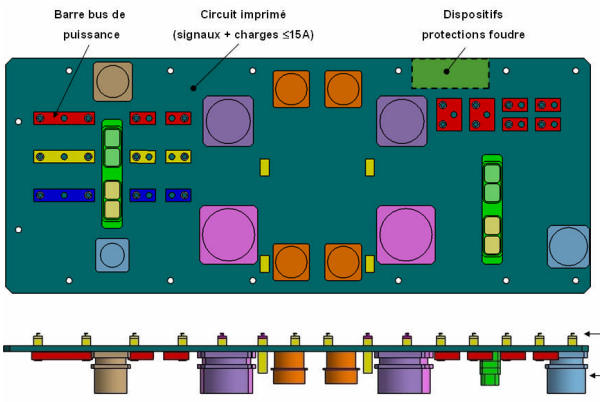
Crouzet has developed 115VAC, 230VAC,+-270VDC and 28VDC power boards. These boards have the same redundant architecture in order to attain the system security objectives.



power board general architecture

These boards communicate through CAN; A CAN/ AFDX concentrator developed by Zodiac Aerospace enables communication with the system and maintenance calculator level. The complete composition of an SEPDC cabinet is illustrated hereunder :





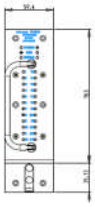
SEPDC : cabinet courtesy of Labinal

<u>Stand alone power distribution units</u>

The SPDU is our contribution to standardizing solid state distributions with off the shelf components & packaging.

Indeed,

With the SPDU we have chosen the ARINC 600 envelope as a standard packaging



With the SPDU we have made a step towards a standardized software interface:

The general queries and replies have been laid down and homogenized with other partners. Today there are around 16 queries and 16 answers possible when you question a cluster of SSCBs (ie a SPDU).

SPDU Queries example

This orders is addressed to each SPDU every 30 msec ; It sets the 24 SSCBs to ON or OFF.

Binary Command Setting

ARBITRING FIELD	FI				CT	DI				
	b25	b24	b23	b22	b16	b10	b9	b8	b7	b6

Requête	
TailleData	TailleTrame
64	131

N° d'octets	Format des données							
1	CDB24	CDB23	CDB22	CDB21	CDB20	CDB19	CDB18	CDB17
2	CDB16	CDB15	CDB14	CDB13	CDB12	CDB11	CDB10	CDB9
3	CDB8	CDB7	CDB6	CDB5	CDB4	CDB3	CDB2	CDB1
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

CDBx	Command TOR

When receiving the above order, the SPDU replies with the effective state of each SSCB it controls (it can be open, closed or tripped thermally, on arc fault or ground fault) :

Binary Command Answer (status)

ARBITRING FIELD	FI				CT	DI				
	b25	b24	b23	b22	b16	b10	b9	b8	b7	b6

Requête	
TailleData	TailleTrame
64	131

N° d'octets	Format des données							
1	CDS24	CDS23	CDS22	CDS21	CDS20	CDS19	CDS18	CDS17
2	CDS16	CDS15	CDS14	CDS13	CDS12	CDS11	CDS10	CDS9
3	CDS8	CDS7	CDS6	CDS5	CDS4	CDS3	CDS2	CDS1
4	UTT8	UTT7	UTT6	UTT5	UTT4	UTT3	UTT2	UTT1
5	TRD24	TRD23	TRD22	TRD21	TRD20	TRD19	TRD18	TRD17
6	TRD16	TRD15	TRD14	TRD13	TRD12	TRD11	TRD10	TRD9
7	TRD8	TRD7	TRD6	TRD5	TRD4	TRD3	TRD2	TRD1
8	GFT8	GFT7	GFT6	GFT5	GFT4	GFT3	GFT2	GFT1

CDSx	Command Status (Real situation)
TRDx	Trip Detection
UTTx	Unbalanced Triphase Trip Status
GFTx	Ground Fault Triphase Trip Status

With the SPDU we have confirmed that off the shelf components can deliver performances equivalent to hybrid solutions

Our previous 2001 technology was mixed hybrid and we have improved performances in the following way :

Electrical performance 28VDC

Power dissipation when maximum current is distributed

Model	current	Power at 25°C	Power at 55°C
DC 24 SSCBs	180A	24 W	35 W
DC 48 SSCBs	360A	48 W	70 W

Voltage drop from feeder to the output pin xy

SPDU DC28	drop at 25°C	drop at 55°C
5A SSCB	80 mV	135 mV
10A SSCB	110 mV	190 mV
15A SSCB	140 mV	230 mV

- With natural convection :
  at 23°C and 71°C :100% utility factor (ie no derating); the SPDU28V can deliver permanently:
  -current : 15*4+4*10+16*5 = 180 Amp
  -power 180*28V = 5400 W

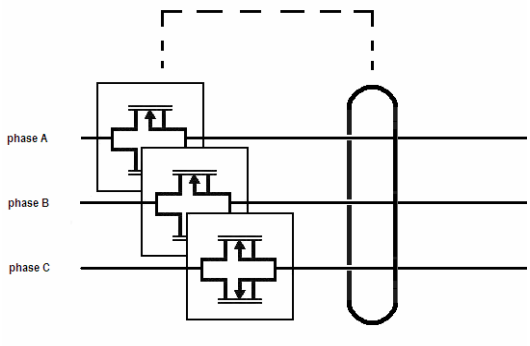
- Each switch is protected by a patented fail safe fuse

GFI and arc fault protection features

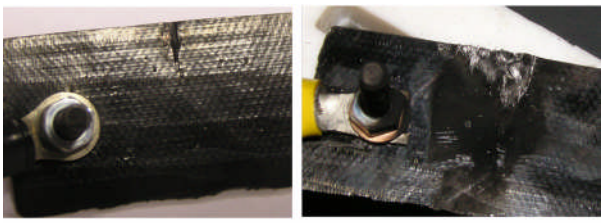
GFI technology required

-the coordination of 3 AC SSCBs (to build a 3 phase AC circuit breaker).
-the monitoring of the homopolar current within the 3 phases, done with a current transformer.

This is why an AC SPDU has 3 power feeders (phase 1, phase 2 and phase 3) and generally contains a number of SSCBs multiple of 3.



Arc fault technology was transferred inside the SPDU by compiling and linking the AC arc fault algorithm in C language already available in Crouzet, with each SSCB application.



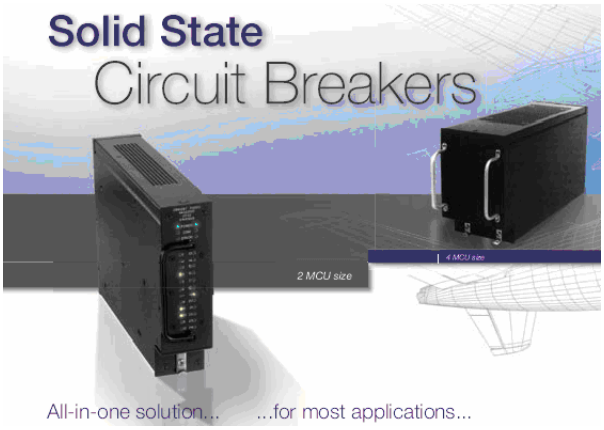
ARCING WITH ARC FAULT PROTECTION

ARCING WITH TRADITIONAL CIRCUIT BREAKER

CONCLUSION

With MOET we can now offer cost efficient equipments to the aircraft industry associating

- off the shell electronics
- off the shelf packaging
- a software interface that answers most needs and can be adapted



ACKNOWLEDGMENTS

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- Airbus France for their coordination and fruitful innovation

REFERENCES

[1] Fred Potter -Astronics- "Solid state power distribution technology" AEISS (Aerospace Electrical Interconnect Symposium) Savannah 2007

[2] Michael Walz –FAA- Aging Aircraft Conference 2007 "A pricing analysis around solid state technology"

[3] Mike Bailey –GE Aviation- Modular distribution considerations on large aircraft

CONTACT

dmeux@crouzet.com

dgirot@crouzet.com

Definitions, Acronyms, Abbreviations

- **AC :** **A**lternative **C**urrent
- **CB :** **C**ircuit **B**reaker
- **GFI :** **G**round **F**ault **I**nterrupter
- **MODERNE:** **MO**dular **E**lect**R**ical **NE**twork
- **MOET** **M**ore **O**pen **E**lectrical **T**echnologies
- **SEPDB :** **S**econdary **E**lectric **P**ower **D**istribution **B**ox
- **SPDU:** **S**tand **A**lone **P**ower **D**istribution **U**nit
- **SSCB :** **S**olid **S**tate **C**ircuit **B**reaker