More Electric Aircraft Forum

Electrical distribution of high power : impacts, technologies

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ABSTRACT

In the MOET program, ECE, from Zodiac Aerospace group, was in charge of the development of high voltages distribution centers.

The Primary Electrical Power Distribution Centers were specifically designed for the MOET objectives using new technologies : contactors 230VAC and moreover contactor +/-270VDC, protections redesigned to fit with these new voltages and high currents, and specific functionalities (e.g. pre-charge system).

The final design of the equipments and their testing on test rigs demonstrate that the distribution of high electrical power (total of 1 MW) with high voltages is possible, in particular through the direct connection to high DC voltage, and feasible with the developed technologies.

INTRODUCTION

To satisfy the more electrical aircraft needs, an increasing amount of power has to be managed.

The distribution of large electrical power is made possible using higher voltages than the 28VDC and the 115VAC currently implemented : Alternative Current voltage 230VAC (HVAC) and Direct Current high voltage +270VDC or +/-270VDC (HVDC).

The MOET program planned to validate the feasibility of aircraft electrical networks with such voltages and to evaluate their performances.

One of the main questions is to validate that the distribution, the control, the management and the protection of the electrical system remain possible, reliable and safe, and that this is done with technologies allowing acceptable weights, volumes and costs.

In MOET, the WP6 assures the distribution of the electrical power in the system. ECE from Zodiac Aerospace was in charge of the development, from design to manufacturing of the HVAC PEPDC (Primary Electrical Power Distribution Center) and the HVDC PEPDC for the Airbus 100m test rig, and of the HVDC PEPDC for the Alenia 10m test rig.

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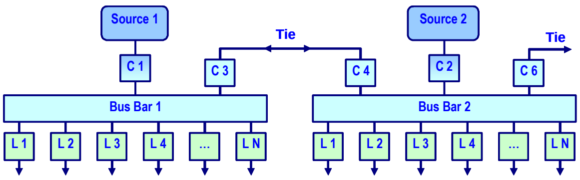
http://www.moetproject.eu

DEVELOPMENT OF PEPDCS

PEPDC MAIN FUNCTIONALITIES

A Power Center is at the center of an electrical system.



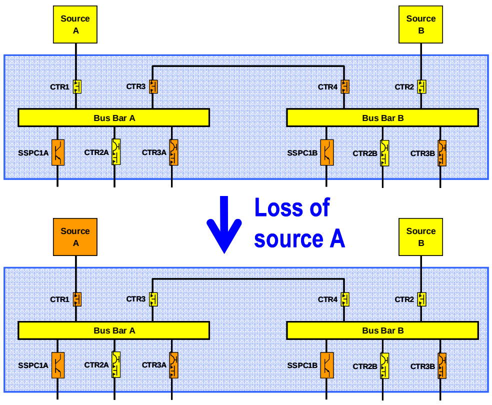
Main functionalities of the Power Center are :

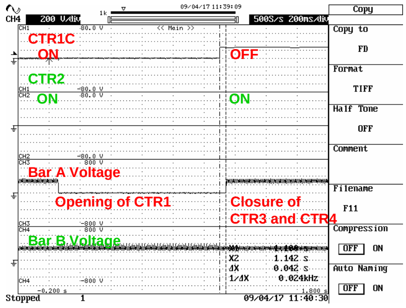
- Connections between sources and main loads.
- Management of the electrical primary distribution : switching ON/OFF of full electrical power, reconfiguration of primary distribution, management of converters.
- Protection of the lines against faults : over-current protection, ground fault protection, differential protection.

<u>Management of reconfiguration</u>

The Power Center manages the electrical network by automatic reconfiguration of the primary distribution on events, availability of sources, failures, etc…, according to a logic defined to ensure the maximal availability of power on the various bus bars of distribution.

Example of reconfiguration :





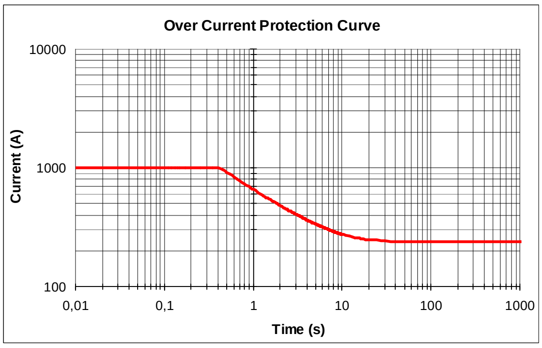
<u>Protection of lines</u>

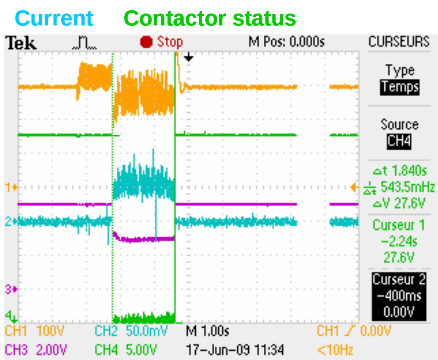
Protections of lines are done by contactor with measure of current and electronic control.

Over-current protection is done by software according to a law $i^2.t$, using as reference a curve max current versus time adapted to the line : value < reference : OK,
value > reference : Trip

The algorithm integrates a "thermal memory" effect (e.g. for low repetitive over-current).

ex. in 270VDC line LOADC4 nominal 200 A, test at 500 A leads to a trip at 1,8 s





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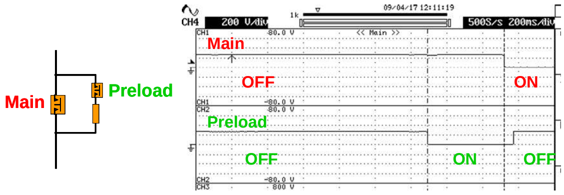
Pre-charge system

A pre-charge system limits the inrush current at the closure of contactor. It is done by an auxiliary contactor and resistors connected in parallel to the main contactor. This new feature is introduced to manage the effects of large capacitor presence in the electrical system.



PEPDCS FOR AIRBUS 100M TEST RIG

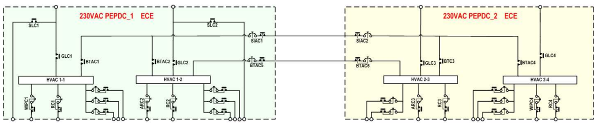
The electrical system for Airbus 100m test rig is with 4 channels, and multi-voltages.

The distribution is dispatched in various boxes, depending on voltages and sides (left / right).

Two configurations were defined, a “Basic” with full distribution in 230VAC and ±270VDC, and an “Advanced” with distribution mainly limited to ±270VDC.

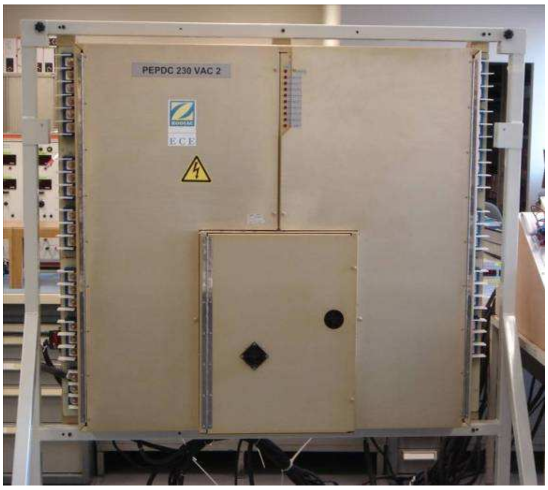
PEPDC 230VAC

PEPDC Architecture



The diagram of the PEPDC was defined by Airbus. ECE developed and manufactured the whole PEPDC. The aim is to simulate the electrical distribution of a full aircraft with 4 channels available. These channels are separated is two sides 1 Left and 2 Right. Each 230VAC channel is rated at 300 kVA.

PEPDC Main items



The PEPDC integrates all the usual functionalities. The main items are :

- ECE’s Contactors 230VAC 3 phases, integrated in various calibers.
  With maximum of 430 A / 230VAC so 300 kVA, corresponding to the power of one AC channel of a 1 MW aircraft.

- All logics and protections are done by electronic and software.
- Protections relative to current use current transformers.
- Communication between PEPDC and terminal is by Flexray.
- The PEPDC manages an auto-transformer (ATU) between 115VAC and 230VAC, with a reversible direction of transfer of power, and by assuring no conflict in the position of the source.

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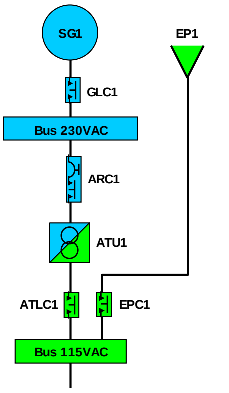
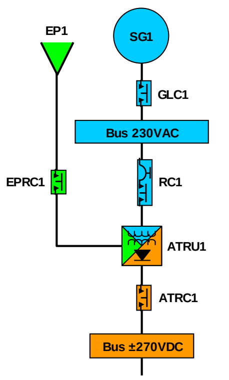


- The PEPDC manages an auto-transformer-rectifier (ATRU) delivering ±270VDC which can be supplied either by 230VAC or 115VAC, by assuring no parallel connection of 230VAC and 115VAC, and by integrating a pre-charge system to limit inrush current



<u>Results</u>

The PEPDC 230VAC was manufactured and installed in the Airbus 100m test rig.

The test showed that the direct management of a high AC voltage is possible and similar to 115VAC distribution, in particular regarding time of transfer < 100 ms, and ratio of under/over-voltages.

The difference is essentially in the hardware design of the PEPDC which has to comply with specific rules to improve insulation and dielectric behavior, and in the contactors.

Quality of electrical power impacts contactor performances. An improved design of the contactor may be necessary but this induces a higher weight of the component.

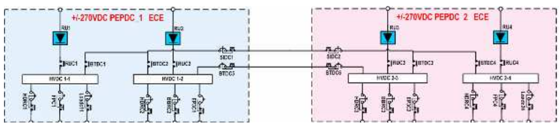
Over-current protection shall be refined, by a reduction of the ratio of maximum and nominal current to avoid too large current (e.g. 10 times not relevant), and as electronic control is very accurate, times can be shorter than thermal circuit breaker to avoid severe constraints.

Protection selectivity becomes sensitive when contactors are in cascade (source / converter / load).

PEPDC ± 270VDC

A novelty of MOET is to test the direct distribution of electrical power under a high DC voltage. This is not done in existing commercial aircraft.

<u>PEPDC Architecture</u>



The diagram of the PEPDC was defined by Airbus. ECE developed and manufactured the whole PEPDC.

The aim is to simulate the electrical distribution of a full aircraft with 4 channels available. These channels are separated is two sides 1 Left and 2 Right. Each ±270VDC channel is rated at 200 kW.

<u>PEPDC Main items</u>

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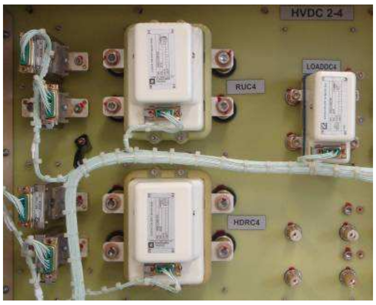
The main items integrated in the PEPDC and used for MOET are :

- ECE's Contactors ±270VDC 2 poles integrated in various calibers, with max of 400A / 540VDC so 216 kW corresponding to one DC channel of a 1 MW aircraft.



- All logics and protections managed by electronic and software.
- Protections relative to the currents are done with Hall effect sensors and adapted to high voltage.
- Communication between PEPDC and monitoring and control terminals are by Flexray.
- In addition to the "classical" distribution, the conversion of AC power in DC power through a rectifier unit is included in the PEPDC to reduce connections ("Advanced" configuration).
- Regarding power quality, pre-charge systems to limit the inrush current at the closure of a contactor are implemented.
- A complementary function is the management of the configuration of the network for an engine start sequence, in association with the starter-converter (MCU).

<u>Results</u>

The PEPDC ±270VDC was manufactured and installed in the Airbus 100m test rig.

The test showed that a direct management of a high DC voltage is possible because switching of power is done properly, loss of power during transfer is in usual limits of time and voltage transients remain in acceptable levels.

Technologies exist to make the protections. Over-current protections are tested for rating from 15 to 360A. Ground fault protection tested for a "fuel pump" line, rated to a very low value (<3% of nominal rating).

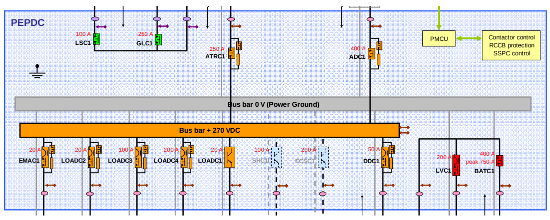
Pre-charge system is necessary for some inputs or lines. However optimisation of the time and value of current of pre-charge is required to avoid over-sizing and penalty for PEPDC weight.

PEPDC FOR ALENIA 10M TEST RIG

A variant of HVDC distribution in MOET is to test the electrical power under a high DC voltage 270VDC in simple pole configuration (no switch on 0V lines). This is foreseen for smaller aircraft : regional aircraft, business jet and helicopters.

<u>PEPDC Architecture</u>

PEPDC for Alenia 10m test rig connects two sources 270VDC and one main bus. In complement, two other areas allow 115VAC and 28VDC management.



ECE developed and manufactured the whole PEPDC. The aim is to be able to test 270VDC equipments, protections, and some specific functions, as electrical start, connection of battery, etc…, but not a full aircraft network.

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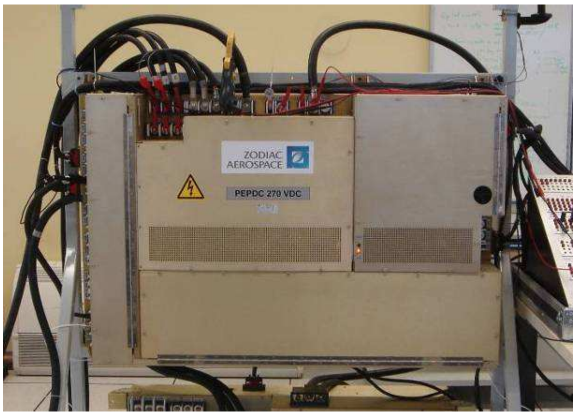
PEPDC Main items



The PEPDC integrates similar functionalities than the PEPDC ±270VDC.

An additional feature is the switching of load by static components (SSPC).

The new items integrated in the PEPDC and used for MOET are :

- ECE's Contactors 270VDC integrated in the PEPDC, with contactor of 400A / 270VDC so 100 kW.
- Protections regarding the currents are done with Hall effect sensor and adapted to high voltages.
- The management of an electrical start of "engine" or "APU" directly connected to 270VDC.
- Management of a 270VDC / 28VDC reversible converter (BBCU).
- High power SSPC 270VDC / 20A.

Results

The PEPDC 270VDC was manufactured and installed in the Alenia 10m test rig.

As for the other HVDC PEPDC, tests show positive results for distribution of 270VDC. The management of 270VDC can be done properly and safely.

Use of SSPC allows a shorter time of switching than a contactor, a limitation of the inrush current at the closure with a pre-charge function directly integrated, and a control of the overvoltage at the switch off by soft opening.

CONCLUSION

The main points of conclusion, at the end of PEPDC development and testing are following.

Management of 230VAC is possible, and better than 115VAC for high power as the currents to be switched are reduced.

Good feasibility of PEPDC HVDC and direct distribution of HVDC. The HVDC is defined depending on the power as 270VDC/0VDC or +270VDC/-270VDC. The behaviour of the PEPDC appears globally similar to the usual one, in term of time of transfer, response of protection, although difference of technologies implicated. Switching of HVDC is reliable and efficient. Functional design of PEPDC HVDC is validated.

Dispatch of the distribution in several PEPDC boxes is validated and operative.

Weight and volume reduction remains a challenge

Lessons learnt during the development and tests :

- Importance of the electrical power quality (power factor, harmonics,...) that a contactor has to open; here is a compromise between safety of the opening and over-sizing (weight penalty)
- Logic and protections (OC, DP, ...) cannot be defined alone independently from the others. A complex network with active protections in series (e.g. ATU line) requires a final adjustment between them to establish the correct selectivity.
- Precision of the definition of conditions used for the configuration of a complex electrical network.
- Adjustment of the pre-charge system design (current / time), to have a system robust but not excessive in weight and volume.

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REFERENCES

None

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

- ATRU — Auto-Transformer Rectifier Unit
- ATU — Auto-Transformer Unit
- BBCU — Buck Boost Converter Unit
- CT — Current Transformer
- GCU — Generator Control Unit
- MCU — Motor Controller Unit
- PEPDC — Primary Electrical Power Distribution Centre
- RU — Rectifier Unit
- SG — Starter Generator
- SGCU — Starter-Generator Control Unit
- SSPC — Solid State Power Controller

APPENDIX

None

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