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Dual DC-Bus Homopolar Generator for Advanced Propulsion Systems

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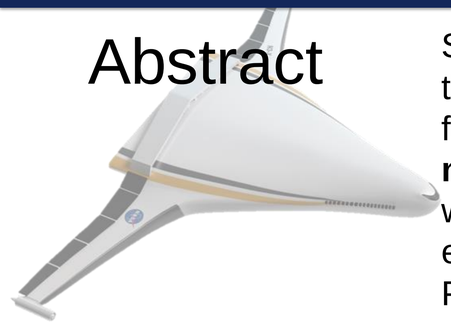
Abstract



Synchronous Homopolar Generators (SHG) represent an attractive solution for the future of **aircraft power generation**, especially when the drivetrain features a **hybrid turbo-electric** layout via primary **medium-voltage DC power distribution**. In fact SHGs feature both a fully controllable excitation, similar to **wound-field synchronous machines**, and a very robust rotor, such as **switched reluctance machines**. In addition, the features above make this machine's topology a promising alternative also to **PM synchronous generators**, which require **full-rated AC/DC active power converters** for their operation, affecting significantly the overall weight, reliability and efficiency. A generation system based on a SHG operating on 2 independent DC buses via diode rectifiers is proposed. The aim of this Ph.D. is to design, manufacture, and test a small-scale prototype of such generation unit, finalised to validate the overall concept.

Background

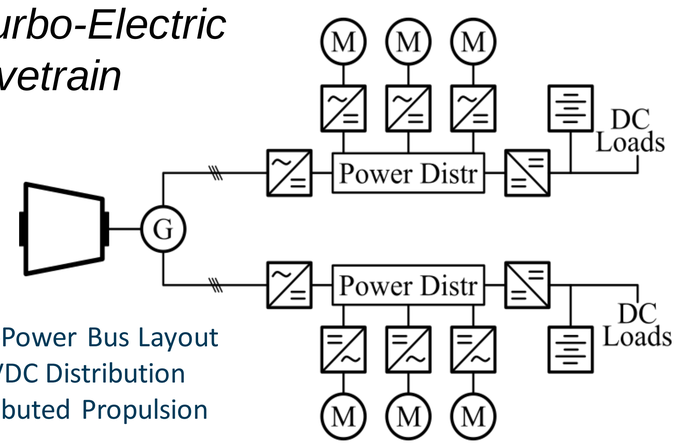
Aircraft Power Generation: S.o.A.

- Three-stages **wound-field synchronous generators** are currently installed on commercial aircraft
- **PM** and **switched reluctance** generators are innovative solutions for the future of aircraft power generation
- Full rated **active AC/DC converters** required (low MTBF, complexity, control)

Aims

- The concept and design of an alternative generation unit based on **synchronous homopolar generators** operating on DC power distribution
- Targets: system **reliability** and simplicity, **high-power density**, **efficiency**, **fault-resilient** architecture
- Complete **field controllability**, permitting the employment of **passive diode rectifiers**

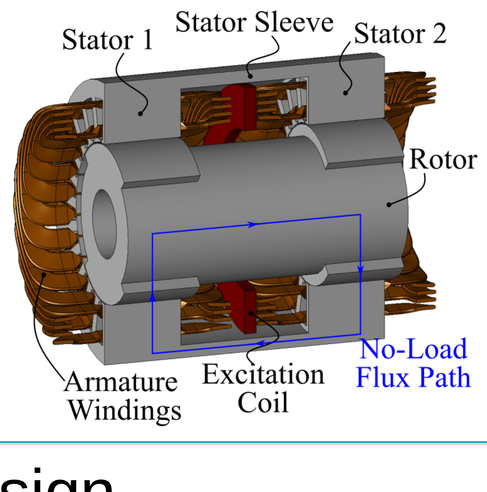
Hybrid Turbo-Electric Drivetrain



Multi-Power Bus Layout
MVDC Distribution
Distributed Propulsion

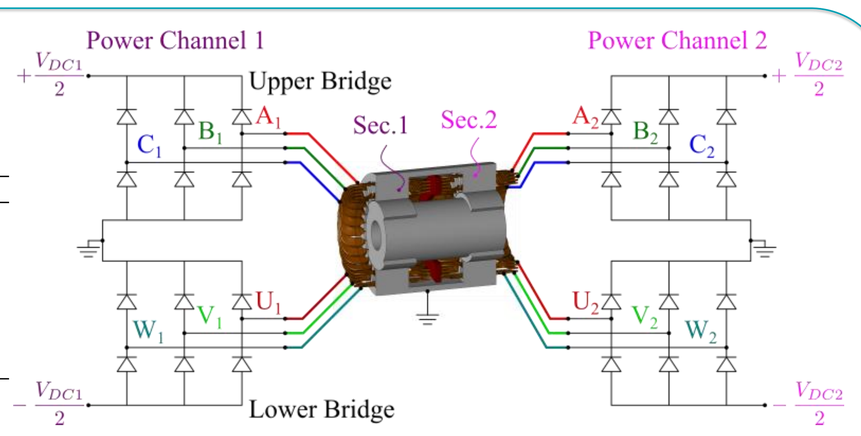
Synchronous Homopolar Generator

- Solenoidal and **stationary excitation winding**
- **Solid** and **robust** rotor
- Reliable de-excitation (no PMs)
- Ease of cooling (no rotating windings)
- No-need of rotating exciters
- Possibility to operate on passive AC/DC rectifiers



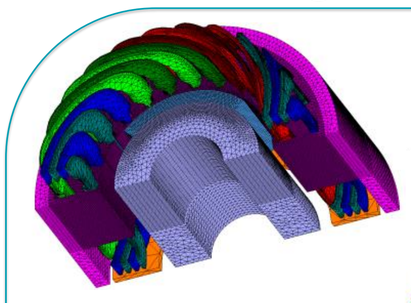
Specs: Proof of Concept

Symbol	Parameter	Unit	Value
$2 \times P_n$	Rated Power	kW	2×7.5
Ω_n	Rated Speed	krpm	15
V_{DC}	Rated DC Voltage	V	600
I_{DC}	Rated DC Current	A	7.8
I_e	Rated Excitation Current	A	25
p	Pairs of Poles	-	2
f_n	Rated Frequency	Hz	500



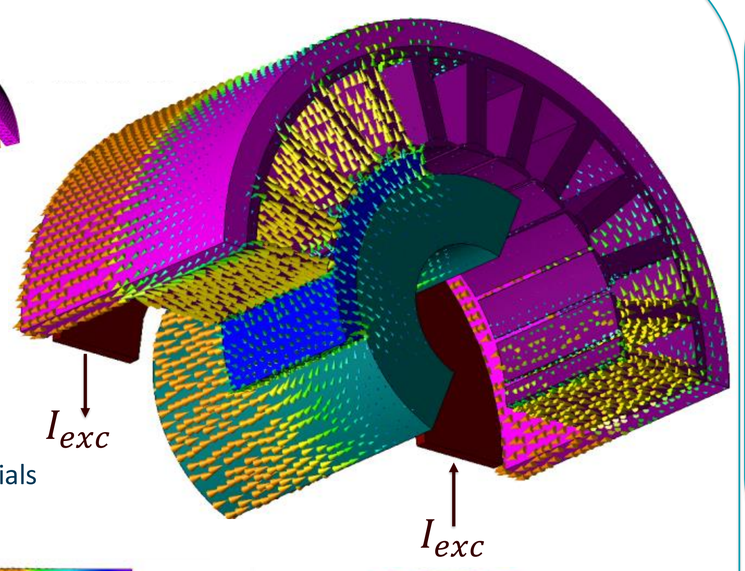
Bipolar Distribution $\pm 300V$

Electromagnetic Design

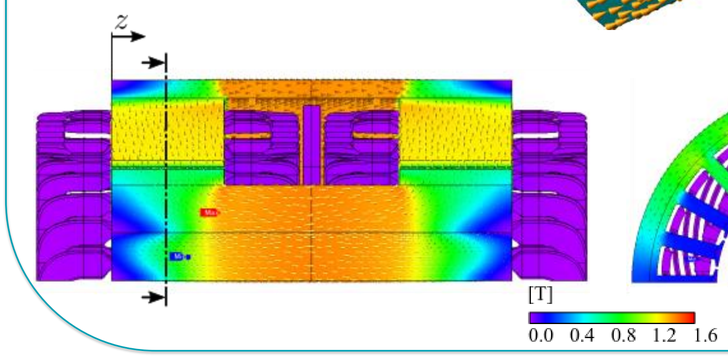


FE Model Mesh

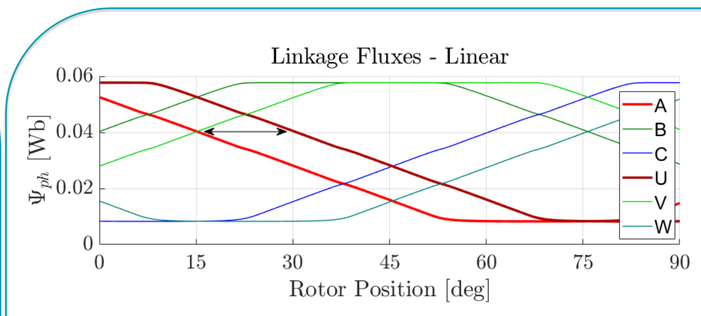
3-D Finite Element

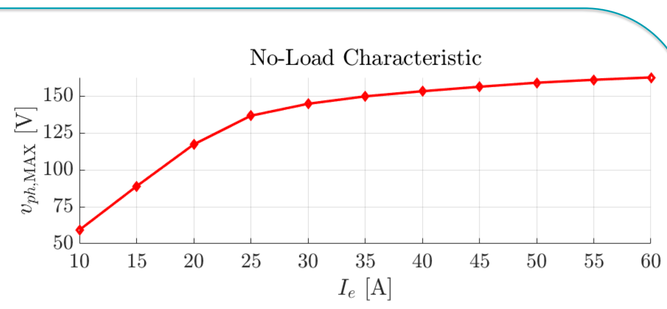


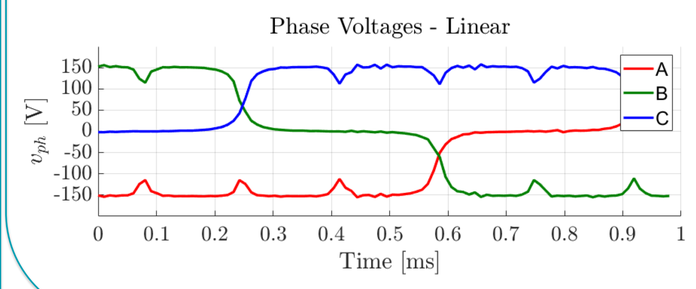
No-Load Simulations:
Linear and Non-Linear Materials



Main Outcomes







- **Concentrated winding** layout for reliability
- Two series rectifiers to reduce the **insulating requirements**
- Effective **regulation of the DC output** voltage
- Trapezoidal flux waveforms to reduce the DC-bus **voltage ripple**

Next Steps

- Development of an general **analytical model** to effectively analyse different operative conditions
- Load FE simulations, including the diode rectifiers in the model
- **Mechanical** and **thermal** analysis
- Manufacturing and testing of the **small-scale concept demonstrator**

Power Electronics, Machines and Control Group