Superconducting electrical propulsion system modelling

As the aircraft industry starts to look at electrification as a means to enable decarbonised commercial aviation, high temperature superconductors (HTS) are gaining interest for their potential to deliver highly efficient and lightweight electrical systems for the high powers involved.

Within this context, Airbus is working to develop the tools and knowledge to develop propulsion architectures that include HTS technologies. A key aspect of this is the ability to perform multi-physical system simulations in a way that is common industrial practice for conventional systems today, e.g. using 1D simulation tools such as Simscape, Dymola, Amesim, etc. or building equivalent functionality in tools such as Simulink. It is a significant gap in the toolchain required for the eventual application of superconductors to transport applications. Such models enable architecture design at an early stage of development and accompany the development of a system through all stages of maturity, becoming a 'digital twin' of the hardware with which components can be sized, dynamics and off-design states can be tested and changes can be assessed.

This PhD project will work towards closing this technology gap by developing the component models of a superconducting aircraft propulsion system and then an entire system with connected components. The models created should be flexible enough to allow limited parameterisation and scaling, as well as recombination into novel architectures. Model detail and speed are kept in balance and are well understood in order to keep the limitations of the final system models within sight. There is an interest in fast models that permit mission-length simulations in conjunction with cooling system models and slower models that show detailed electrical behaviour over milliseconds. The trade between performance and accuracy of these different model types should be well analysed and understood.

The key system components will consist of:

- DC and AC cables
- Fault current limiters
- Current leads
- Conventionally conducting (copper or aluminium) connectors and circuit breakers
- Cryogenically cooled semiconductor power electronics
- Fully and partially superconducting AC synchronous motor and generator
- The cooling system components pertinent to the behaviour of the electrical system

The following tasks are planned within this thesis:

- Electrical modelling of each component of a superconducting electrical propulsion system with Matlab/Simulink. Models need to be adapted to enable transient simulations in the ms range.
- Combined thermal simulation of cooling fluid (liquid nitrogen or liquid hydrogen) in the individual components and in a cooling channel of the superconducting electrical propulsion system.
- Modelling of normal operation flight missions. (Long h time frame)
- Modelling of critical situations for the electrical propulsion systems and outages of individual components. (Short ms time frame)

The PhD student will be located at Karlsruhe Institute of Technology (supervision by Prof. Mathias Noe) as well as working closely with industrial supervision at Airbus E-Aircraft Systems, and Airbus UpNext.

The project will be linked to a major project at Airbus taking place in Munich and Toulouse, as well as with numerous international industrial and academic partners. The student will take

benefit of this project through the input of specific component models (depending on IP issues), and the opportunity to perform partial hardware-based validation of the component and system models using results from a physical demonstrator and individual hardware tests.