ALEA

Accelerated Life tests for Electric drives in Aircrafts

State of the art – Background

Electro Mechanical Actuators (EMA) are safety-critical components of an aerospace system, where an undetected actuator failure can lead to serious consequences. EMA fault diagnosis poses an interesting research problem as it is composed of electrical, electronic and mechanical subsystems, which results in intricate failure modes and effects.
Among the different causes of failures in EMA, studies revealed that approximately 30% of the failures are related to electrical faults and that the majority of electrical fault happens in stator or rotor windings as a consequence of insulation degradation. The breakdown of the stator insulation system is usually a slowly developing process, which at first leads to deterioration of the inter-turn insulation and finally leads to phase-to-phase or phase-to-ground insulation respectively. A lifetime model capable of taking into account also data other than the diagnostic measurements alone, can combine information from past use as well as expected future to perform a better estimation of the remaining EMA lifetime. The target of the lifetime estimation is to maximize the EMA useful life but also to still keep enough risk tolerance to prevent major failures from happening in the near future.
In this context, for many years the mainstream method was the quantitative reliability prediction based on empirical data and various handbooks on reliability, released by both the military and the industry. A different approach is the Physics Of Failure (PoF): a methodology based on root-cause failure mechanism analysis and the impact of materials, defects, and stresses on product reliability. The integration of different models, related to different failure mechanisms, into a unique model, taking into account all the physical processes and stress factors involving in a given component fault, is not an easy task. The approach is even more difficult at system level, as a variable number of components could be involved.

Objectives

ALEA project aims at laying foundations for the development of the ageing super-model for electric drives in aerospace applications. The initial model is a lifetime estimation supermodel for electric machine insulation. The project involves the development and construction of a specialized test rig for the future develpoment and validation of lifetime degradation model as well as other electric drive lifetime models. The test rig will be capable of experimentally investigate the effects of four major sources of stress in winding insulation (thermal, ambient, electrical and mechanical), both as single effects and in combination.
The test rig is aimed at characterizing electric motors with mechanical rating of 40kW at 10kRPM with constant power up to 20kRPM.
The test rig comprises four main components: a thermal vacuum chamber to apply environmental stress factors; a reconfigurable test bench that can be embedded in the test chamber; a data acquisition and control system to monitor an acquire relevant operating parameters and a custom inverter to drive the motor under test (MUT) while applying different levels of stress.
The test rig will be capable of replicating mission profiles encounterd in aerospace applications: test environment at various temperatures and pressures within a thermal vacuum chamber, where test temperature range of -40 to +180°C and a pressure range from 1000 mBar down to 30 mBar, equivalent to altitudes from sea level to 50,000 ft, can be replicated. A peculiar characteristic of the ALEA test rig is the development of a custom motor under test (MUT) inverter for the variable dv/dt operation of the MUT in order to assess the impact on insulation degradation of wide bandgap devices adoption in high speed drives.

Description of work

During the ALEA project duration, the following activities were carried out:

- design of the proposed test rig, with the MUT test bench integrated into the thermal vacuum chamber. the choice of the relevant components and the final assembly configuration for the MUT.
- design and development of the DAQ system and associated transducers for monitoring the relevant operating parameters
- development of the control and acquisition interface for automated test execution and data logging
- design and construction of the custom MUT inverter featuring wide bandgap switches (SiC) a specially developed gate driver architecture to allow for the dynamically variable dv/dt operation of the MUT.
- development of a multistress ageing model for insulation degradation of electric drives in aerospace applications.

Results

a) Timeline & main milestones

The ALEA project was developed over a timespan of 22 months, divided in 2 period: a first period of 12 months for the system design and critical design review and a second one of 10 months for the test rig fabrication.

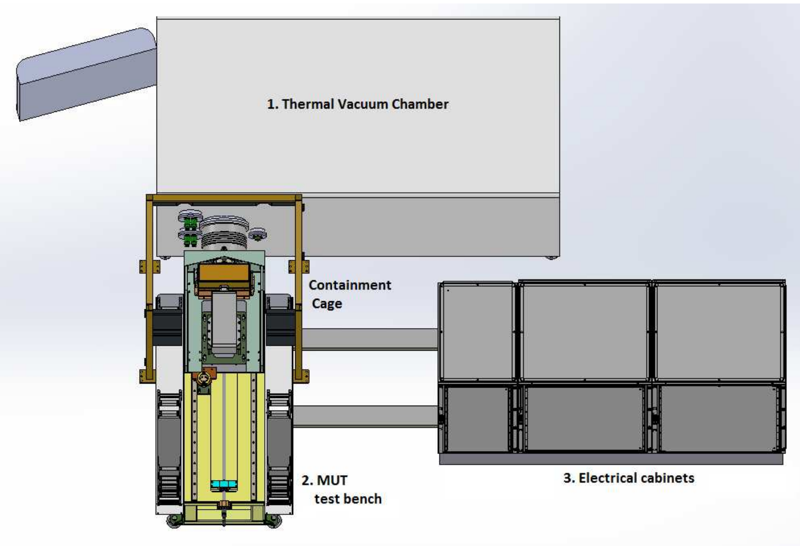
Milestones achieved during the project
Milestone 1: Specifications and requirements for the test set-up
Milestone 2: Specifications and requirements for the lifetime model
Milestone 3: System Architecture
Milestone 4: System Design Validation
Milestone 5: System functional tests and validation at UniPr premises
Milestones achieved within two months after the project deadline:
Milestone 6: Delivery, installation and commissioning of test setup at Topic Manager's premises
Milestone 7: MUT accelerated lifetime test – preliminary lifetime model validation

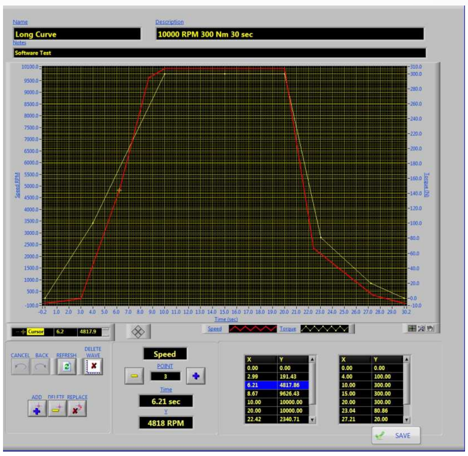
b) Environmental benefits

In the framework of the All Electric Aircraft (AEA) and More Electric Aircraft (MEA), electric machines and drive will gain more and more impact on the aircraft weight. By allowing a more insightful knowledge of the electric machine insulation degradation mechanisms, the design procedure would be more efficient. Moreover, by avoiding over engineering in the machine design, it will be possible to reduce the size and weight of the electric drive without sacrificing safety and reliability.

c) Maturity of works performed

Complete validation of the multistress lifetime degradation model developed during the project will require extensive test on the developed test rig. The activity is required to account for the different mission profiles and stress combinations typical of aircraft electric drives. The tests performed on the thermal vacuum chamber MUT test bed have shown that the ALEA test rig in the future will allow the characterization of entire drive units (MUT + converter) in the thermal vacuum chamber without risks of overheating.





Project Summary

Acronym:	ALEA
Name of proposal:	Accelerated Life tests for Electric drives in Aircrafts
Technical domain:	Area-02 - Management of Aircraft Energy
Involved ITD	Systems for Green Operations - SGO-02-088
Grant Agreement:	641496
Instrument:	Clean Sky JU
Total Cost:	€ 799,676.07
Clean Sky contribution:	€ 599,757.06
Call:	CS-2013-3-SGO-02-088
Starting date:	01-October-2014
Ending date:	31-July-2016
Duration:	22 Months

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