ADAPTATION KIT DESIGN & MANUFACTURING: APU DRIVE

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Project No. 298147

FINAL REPORT

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Final report

Executive Summary

The STARTGENSYS project has been started in May 2012 in order to design, manufacture, commission and validate of one complete driving system for a ground test bench intended to be used for aircraft starters/generators testing. The project, funded by the European Community's Seventh Framework Program (Clean Sky / Green Rotorcraft) under the grant agreement n° 298147, involved two Romanian organisations: National Research and Development Institute for Gas Turbines COMOTI and Institute for Theoretical & Experimental Analysis of Aeronautical Structures STRAERO S.A. The STARTGENSYS consortium was coordinated by COMOTI and the specific project requirements were provided by Labinal Power Systems as Topic Manager and end user of the STARTGENSYS Test Bench. The main project final result is the STARTGENSYS Test Bench which was delivered at Labinal Power Systems's COPPER Bird® bench in Colombes, France. The project was completed in December 2015.

The STARTGENSYS Test Bench consists in a Control Cabinet, Power Electronics Cabinets and the Driving System. The Control Cabinet is based on a Panel PC equipped with a high-speed control and data acquisition board. The Power Electronics Cabinets contain the converter and the active front end and power the electric motor and regenerate energy back into the lines when the electric motor works as generator. The Driving System is composed of Supporting Frame, Electric Motor, Gearbox (Speed multiplier), Lubrication and Cooling Group for Gearbox, Motor Cooling System, Low Speed Coupling, High Speed Coupling with Torque Meter, EUT (Equipment Under Test) mounting interfaces and a Bursting Shield. The Driving System drives one single generator or starter/generator and is able to simulate electrical start of the aircraft engine, as well as electrical generation. The test bench can be locally or remote controlled and is integrated with ancillaries and central control system available at place of use. A complete measurement channel deserves the entire test bench.

The STARTGENSYS Test Bench will be used at Labinal Power Systems's COPPER Bird® bench in Colombes, France, in the frame of Clean Sky programme, for testing generators and/or starter-generators in order to validate the integration of electrical systems and equipment, the quality of the energy produced, as well as demonstrating the maturity of technologies and systems for more electric aircraft.

Summary description of project context and objectives

Clean Sky is the most ambitious aeronautical research programme ever launched in Europe. Its mission is to develop breakthrough technologies to significantly increase the environmental performances of airplanes and air transport, resulting in less noisy and more fuel efficient aircraft. As a component of the Clean Sky initiative, the Green Rotorcraft ITD responds to the challenge of halving the specific impact of any rotorcraft operation on the environment. The feasibility of the new developed technologies, specifically rotorcraft starter/generators, has to be investigated trough the use of a specific test bench.

In this context, The STARTGENSYS project has been started in order to design, manufacture, commission and validate of one complete driving system intended to be used for starters/generators testing. The driving system, with its control and power cabinets, had to be integrated into a single product: STARTGENSYS Test Bench. The test bench, which will be used at Labinal Power Systems's COPPER Bird®, must be integrated with ancillaries and

a central control system. Being used in conjunction with other equipment developed in the Clean Sky programme, a high compatibility is needed: mechanical interfaces with the new developed generators and starter/generators, torque and speed characteristics, control and measurement, dimensions/compactness.

Description of main S & T results/foregrounds

The main project final result is the STARTGENSYS Test Bench which consists in a Control Cabinet, Power Electronics Cabinets and the Driving System.

The Control Cabinet has an industrial Panel PC equipped with a high-speed control and data acquisition board. The Control System works with preloaded Torque(Speed) and Speed(Time) characteristics. These characteristics have to be provided, before any test, by the operator directly at the Panel PC or trough Ethernet.

The Power Electronics Cabinets contain the Converter and all electrical facilities and are used to transfer power between the AC input and the Electric Motor in a controlled manner. The power cabinets work in the four quadrants.

Power Cabinets and Control Cabinet

Driving System

The Driving System is composed of Supporting Frame, Electric Motor, Gearbox (Speed multiplier), Lubrication and Cooling Group for Gearbox, Motor Cooling System, Low Speed Coupling, High Speed Coupling with Torque Meter, EUT (Equipment Under Test) mounting interfaces and a Bursting Shield.

The Supporting Frame incorporates the Lubrication and Cooling Group for Gearbox, the Motor Cooling System and the oil tank.

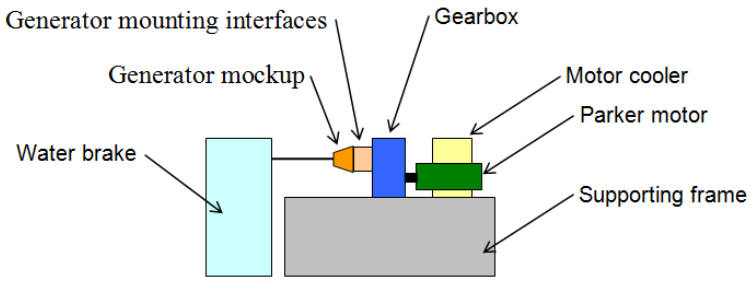
The Gearbox is a cylindrical type, single stage helical gearbox. It is bidirectional, birotational, has recess gears and has max 16000 RPM input, max 51000 RPM output and max 50 Nm. At the low speed shaft, the gearbox is connected to the electric motor trough a backlash-free torsionally stiff metal bellows coupling. At the high speed shaft, the coupling with the EUT incorporates the torquemeter and corrects the centering errors, the solution being based on an elastic beam. The Gearbox case is in welded construction.

The electric motor is a permanent-magnet synchronous motor with the rotor balanced in G1 class. The maximum speed is 16000 RPM and the maximum torque 270 Nm (constant up to 4500 RPM). The maximum torque at 16000 RPM is 80 Nm. A dedicated water-water heat exchanger was incorporated in the supporting frame for motor cooling.

The EUT mounting interfaces accommodates the generator/starter-generator on the test bench and the Bursting Shield covers it during tests for safety purposes.

The test bench components were finalized sequentially and the assembly, integration and calibration were performed, in a first phase, at the level of Control Cabinet, Power

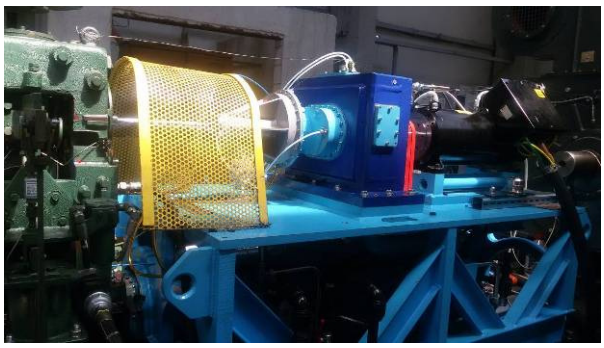
Cabinets and Driving System without gearbox. When the gearbox was finalized, it was integrated into the test bench and its output was connected to a high speed / high power water brake. This test configuration, intended to test the full capability of the test bench (maximum speed with maximum torque) is depicted below.



STARTGENSYS test configuration

The STARTGENSYS Test Bench has been factory tested between February and September 2015. The first tests have shown that the electric motor, with no load, is able to reach the maximum speed in both senses of rotation and the Power Cabinets and Control Cabinet work together as designed. Next in the testing process, the gearbox has been integrated in the test bench and tested, without load, up to 27000 RPM for 8 hours in each sense of rotation. When the full test configuration pictured above has been set, a series of load tests has been started. These tests were performed in several stages, with progressively increased speed and torque: 21800 RPM @ 8.5 Nm, 23700 RPM @ 30 Nm, 27000 RPM @ 7.2 Nm.

No load test configuration



Load test configuration

STARTGENSYS Test Bench Factory Testing

While the midrange capabilities have been proved by these tests, we decided to go to higher speeds with no load in a first attempt. The shaft between gearbox output and the water brake has been removed in order to perform the first high speed test without load. Speed was progresively increased in small steps, with small acceleration. At the speed of 41600 RPM, one of the high speed bearings has been destroyed without prior noticeable abnormal behavior. The debris from the broken bearing has reached the gears compromising them irremediably. Also, the low speed coupling has been destroyed.

While the gearbox could not be repaired with regard to remaining budget, the Consortium (Comoti and Straero) and the Topic Manager (Labinal Power Systems) have agreed that the STARTGENSYS Test Bench deliverable will not include the gearbox.

The STARTGENSYS Test Bench has been sent by truck to Copper Bird ® facilities on 23.02.2016 for further use without gearbox.

Potential impact and main dissemination activities and exploitation results

STARTGENSYS project had and will have significant impacts. With the project, a productive collaboration between STRAERO, COMOTI and Labinal Power Systems has started. Fruitful contacts between Romanian and French specialists have been made. In the international context, favourable to integrating national resources to EU capabilities, the STARTGENSYS project allowed the development of a stimulating and attractive environment for young researchers. The project not only provides work to them but also provides motivation, encourages communication and stimulates their inclusion in the European scientific environment.

After the project ends, the STARTGENSYS Test Bench will be used near Paris, France, in the frame of Clean Sky programme, for testing generators and/or starter-generators in order to validate the integration of electrical systems and equipment, the quality of the energy produced, as well as demonstrating the maturity of technologies and systems for more/all-electric aircraft.

The project was promoted at Le Bourget Airshow 2013 and Farnborough International Airshow 2014, in the Romanian pavilion. The promotional material consists in a poster which advertises the European projects in that COMOTI and STRAERO are involved. STARTGENSYS was included in the poster with an overall view of the project and the consortium. At the end of the project the Consortium has organized a dissemination workshop. The STARTGENSYS Workshop Dissemination took place on Tuesday 16th December 2015 at COMOTI facilities, Bucharest, Romania.

A project website was developed which is available at www.startgensys-project.eu.

Address of project public website and relevant contact details

www.startgensys-project.eu/

Project Coordinator:
National Research and Development Institute for Gas Turbines COMOTI

220 D Iuliu Maniu Bd., sector 6, cod 061126, OP 76, CP174, Bucharest, Romania.

Project Manager: Ionel-Sorin Gabroveanu
E-mail: sorin.gabroveanu@comoti.ro
Phone: +40214340240
Fax: +40214340241

Project Participant:
Institute for Theoretical & Experimental Analysis of Aeronautical Structures STRAERO S.A.

220, Iuliu Maniu Bd., P.O. Box 76/175, Postal Code 061126, Bucharest, Sector 6, ROMANIA

Project Responsible: Lică Flore
E-mail: lica.flore@straero.ro
Phone: +40214340169
Fax: +40214340170