

# RENERGISE

## Innovative management of energy recovery for reduction of electrical power consumption on fuel consumption

### State of the art – Background

The electrical grid of an aircraft is used to supply a variety of different loads. Electrical power can be derived from a variety of sources, categorized as either primary or secondary sources. Batteries and generators are primary sources; inverters and transformer rectifier units are secondary sources of power. Power comes either in the form of direct or alternating current depending on system requirements, even though different load supply voltages can be simultaneously used, depending on load characteristics.

In modern aircraft systems the trend is to reduce emissions and increase efficiency by exploiting residual energy in exhaust gases from the aircraft's main engine.

In our specific system the main generator provides a 270V DC network, as the intermediate level for absorbing electric energy produced by any possible source (including regenerative schemes) and for feeding aircraft electrical loads.

### Objectives

RENERGISE, in order to increase system's efficiency, introduced two power generation units, which produce electrical power from waste heat, thanks to an energy recovery system. This power generation is used in replacement of or in addition to usual generation systems, which retrieve their power from the Main Gear Box (i.e. have a direct cost in fuel burning). Two ad hoc methods of converting waste heat into electrical power have been studied and implemented, namely Static and Dynamic Energy Recovery Systems.

To implement Static Recovery (SWHR), the heat of the exhaust gases is directly converted to electrical energy with a thermoelectric generator. This thermoelectric generator is installed on the engine cover where the temperature difference with the ambient corresponds to a typical thermoelectric module's operating temperature difference. The generated voltage of the module drops with the increase of its current; hence an MPPT is required in order to achieve the maximum power output.

Another challenge within this project has been the introduction of a super-capacitor based energy storage subsystem, as an intermediate energy bank between the thermoelectric modules generation and the main DC bus. The main

objective of this subsystem is to compensate transient load component, reducing so main generator rating.

Regarding Dynamic Recovery (DWHR), the kinetic energy of the exhaust gases is used to rotate a gas turbine connected to an electrical generator. This way, significant amounts of electric energy are regenerated, reducing dramatically fuel consumption. However, the speed and pressure of the gases differ according to the main engine's power output, although the waste heat source remains at very high enthalpy levels over all flight conditions. As a result, the torque/speed characteristic of the turbine may also change; therefore a feedback control is necessary on the electric generator's output. Evidently, with the use of the above energy recovery systems, fuel consumption as well as carbon emissions decreases, improving the overall efficiency of the aircraft.

### Description of work

The issue of high efficiency has been tackled with appropriate converter design for each subsystem, namely the SWHR and the DWHR; more specifically, the research team has designed and developed the following solutions:

- SWHR

The thermoelectric generator is connected directly to the 270 VDC bus (thus injecting constant active power), while the supercapacitor subsystem and its DC link-converter are connected as a power active filter, reducing the necessary capacitance (although higher supercapacitor voltage fluctuation is established).

- DWHR

As the generator connected to the gas turbine is a three-phase PM synchronous one, an AC/DC conversion has been implemented by the use of a three phase square wave inverter, operating in the rectifying mode.

Different solutions have been examined by the research team, concerning the cooling design, in order to meet the power density demand (~3 kW/kg).

## Project results

The main results and benefits from the implementation and adaptation of RENERGISE are:

- Both static and dynamic recovery systems have been designed in a modular and scalable manner, making these solutions applicable to any power level.
- Energy conversion efficiency; RENERGISE implemented the appropriate application of the most effective and robust MPPT algorithms to the case of thermoelectric modules, while for dynamic energy recovery an MPPT algorithm based on positive feedback has been developed. The scope was to achieve MPPT detection in both static and dynamic recovery by more than 98% under any operational point.
- The converter topologies under study are characterized by simple and reliable structure, including limited number of semiconductor switches and magnetic components (and consequently minimum cooling volume), as well as small high frequency filters. Thus, RENERGISE meets the objective of Power density /Unit mass in the range of 3 kW/kg.
- The recovery system is sustainable by making a net saving in fuel consumption.
- The use of standard and well established switching converters, the transformer-less design and the use of super-capacitors instead of batteries guarantee low maintenance demand.
- All converters are well-established commercial solutions and meet all applicable standards. Moreover, the energy recovery amount drastically reduces fuel consumption and consequently CO<sub>2</sub> emission during flight.

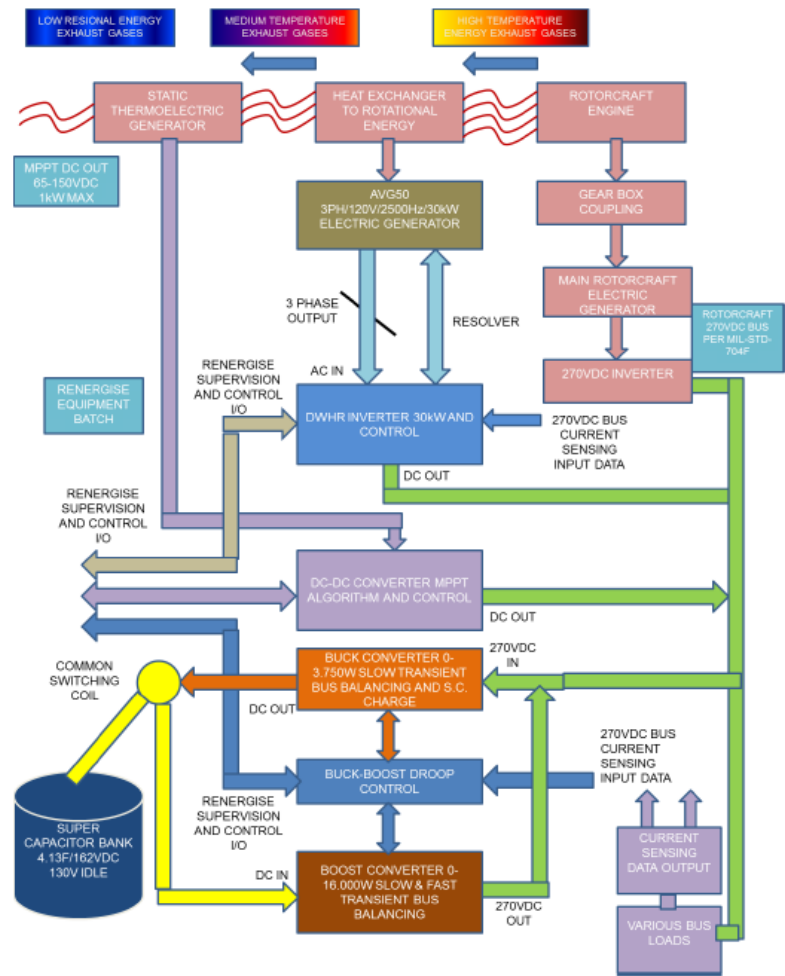


Figure 1: RENERGISE Block Diagram

## Project Summary

Acronym : RENERGISE

Name of proposal: Innovative management of energy recovery for reduction of electrical power consumption on fuel consumption

Technical domain: Electrical Systems

Involved ITD  
Green Rotorcraft  
Integration of innovative electrical systems

Grant Agreement: 287076

Instrument: Clean Sky

Total Cost: 475 042.00€

Clean Sky contribution: 344 735.50€

Call: JTI-CS-2010-5

Starting date: July 2011

Ending date: July 2014

Duration: 37 months

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