Electrical Power Generation & Start Solutions for the Falcon 5X Program

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Abstract Based on its experience on AC power generation and motor control, Thales has worked for 20 years on electric starting of aircraft engines using conventional brushless 3-stage variable frequency AC generators. Successive demonstrations and prototype testing addressed the challenges of this major evolution of AC generators and enabled Thales to develop a complete generation and start solution for the More Electric Aircraft and the new Falcon 5X business jet. The Falcon 5X Thales TopStart™ shipset includes air-cooled 115 VAC starter generators associated with power electronics capable of starting the aircraft engine from the 115 VAC bus and the APU from the battery bus.

Introduction

In More Electric Aircraft (MEA) conventional starting of the engines tends to be replaced by electric starting provided by AC generators thanks to their capability to operate in AC synchronous motor mode. Moreover the use of high power AC generators makes it possible to deliver the required torque during engine start even in worst conditions.

Thales has been working on the development of these AC electrical start solutions for 20 years now: back in 1995 for the first time a Roll-Royce Allison turboprop engine was started by a Thales AC generator.

This paper presents the Thales power generation and start solution selected on the Falcon 5X, achievement made possible by know-how acquired over a long span of time.

Background

Electric start of engines is widely used based on 28 VDC machines: thousands of Thales DC starter generators and DC starters are mounted on business jet engines, commuter aircraft engines and APU turbines on large transport aircraft.

Years ago the interest in electric start based on a conventional brushless 3-stage AC generator appeared with the advent of variable frequency AC generators directly driven by the engine accessory gearbox and performance enhancement of power converters. Back then, based on experience with both AC power generation and motor control (“autosynchronous” motor control), Thales set up a test to validate the feasibility of electric start.

The first electric engine start was successfully demonstrated in 1995 by Thales thanks to a modified off-the-shelf 115 VAC, 30 kVA, 12000RPM generator. This proved the capability of an AC generator to start an engine. The generator modifications incorporated the two main sub-assemblies required for operation in motor mode: firstly the exciter stage was modified so that when supplied by an AC current and operated as a transformer it could provide the main field with the machine at standstill; secondly a rotor position sensor was installed to enable synchronous control of the motor [1]. A converter supplied the single phase exciter stage at constant frequency and the 3- phase main stage at variable frequency in synchronous mode.

After this demonstration, a further improvement was addressed when later a high power Variable Frequency Starter Generator was developed [3]: this prototype called “MEGEVE” was rated at 200kVA/230VAC with a speed range of 7600-16000RPM in generating mode and a starting torque of 300Nm in motoring mode. The main exciter of this machine was designed so as to provide the main field in both starting mode (exciter operating as a transformer when supplied by AC current) and generating mode (exciter operating in generator mode when excited by DC current).

The thermal behavior of this oil-cooled starter generator during the starting phase was deeply studied and measured during tests so as to validate this operation mode, with particular focus on rotating diodes with reduced oil flow rates (fig 1).

Fig. 1: temperature (°C) vs time (sec) during 2 consecutive start sequences on the 200 kVA MEGEVE starter generator (red curve = rotating diode bridge temperature, other curves = exciter windings)
In addition to these 3-stage AC starter generator developments and within the European Power Optimized Aircraft (POA) program an engine-embedded 150kW/350Nm Permanent Magnet Starter Generator was developed, built and fully tested on a Rolls-Royce engine in 2008 [2]. Notwithstanding integration challenges of such a PM machine in harsh environment, both starting and generating operations were successfully validated.

This is the first time that Dassault Aviation has chosen a brushless variable frequency AC starter generator on any of its business jet programs. The combination of the electrical engine or Auxiliary Power Unit (APU) starting and power generation functions in a single unit leads to the best trade-off between weight, size and power compared to any other aircraft in the same category. The extensive use of electrical power in this new business jet represents a significant move towards more environment friendly aircraft and will significantly reduce the total cost of ownership.

The Thales TopStart™ shipset for the new Dassault Falcon leverages new technologies to meet power requirements of a business aircraft with the highest levels of comfort and performance as well as the ability to start latest-generation engines which are designed to consume less fuel and produce less pollution.

**Falcon 5X starter generator**

The functions provided on the Falcon 5X by the starter generators (fig. 3) are as follows:

- Electrically start the Snecma Silvercrest turbofan engines and the APU turbine
- Generate main electrical power for the variable frequency aircraft network
- Rated 115VAC voltage for generator outputs
- Air-cooled machine

**Power generation and start solution for the Falcon 5X**

Thales was selected to provide the electrical starter generator and power conversion solution for the Dassault Aviation’s latest Falcon 5X business jet. This ground-breaking aircraft incorporates many novel innovations including a Thales-built and optimized system for the conversion and generation of electrical power called TopStart™ which includes AC starter generators, digital Generator Control, Start Box, Start Power and Transformer Rectifier Units.
Falcon 5X Start Box Unit / Start Power Unit

The power electronics behind the Start Box and Start Power Units (fig. 4) include the Motor Control Unit (MCU) delivering start power under 115VAC to the starter generator stator windings for engine or APU start. The APU is started using 24VDC battery power supplied to the built-in DC/DC boost converter connected to the MCU. The MCU input rectifier stage also allows operation under 115VAC derived from either the AC starter generator or the Ground Power Unit. Input and output EMI filters ensure performance in line with stringent power quality levels. Inrush current limiters along with the APU and engine exciter start relays allow operation under smooth conditions. Digital control featuring acceleration and torque control loops provide optimized start performance. Using forced air cooling the power electronics are able to operate over a broad range of ambient temperature (from -55°C up to +70°C).

Conclusions

Using state-of-the-art technology developed through years of experience and continuous development, Thales is a major player in designing high quality AC starter generators for all types of aircraft. Thales has a proven track record in electrical systems and proposes a wide range of electrical starter, generator and converter technologies currently in service on board various types of large-capacity transport aircraft, regional transport aircraft, business jets and helicopters. The solution proposed on the Falcon 5X draws from this longstanding know-how meeting high customer expectations with regards to performance, availability, comfort and reliability whilst supporting greener and sustainable air transport solutions paving the way towards the More Electrical Aircraft.

The Thales TopStart™ for the new Falcon 5X business jet benefits from optimizations reached during various concept development and demonstration stages over the past two decades addressing the challenges of electric engine starting via AC starter generators supplied by on board power electronics.

References

1. H. Devred, JP. Besnard, M. Martinez “AC starting demonstration with Allison AE2100 Turboprop Engine”, SAE, 1997
2. F. Delhasse, M. Martinez “Starter Generator embedded in an aircraft engine”, AAAF, 2004

Fig. 4: Falcon 5X Start Box and Start Power Units