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Electrical Power Generation and Start Solution for the Falcon F5X Program

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Electric start by DC machines

Electric start of engines is widely used, based on 28 Vdc starters or starter/generators:

- Business jet engines
- Commuter aircraft engines
- APU turbines
Introduction of Variable Frequency AC Generators

Variable Frequency Generators directly driven by the engine Gearbox
(constant speed drive removed)

combined with

Power converter performances

Makes possible the replacement of the engine air start
by
brushless 3-stage AC generator start
(operating as a synchronous motor supplied by a converter)
Background on electric start

Thales demonstrations of electric start by brushless 3-stage AC generator

Based on its experience on

- brushless 3-stage AC generators

and

- “autosynchronous” motors and control

Thales demonstrated back in 1995 the AC electric start by a brushless 3-stage generator
1st demonstration of electric start by brushless 3-stage AC generator

In 1995 an off-the-shelf air-cooled 115 VAC 30 kVA 12000 rpm generator was modified so as to operate in motor mode in low speed range (0 to idle):

- Exciter modified to operate as a transformer
- Rotor position sensor introduced to enable autosynchronous control
- Supply of the 3-phase main stator with flux weakening capability and the main exciter by a converter

A turboprop engine was successfully started by this modified generator.
Challenges for the brushless 3-stage starter-generator to operate in both starting and generating modes

- **Exciter**: The same exciter must be capable of operating in two different modes:
  
  In **generating** mode: is excited by GCU DC current, operates as a synchronous machine, and delivers the power to the main rotor from mechanical power.
  
  In **starting** mode: is supplied by AC converter, provides full AC power to the exciter rotor through transformer effect.

- **Main stator**:
  
  In **generating mode**: provides electric power meeting voltage standards constraints.
  
  In **motoring** mode: provides torque within converter current constraints.

- **Cooling**:
  
  Oil or air flow rate is reduced during starting sequence at low speed.
  > challenge on rotating diodes.
Development of a high power Starter Generator (MEGEVE)

In 2005 an oil-cooled 200 kVA starter-generator demonstrator was developed by Thales:

- Including “hybrid” exciter with both generating and starting functions
- Including position sensor
- Generating and starting modes were validated
- Various starting control laws were incorporated and tested.
Development of a high power Starter Generator (MEGEVE)

- Starting sequences were tested
- Thermal behavior during starting sequence was analyzed on the instrumented Starter generator (stator, and also rotor through tele-transmission)

Temperature on stator winding, exciter winding and rotating diodes
Development of an embedded high power Permanent Magnet Starter Generator in Rolls Royce engine (POA program)

A 150 kW (Gen) / 175 kW (Start) embedded Permanent magnet generator was developed and tested in a RR engine (on HP shaft).

- Integration challenge of a PM machine in harsh environment
- Starting and generating operation were validated

Embedded stator immersed in cooling oil with ceramic sleeve separation

Rotor on High pressure shaft
Challenges addressed during these advanced developments

• Optimization of double operation of the exciter
• Machine cooling during start phase
• Optimization of kVA rating of main and auxiliary converter

Complete generation and start solution TopStart™ proposed for the new Dassault Falcon F5X
Falcon F5X : Thales generation and start solution

- 2 x main Starter Generators
  - 115 V, air cooled
  - Start the Snecma Silvercrest engine

- 1 APU Starter Generator
  - 115 V, air cooled
  - Start the PW APU turbine

3 GCU
Falcon F5X : Thales generation and start solution

1 Start box

- Delivers AC power to the APU Starter/Generator from Battery through DC/DC boost converter
- Delivers AC power to the Main Starter/Generator from Ground Power Unit / Main Starter Generator / APU through rectifier
- Air cooled (-55°C to +70°C)