Integration of Electrical Machines into the Engine: Routemap of Technology Options & Opportunities

03/02/2015
Auteurs: Philip McGoldrick
Publication: MEA 2015 More Electric Aircraft
OAI: oai:www.see.asso.fr:10638:12651
DOI:

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    <publisher>SEE</publisher>
    <publicationYear>2015</publicationYear>
    <resourceType resourceTypeGeneral="Text">Text</resourceType>
    <dates>
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Engine related electrical machine technologies – for both generation and power usage – will need to be developed to move beyond this current state-of-the-art. Labinal Power Systems More Electric Aircraft 2015 Toulouse Boeing 787: No-bleed main engines - no pneumatic system. Electric engine starting, cabin pressurisation, anti-ice. Central water-cooled dual-use Power Electronics Traditional hydraulic actuation system Electric braking 29.6 V, 65 Ah Li-Ion batteries... The provision of electrical power has become more critical. 3 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. MORE ELECTRIC AIRCRAFT Generation 400Hz 115VAC (VF on A380, 230VAC VF on A350), 5 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. MORE ELECTRIC AIRCRAFT POWER OFFTAKE Current State-of-the-Art Boeing 787: Labinal Power Systems More Electric Aircraft 2015 Toulouse MECHANICAL Oil and High Pressure Fuel Pumping, independent electrical power sources for engine controls. HYDRAULIC MAINS Flight Controls, Landing Gear, Nose Wheel Steering, High Lift, etc. PNEUMATIC Icing Protection ( Wing & Nacelle), Environmental Control System, Engine Start (from APU, especially on rotorcraft). ELECTRICAL Constant Frequency Oil Cooled Generation 400Hz 115VAC (VF on A380, 230VAC VF on A350), 5 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. CONVENTIONAL POWER OFFTAKE IN THE ENGINE Conventional large civil aircraft power offtake from the engine is via the AGB (Auxiliary Gear Box): Labinal Power Systems More Electric Aircraft 2015 Toulouse MECHANICAL Oil and High Pressure Fuel Pumping, independent electrical power sources for engine controls. HYDRAULIC MAINS Electrically Driven – Fight Controls, Landing Gear, Nose Wheel Steering, High Lift, etc. PNEUMATIC Electrically Driven – Icing Protection, Environmental Control System, Engine Start. ELECTRICAL 230VAC VF, +/-270VDC for specific large loads and alternate power sources (Fuel Cell APU's, etc) DELETED DELETED Some local electrical pumped hydraulically for specific actuators 6 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. MORE ELECTRIC AIRCRAFT ENGINE POWER OFFTAKE Options on power offtake on future More Electric Engine : Labinal Power Systems More Electric Aircraft 2015 Toulouse MECHANICAL Electrically Driven – Oil and High Pressure Fuel Pumping, variety of electrical power sources. HYDRAULIC MAINS Electrically Driven – Flight Controls, Landing Gear, Nose Wheel Steering, High Lift, etc. PNEUMATIC Electrically Driven – Icing Protection, Environmental Control System, Engine Start. ELECTRICAL 230VAC VF and +/-270VDC for specific large loads DELETED DELETED Some local electrical pumped hydraulically for specific actuators DELETED This power system is now beyond the perimeter of ATA Chapter 24 7 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. MORE ELECTRIC ENGINE POWER OFFTAKE Options on power offtake on future More Electric Engine: Labinal Power Systems More Electric Aircraft 2015 Toulouse MECHANICAL Electrically Driven – Oil and High Pressure Fuel Pumping, variety of electrical power sources. HYDRAULIC MAINS Electrically Driven – Flight Controls, Landing Gear, Nose Wheel Steering, High Lift, etc. PNEUMATIC Electrically Driven – Icing Protection, Environmental Control System, Engine Start. 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KERNEL MESSAGE – THERMAL MANAGEMENT Labinal Power Systems More Electric Aircraft 2015 Toulouse As we make additional progress into the More Electric Aircraft Technology Routemap there are more opportunities for Electrical Machines in engine related applications, but as well as improvements in performance, cost and robustness against the harsh environment, more consideration must also be made for systems’ level optimisation, Certification and Safety Case analyses. Thermal Management via the oil system is viewed as the key aspect of machine, equipment, engine system and
overall aircraft integration and optimisation that will dominate the design criteria of the electrical power system, and to a degree determine improvements in efficiency and performance. 9 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. OPTIONS / STRANDS OF TECHNOLOGY Labinal Power Systems More Electric Aircraft 2015 Toulouse Technical considerations for Electrical Equipment within the Engine Pod Unit Design Integration Certification Safety Case Electrical pumping in Engine Pod for Oil and High Pressure Fuel “Cluster of Large PMAs” Engine Pod Icing Protection Batteries, Supercaps, Fuel Cells, Electrical power generation from conventional APU gas turbine Ultra High Bypass Engine – AGB equipment suite relocated to fuselage or nearer engine core Low Pressure Shaft Generator Core Mounted Starter / Generator Technologies RAT Replacement Concept of “APU Always Available” 10 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement From the High Bypass Ratio Turbomachinery to the Open Rotor concept for fixed wing airliners, pressure is on for the equipment suite in the engine pod fusing to take up much less space. Some technology and system architectures could enable lower profile equipment, but some kit would simply have to move. Electronic controllers and drives are a candidate to move to the Equipment Bay in the fuselage, . . . . 11 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement The environment here is distinctly harsher than in the lifting – for temperature and vibration. The process of building up the new Safety Case as part of the Qualification and Certification of both equipment and systems is a considerable challenge. 13 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement The environment here is distinctly harsher than in the lifting – for temperature and vibration. The process of building up the new Safety Case as part of the Qualification and Certification of both equipment and systems is a considerable challenge. 13 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. 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ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement The main element of Integration and Safety Case consideration with this architecture option is to use high frequency AC or relatively unconditioned DC generated on the engine pod itself for this local load. Savings would be on weight of passive components and electrical control boxes as the power would not need to be routed to the Primary Distribution Centre in the Equipment Bay, only to be then transmitted back out to the engine pod. 16 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement The significant power applications of Oil and High Pressure Fuel pumping. Some variants of this concept would have one or more of this “array of PMAs” backdropped for the electrical engine start function. 15 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement The significant power applications of Oil and High Pressure Fuel pumping. Some variants of this concept would have one or more of this “array of PMAs” backdropped for the electrical engine start function. 15 / This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. 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currently mounted in the fancasing to elsewhere in the engine pod, this is one candidate application for swapping to electrical pumping. The main benefit from electrification of this power load could be to run the engine oil services independent of the cranking or operation of the gas turbine itself. 17 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement Concept of “APU Always On.” Related to some of the engine optimisations potentially available from Low Pressure Shaft generation – generally lowering the imbalance of power oﬄake from the High Pressure Shaft (improved Surge Margin). If redundant / parallel channels are available this could be a potential RAT replacement. 19 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. ELECTRICAL MACHINES Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement Two disadvantages to conventional RAT systems: Installed weight is carried permanently without any power being generated; It is possible during an emergency scenario that the pilot doesn't find out that the RAT is non-operational until he has already pulled the deployment lever. 21 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. TECHNOLOGY CHALLENGE ON CHAPTER ATA 24 Labinal Power Systems More Electric Aircraft 2015 Toulouse Even if the technical tasks of integration of diverse equipments are derived from the conventional approach to ATA Chapter 24, the selection of Architectures, Topologies, their Integration and subsequent Qualification and composition of the Safety Case will all be new. Unit Design Integration Certification Safety Case 22 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. /03/ CASE STUDY – VARIABLE FREQUENCY STARTER-GENERATORS (VFSG) /03/ 23 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. THERMAL MANAGEMENT – PIVOTAL TECHNOLOGY FOR ELECTRIC MACHINES ON ENGINE POD Labinal Power Systems More Electric Aircraft 2015 Toulouse Outline comparison on a nominal 90kVA aircraft electrical generator 1960s (Concorde) Indirect Oil Cooling, 6-Pole, 85kg 1970s Spray Oil Cooling, 4-Pole, 40kg 1980s (APU) Spray Oil Cooling, 2-Pole, 23kg The Thermal Management technology (change from indirect to spray) was not used in isolation: Architecture and Topology selection permitted higher rotor speed (therefore physically smaller rotor); Then new Sleeve technology permitted even higher speeds / smaller rotors. The changes to Architecture and Topology used to enable lower weight are outside the perimeter of ATA 24. 24 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. THERMAL MANAGEMENT – R&T MACHINES VULCAN VFSG (Variable Frequency Starter-Generator) Labinal Power Systems More Electric Aircraft 2015 Toulouse Recorded Start Data 0 100 200 300 400 500 600 700 800 4 6 8 10 12 14 16 18 20 Time (s) Torque (lb-ft)/MainStator Current(Arms) 0 500 1000 1500 2000 2500 3000 3500 4000 GeneraorSpeed rpm Calculated Torque (lb-ft) Main Stator Current (A rms) Speed (rpm) 25 / This document and the information therein are the property of Labinal Power Systems, They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems.
Circuit The function of the VFSGs is outside the perimeter of ATA 24, Thermal Management is a major part of the system. 90kVA VFSG 230VAC Oil Circuit development underway in current R&T 27. This document and the information therein are the property of Labinal Power Systems. They must not be copied or communicated to a third party without the prior written authorization of Labinal Power Systems. CONCLUSION Labinal Power Systems More Electric Aircraft 2015 Toulouse Relocation of AGB equipment to Fuselage . . . . & Nearer Engine Core Core Mounted Starter / Generator LP Generation Large PMAs Engine Pod Icing Protection Engine Pod Oil Pumping Engine Pod Fuel Pumping APU Generation Channel Alternate Power Sources / Thermal Management RAT Replacement New technology electrical machines are crossing over the perimeter of the conventional ATA Chapter 24 for Electrical Power Systems. Interface is with the AGB and Engine Pod, as well as the Electrical Network feeding into Distribution, Technical and Hotel electrical loads. Harsher Environments for future systems mean Thermal Management will play a very large role in Integration, Certification and Safety Case.

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