The University of Manchester

Superconducting DC Electrical Systems for Hybrid-Electric Aerospace

Introduction

- Future Hybrid Electric Aerospace Propulsion will need MW scale electrical networks
- NASA Hybrid Electric Technology Roadmap targets superconducting machines will be needed for large aircraft systems (300 PAX) to achieve power densities of 40 kW/kg by 2035
- HTS Superconducting Propulsion Drives the 'encourages' use of superconducting electrical networks to reduce weight and losses
- Superconducting networks would favour low voltage, high current DC
- Meshed DC network would be needed for greater flexibility and security of supply

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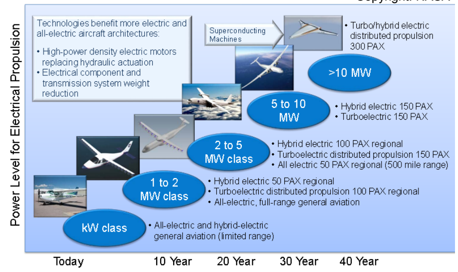


Project Objectives

Fig1 shows a typical Hybrid-Electric Distributed Fan Propulsion System (HEDP). Fig. 2 shows a schematic of a meshed DC superconducting electrical network connecting multiple generators and superconducting propulsion motors. The project objectives were:

- Understand current load flow in meshed DC superconducting networks
- Look at technologies for current management to improve the capacity of the system

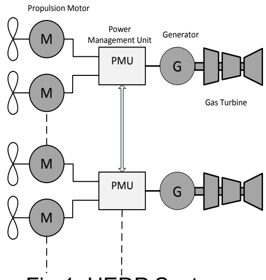


Fig 1: HEDP System

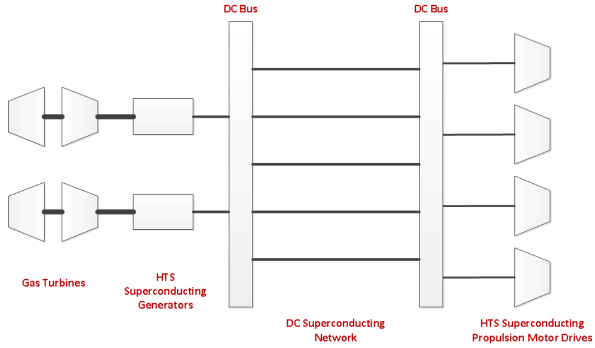
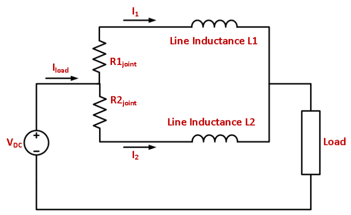


Fig 2: Electrical DC superconducting network

The Problem



$$i_1^S = \left(\frac{V}{R_L + r_1//r_2}\right)\left(\frac{r_2}{r_1 + r_2}\right)$$

Simplify the DC network to two parallel branches and load. What is the value of the current I1 for example if the line resistances r1 and r2 approach zero?

Superconducting DC networks do not behave like conventional DC networks and a fundamental understanding of how they behave and operate is needed.

$$i_1(t) = i_1^S + \left(\frac{V}{L_1(\alpha_1 - \alpha_2)} + \left(\frac{\alpha_2}{\alpha_1 - \alpha_2}\right) i_1^S\right) e^{\alpha_1 t} + \left(\frac{V}{L_1(\alpha_2 - \alpha_1)} + \left(\frac{\alpha_1}{\alpha_2 - \alpha_1}\right) i_1^S\right) e^{\alpha_2 t}$$

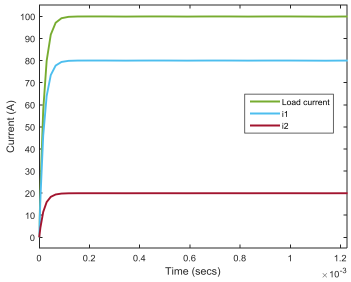
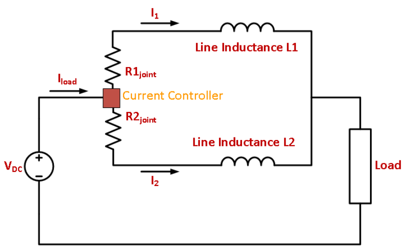


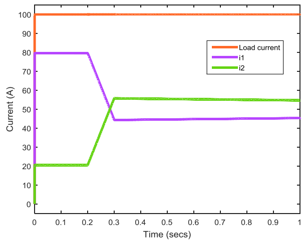
Fig 3: DC superconducting network response

The full dynamic solution above helps us to understand the behaviour of the network as the resistances approach zero. In this case the line inductances determine how the current shares – as modelled in Figure 3.

Unbalanced line currents in a superconducting DC network reduces the electrical capacity of the system so load current management will be needed.

Load Current Management





A new technique for controlling the current flow has been developed and modelling confirms operation when switched on at 0.2secs and asked to bring the currents into balance.

Next step is to validate this experimentally in a superconducting test tank.

Conclusions

- Hybrid-Electric Distributed Propulsion Systems using superconducting motors would 'promote' the use DC superconducting electrical networks
- DC superconducting networks do not behave like conventional DC networks because of the very low resistances
- Fundamental operation of these needs to be fully understood and load flow management will be needed
- A new current controller has been developed to balance network branch currents and increase the capacity of the network.
- More work needed on system operation and control and on the dynamic behaviour of superconducting materials

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Acknowledgements: EPSRC and the ATI