A LANDING GEAR ACTUATOR USING A DUAL-OUTPUT POWER CONVERTER BASED MOTOR DRIVE

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Abstract

This paper considers the design, construction and testing of a dual-output power converter concept where only the large components, such as the DC link capacitor and heat-sink, are shared between two actuators which are used sequentially in the deployment of aircraft landing gear. This mutual component approach combines the advantages of dual-use power converters with the flexibility of one power converter per application. Practical results of the converter operating are included in the presentation for a range of test conditions in order to validate the simulation study.

1 Introduction

The Landing Gear application described in this paper is aimed at a future single aisle narrow-body civil aircraft application where the converter will be used to control the extension and retraction of the undercarriage leg and the steering of the nose wheel on the ground. The work is being performed in support of the ELGEAR programme, part funded by the Technology Strategy Board, and involving several prime Aerospace companies. Overall system control will be by a GE Aviation Remote Electronic Unit (REU), this will provide a high integrity command and control system interfacing to various feedback position sensors and providing appropriate demands to the dual output power converter.

This paper describes a dual-output power converter where large components, such as the DC link capacitor, rectifier and heat-sink, are shared between the output bridges for two motor loads. These motors are used to control two actuators for a landing gear application. The actuators are used sequentially, so the power converter will only feed one load at a time. This type of converter is a compromise solution between having one power converter per load [1] and having a dual-use power converter with an output selection switch [2].

The parts of a power converter which occupy size and weight are the DC link energy storage components, control platform and the power semiconductor device heat-sinks. It is possible to design a power converter which will share these high size, cost and weight components, but still allow individual power semiconductors devices to be directly attached to each load. The power semiconductor devices are very small and light in comparison to these components, and hence this provides an alternative and potentially optimum solution.

2. The Actuation System

The actuation system under consideration is the nose landing gear extension/retraction and nose wheel steering. The basic arrangement of the system is shown in Figure 1. A single Motor Control Unit drives two motor which are connected separate Electro Mechanical Actuators (EMA).

One of the EMA is used for the extension and retraction operation and the other for the steering. The actuators are obviously used sequentially so the power converter is only required to drive one load at any given point in time. This is an interesting feature of aerospace applications which do not require constant use.

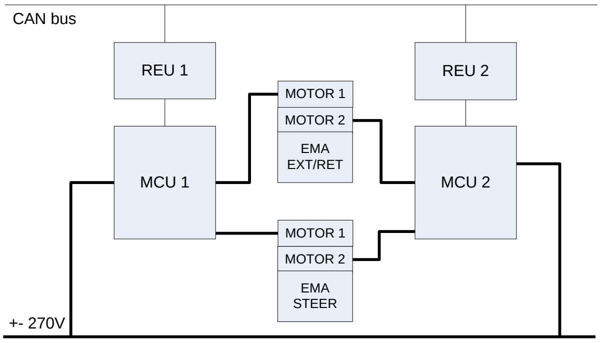

Figure 1: System overview of the nose landing gear

As can be seen from Figure 1, the actuator system features dual modular redundancy for each Electo-Mechanical Actuator [EMA] unit for both the steering and Extension/Retraction operations. Each EMA has two motors mounted on the same shaft which are driven by two separate Motor Control Units. A separate and independent Remote Electronic Unit (REU) is allocated to each Motor Control Unit. Each REU has command and monitoring modules which are interconnected by a CAN interface bus used for the communications.

The basic power circuit topologies that can be considered for this application are shown in Figures 2 to 4. The dual-output power converter configuration is a compromise solution between having one power converter per load (Figure2) and having a dual-use power converter with an output selection switch (Figure 3).

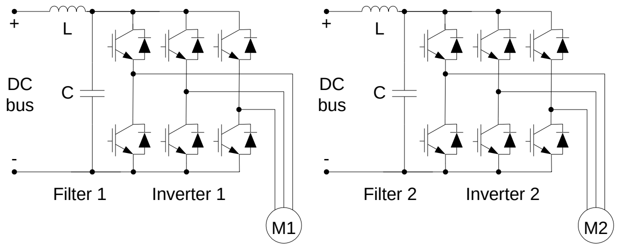

Figure 2: Two separate power converters for each motor load

For the dual-use power converter, shown in Figure 3, an additional switch is used to switch the converter output between the two loads. This additional switch adds to the cost and size of the converter. If a solid sate switching component is used then this switch will also add to the losses of the power converter.

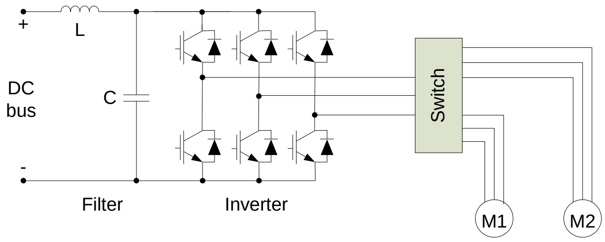

Figure 3: A dual-use power converter

The components of a power converter which significantly contribute to the size and weight of the system are usually the DC link energy storage components and the heat-sinks for the power semiconductor devices. It is possible to design a power converter which will share these high size, cost and weight components, but still allow individual power semiconductor devices to be directly attached to each load. Power semiconductor devices are very small and light weight in comparison to these components heavy and large components. Hence this proposed configuration, shown in Figure 4, provides an alternative and potentially optimum solution.

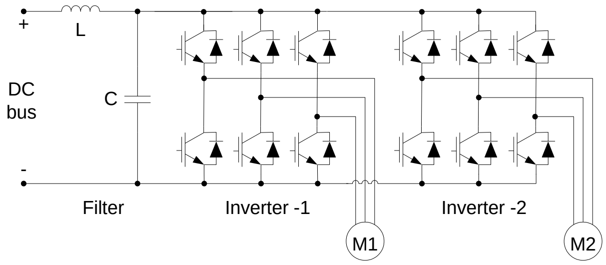

Figure 4: A dual-output power converter with mutual components

3 Simulation Study

For this demonstration a Permanent Magnet motor with a trapezoidal back emf is used. This machine has been chosen for the use of low cost sensors and high power/weight ratio. Figure 5 shows the control and modulation of this converter and machines. The control uses a simple Hysteresis controller implemented on an FPGA Control Platform.

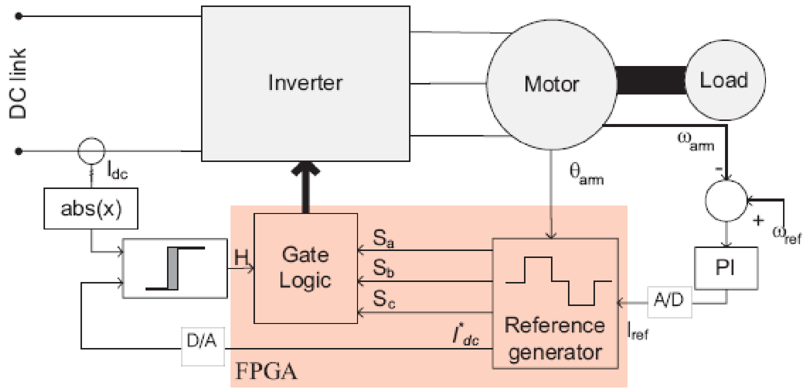

Figure 5: Hysteresis Modulation of Trapezoidal BLDC using one Current Sensor

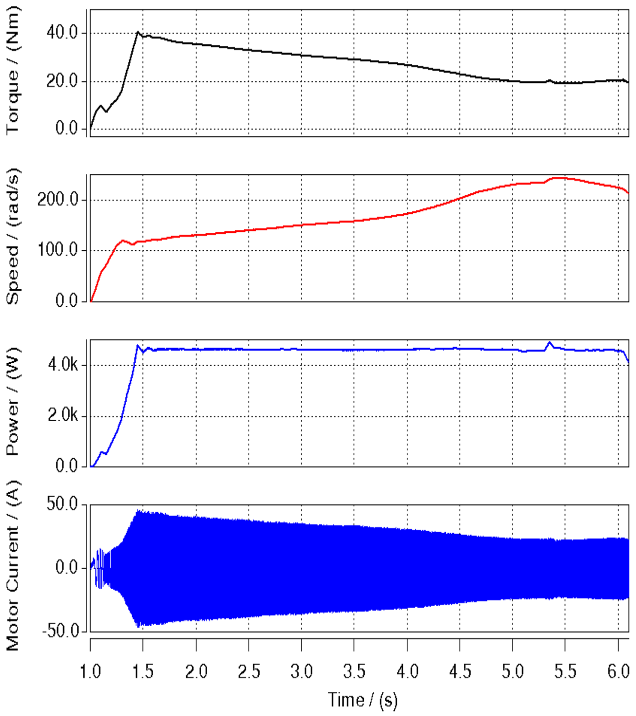

Figure 6: Simulation results of the drive for retraction operation of the landing gear. (a) Torque, (b) Speed, (c) Power, (d) Motor current

Figure 6 shows the simulation result of the Motor Control Unit acting as a motor drive during the retraction operation of the landing gear. The retraction operation is the worst case operating condition in terms of the motor drive power requirements. These simulation results have been obtained using a SABER simulation model of the converter, motor and actuator load.

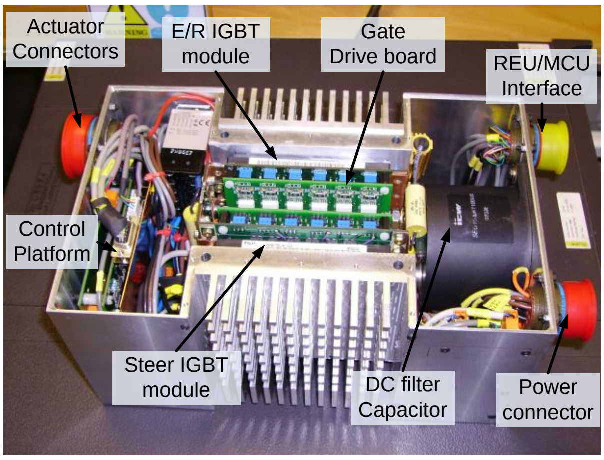

Figure 7: Prototype Power Converter hardware

4 Results from the Prototype Testing

Figure 7 shows the prototype power converter hardware for the dual-output Motor Control Unit. Each unit of the dual-output Motor Control system is rated at 8 kW per each output.

This Motor Control Unit was built to demonstrate the minimization of volume and weight of the power converter, not the housing. The thermal dissipation requirement for the heat-sink was estimated using analytical methods [7][8] which give the power loss of the drive under continuous, worst case operating conditions. The housing and cooling arrangement, shown in figure 7, is therefore not optimized for the final application and could be significantly reduced in size and weight by using suitable thermodynamic design methods.

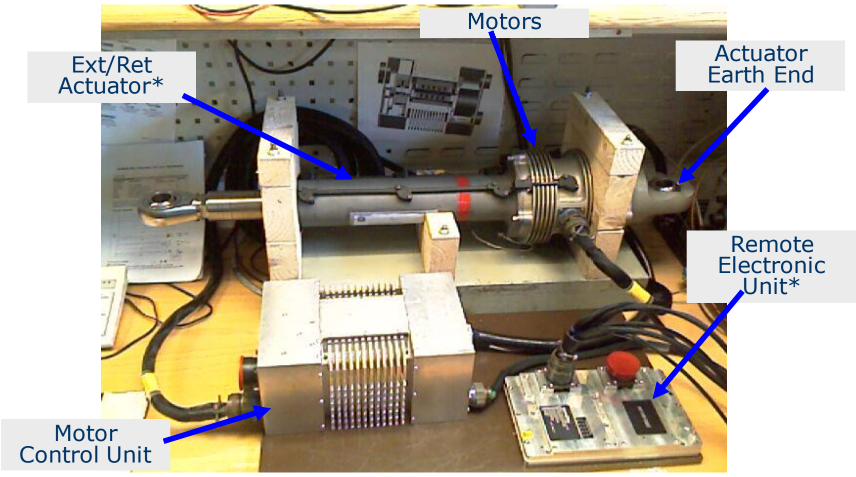

Figure 8: The control system, converter and actuator hardware during initial laboratory testing

Figure 8 shows the system set up on a temporary bench during laboratory testing. As well as the power converter hardware the figure shows the actuator and REU hardware. Results from the operation of the actuator during an extension and retraction cycle are shown in Figure 9. This figure shows the demanded and actual motor speed and torque producing motor current.

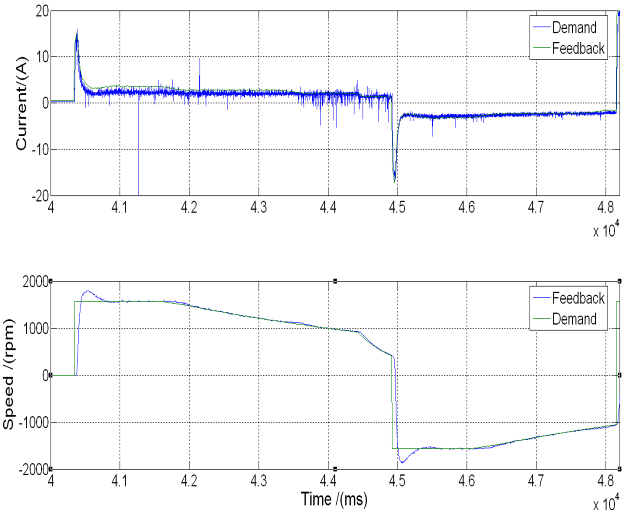

Figure 9. Results from the Extension and Retraction Operation showing the demanded and actual torque producing motor current and motor speed

5 Conclusions

This paper has demonstrated the design, construction and operation of an example of a dual-output power converter with mutual large power circuit components. This power converter structure has the benefits of sharing the large or expensive components between converters whilst maintaining an output inverter bridge for each load.

For higher power converters the benefits of this solution will be even greater, for example as a replacement of the concept of a dual use converter for ECS and engine start applications. This paper has demonstrated that this type of advanced dual-output power converter is achievable and practical for aerospace some applications.

References

[1] P. Pillay and R. Krishnan, “Modeling, simulation and analysis of permanent-magnet motor drives, Part II: The brushless DC motor drive”, IEEE Transactions on Industry Applications, vol. 25, no. 2, pp 274-278, 1989.

[2] K.Y. Nam, W.T. Lee, C.M. Lee and J.P. Hong, “Reducing torque ripple of brushless DC motor by varying input voltage”, IEEE Transactions on Magnetics, vol. 42, no. 4, pp 1307-1310, 2006.

[3] D.G. Holmes and T.A. Lipo, "Pulse width modulation for power converters: Principles and Practice", ISBN: 0-471-20814-0, Wiley.
[4] J.W, Dixon and I.A. Leal, "Current control for AC motor drives using a single dc-link current sensor and measurement voltage vectors", IEEE Transactions on Power Electronics, vol. 17, no. 2, 2002.
[5] H. Kim and T.M. Jahns, "Current control strategy for brushless dc motors based on a common DC signal", IEEE Transactions on Industry Applications, vol. 42, no. 6, 2006.
[6] DDIS, "Aircraft electric power characteristics: MIL-STD-704F", March 2004.
[7] F. Schafmeister and J. Kolar, "Analytical calculation of the conduction and switching losses of the conventional matrix converter and the sparse matrix converter", Proc. of IEEE Applied Power Electronics Conference, vol. 2, pp. 875 - 881, 2005.
[8] L. Abraham and M. Reddig, "Determination of switching losses in IGBTs by loss-summation method", Proc. of IEEE Industry Applications Society Annual Meeting, vol. 2, pp. 1061 – 1068, 1995.

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