The Development and Challenges of More Electric Aircraft

Yide Lin*

Department of Electrical and Electronic Engineering, University of Bristol, Bristol, United Kingdom

*ed19115@bristol.ac.uk

Abstract. The development of electrical and electronic engineering makes the replacement of conventional hydraulic, mechanic, and pneumatic system into electrical system become much more possible. That means the secondary power of aircraft will be dominated by electricity, rather than hydraulic oil or bleed air from the engine. The Boeing 787 and Airbus A380 has applied these technologies significantly and their fuel consumption and noise level during flight are also get improved by comparison with their counterpart which has traditional hydraulic and pneumatic system. On the other side, the mass application of electrical driven components on board will lead to various new challenges to aircraft design when concerning the weight and flight safety due to the characteristics of those components. In this paper, technologies implemented, and challenges will be introduced through reviewing literatures. The benefit and drawbacks will be concluded by comparing electrical and hydraulic and pneumatic system.

Keywords: More-electric aircraft; Electrification; Electric Actuator.

1. Introduction

More-electric aircraft is the aircraft that their original mechanical, hydraulic and pneumatic system is massively replaced by electrical system. The Boeing 787 is a typical aircraft that its engine starting system, hydraulic pump and pressurisation system, cabin HVAC (Heating, Ventilation, Air-Conditioning) system is electrified where they are powered pneumatically on previous generation. The utilisation of electrical energy facilitating the future aircraft becoming more fuel efficient, quieter, more environmentally friendly and reducing cost on maintenance [1].

This paper will compare electrified flight control, environmental control, and engine starting system with that powered by hydraulic and pneumatic ones. Benefits and restrictions of electrified system will be discussed.

2. Aircraft hydraulic and pneumatic system

2.1 Hydraulic system

Hydraulic system is a significant part of flight control system. Without hydraulic system, the yaw, roll, and pitch of the aircraft will be difficult to achieve since the ailerons, rudder, elevators, landing gear and flaps are mostly controlled by hydraulic system. In modern aircraft, as Airbus A320 as an example displayed in Fig. 1. The overall shows the aircraft has three hydraulic system notated as green, blue, and yellow system. The green and yellow system are both driven directly by turbofan engine installed under the wings of the aircraft. The blue system is driven by ram air turbine (RAT), which allows the critical components such as rudders and elevators works properly when engine failed.

It is noticeable that a power transfer unit installed across the green and yellow system. Which ensure the hydraulic oil can flow from green to yellow system or otherwise when one of the systems failed. Therefore, the components attached to each system will not stop working.

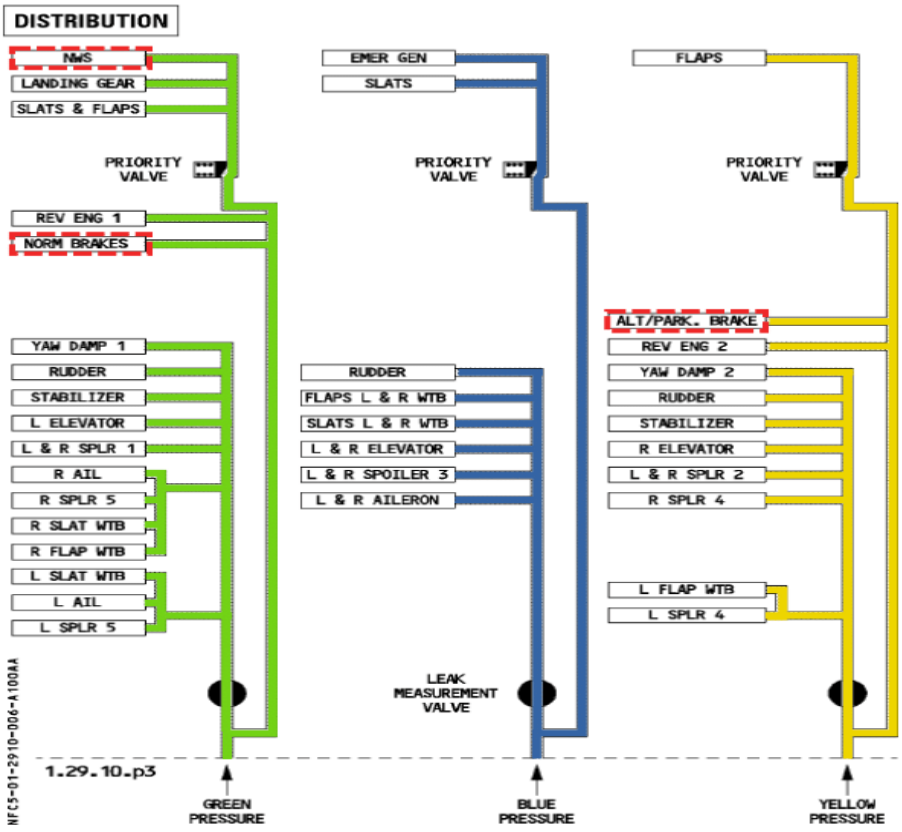


Fig. 1 The hydraulic system layout of Airbus A320 [2]

2.2 Pneumatic system

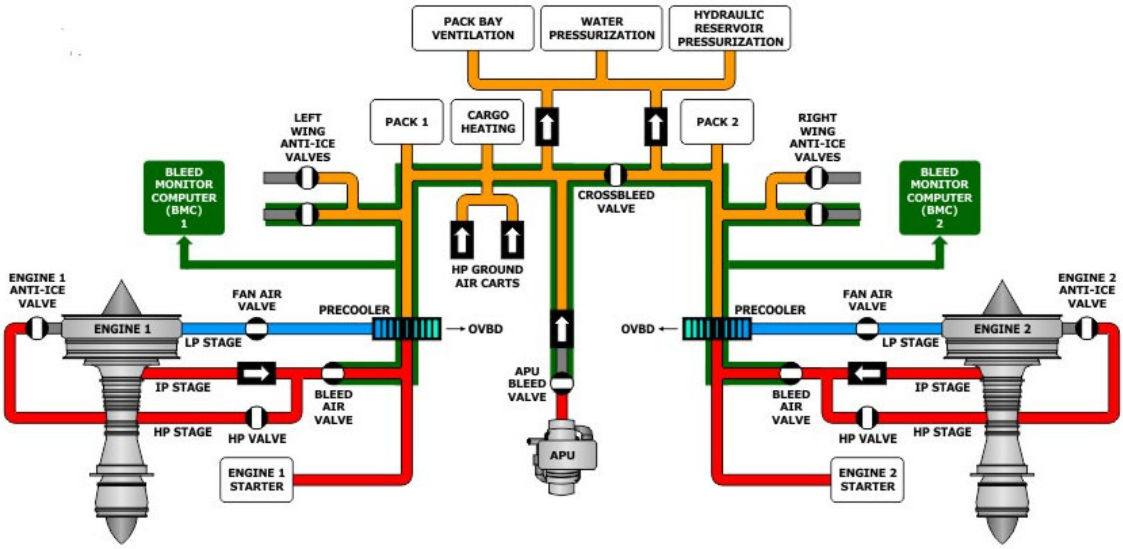


Fig. 2 Pneumatic system layout of Airbus A320 [3]

Pneumatic system is another crucial system to modern jet aircraft, the function of it is to provide power to start engines, control the temperature in cabin and remove the ice on wings. As the system diagram illustrated given by Fig 2, like hydraulic system, the entire system is driven by engine and Auxiliary Power Unit (APU). When the revolution speed of engine is low, the source of the pressurised air will come from the hight pressure compressor of the engine, ensures the air pressure will not be lower than rated pressure of components; during the flight stage, the source will be switch

to that come from the low-pressure compressor and high-pressure valve (HP VALVE in Fig. 2) will close. However, the air temperature after compression is higher than the system designed, the pre-cooler is installed at the output terminal of compressed air to cool down the air, the cooling source of the air comes from the fan of engines.

3. Aircraft electrified systems

3.1 Electrified actuation system

There are two types of electric actuators applied on current commercial aircraft, Electro-Hydrostatic Actuator (EHA) and Electromechanical Actuator (EMA), which shown in Fig. 3. Both Boeing 787 and Airbus A380 replaces part of their existing hydraulic actuation system into electrically powered actuation system [4]. The block diagram for power transmission of both types of actuating system is displayed in Fig. 4 and Fig. 5.



Fig. 3 Electro-Hydraulic Actuator (left) and Electromechanical Actuator (right) [4]

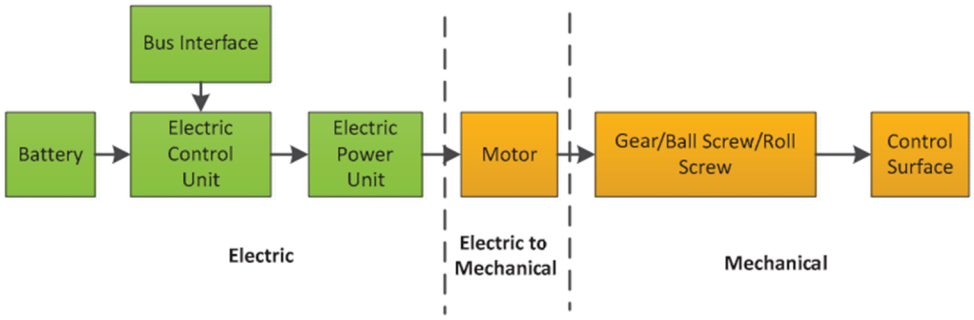


Fig 4. Block diagram and energy transmission of EMA [5]

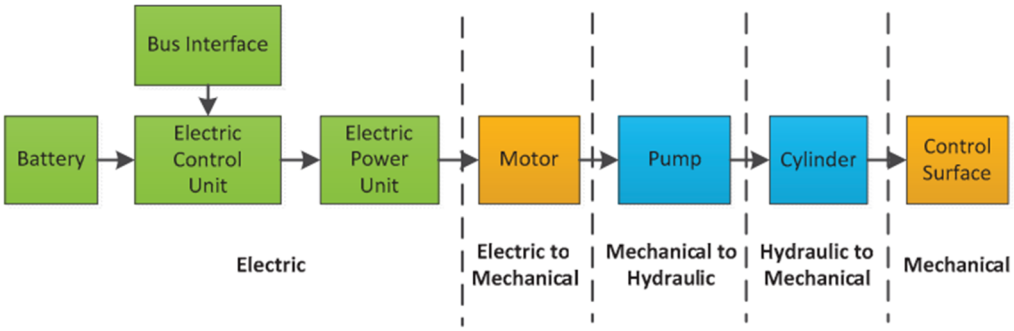


Fig 5. Block diagram and energy transmission of EHA [5]

In EHA, the electrical energy provided by aircraft electricity supply system will transfer in to mechanical and hydraulic energy through electric motor and hydraulic pump driven by motor before terminating at control surfaces of aircraft; the electrical energy supplied to EMA will directly transfer to mechanical energy act on control surfaces via the electric motor. Comparing EMA and EHA, several benefits of EMA can be summarised. Initially, EMA is more energy efficient than EHA due to less energy conversion procedure. The next benefit of implementing is that the maintenance cost will be reduced. Since the structural complexity of EMA is less than EHA.

3.2 Electrified environmental control system

Environmental control system (ECS) of the aircraft includes cabin pressurisation and air-conditioning system. Instead of driven by compressed air supplied by engines, the components of the system are mostly driven by electricity in more electric aircraft. As Boeing 787 as an example shown in Fig. 6, the air enters the ECS through the ram air duct on the aircraft body, then compressed by electrically driven compressor and finally fed into the cabin. By comparison with traditional pneumatic system, electrically powered ECS allows further optimisation of energy usage due to the variable speed feature of motor [6] instead of depending on the revolution speed of engine in pneumatic bleed air system.

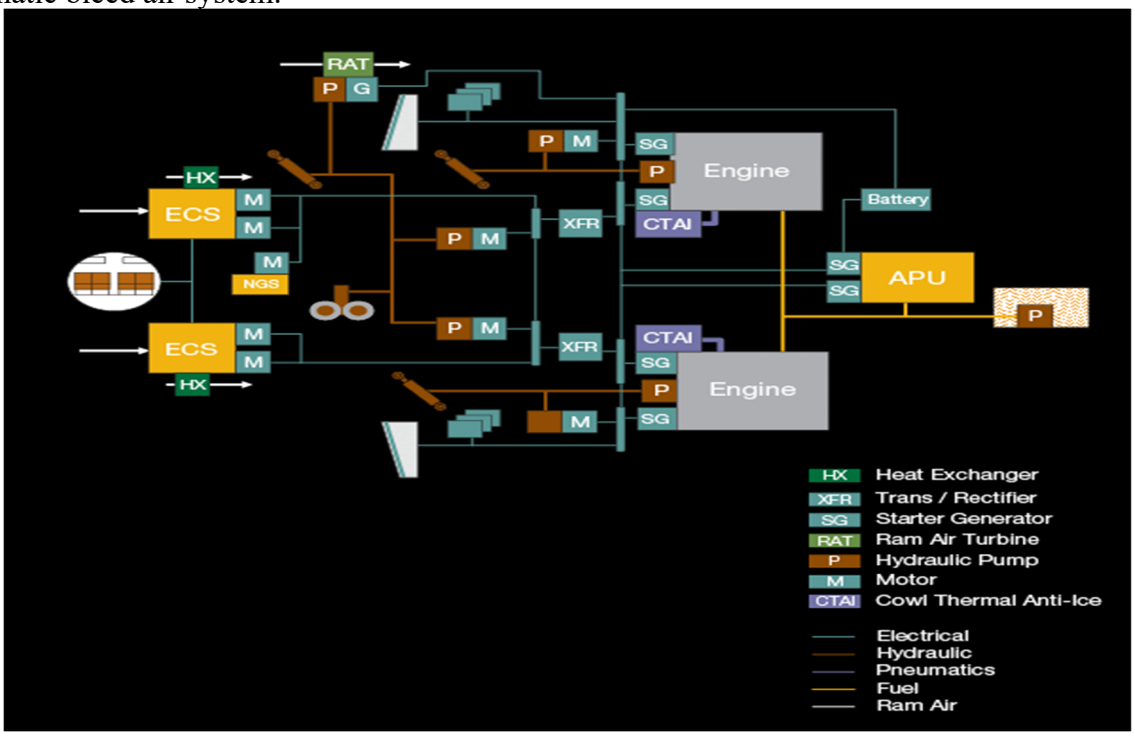


Fig 6. The electrical system of Boeing 787 [6]

3.3 Electrified engine starting system

In more electric aircraft, the power source to start engine is electricity instead of compressed air. Fig. 6 also illustrates the electrical system architecture of Boeing 787, the electric generators functions as starter motor when engines at stall state. Thus, this type of electrical machine is notated as Starter Generator (SG).

Since air compressor is not required on board to drive pneumatic system, there will be more spare space to install SGs. On Boeing 787, there are two SGs connected directly to each engine.

4. Comparison of electrified and hydraulic/pneumatic system

After comparing EMA and hydraulic actuator, a chart in terms of power losses was made shown in Table 1.

Table 1. The comparison of Electromechanical Actuator and Hydraulic Actuator in power losses [7]

Type Of Devices	Type Of Loss	Peak power (kW)	Energy Consumption (kJ)	Average Power (kW)
Electromechanical Actuator	Actuator loss	2.12	0.463	0.154
	Transmission loss	0.05	0.012	0.004
	Total loss	---	0.475	0.158
Hydraulic Actuator	Actuator loss	1.71	0.480	0.160
	Transmission loss	0.51	0.106	0.035
	Total loss	---	0.586	0.195

It is considerable that the power consumed by the electromechanical actuator is the same as the hydraulic actuator. However, the transmission loss of hydraulic actuator is 23% higher than that of electromechanical actuator due to the energy conversion losses between mechanical and hydraulic energy. To summarise that, the EMA is more power efficient than hydraulic actuator. Nevertheless, there is one significant challenge that EMA should overcome, which is mechanical jamming. Due to this risk, EMA cannot be installed on primary surfaces and landing gear system unless this potential risk can be removed properly [7].

By comparison with pneumatic and electric starting method, higher energy transfer efficiency is the primary advantage of electric starting system, due to less energy loss of transmitting electricity from generator to motor compared with bleed air system. The restriction of electric starting system is still obvious since power electronics converter is required to drive starter motor. And, that converter usually gives additional weight the entire aircraft [8].

5. Conclusion

This paper discussed the positive and negative impact of replacing existing hydraulic and pneumatic system by electrically powered system. To overcome the mechanical jamming of the EMA, the structural optimisation of the accessories can be proceeded. The weight reduction of engine starting system can be carried out by applying 3rd generation semiconductor material like silicon carbide (SiC) and gallium nitride (GaN), and applying permanent magnet material to starter generator (SG) manufacturing.

References

[1] Wheeler Pat, Technology for the More and All Electric Aircraft of the Future. Curico: 2016 IEEE International Conference on Automatica (ICA-ACCA), 2016.

[2] Labidi Aymen, "Skydrol," 12 7 2020. [Online]. Available: https://www.researchgate.net/publication/342877726_Skydrol. [Accessed 28 7 2022].

[3] Pinto Jhonny, "Linkedin," 7 10 2019. [Online]. Available: https://www.linkedin.com/pulse/pneumatic-system-ata-36-jhonny-pinto/. [Accessed 28 7 2022].

[4] Bae Junhyung, A Review of Electric Actuation and Flight Control System for More/All Electric Aircraft. Gyeongsan: 24th International Conference on Electrical Machines and Systems (ICEMS), 2021.

[5] Li Jiamming, Yu Zhiyuan, Huang Yuping and Li Zhiguo, A Review of electromechanical actuation system for more electric aircraft. Beijing: 2016 IEEE/CSAA International Conference on Aircraft Utility Systems (AUS), 2016.

[6] Sinnett Mike, "787 No-Bleed Systems: Saving Fuel and Enhancing Operational Efficiencies," Boeing, 28 April 2007. [Online]. Available:
https://www.boeing.com/commercial/aeromagazine/articles/qtr_4_07/article_02_1.html. [Accessed 22 July 2022].

[7] Sarlioglu Bulent and Morris Casey T, More Electric Aircraft: Review, Challenges, and Opportunities for Commercial Transport Aircraft. IEEE TRANSACTIONS ON TRANSPORTATION ELECTRIFICATION, 2015 1(1): 58-59

[8] Cao Zheng, Zhou Yuanjun, Liu Haigang and Zhang Chen. Energy optimization Charateristic Analysis of More Electric Aircraft Flight Control System. Beijing: 2018 IEEE 2nd International Electrical and Energy Conference (CIEEC), 2018.