ELECTRIFICATION OF THE ENVIRONMENTAL CONTROL SYSTEM

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Abstract

Today's large civil Aircrafts use pneumatic power delivered from the engines as energy source to run the Environmental Control System (ECS). The three main tasks of the ECS are to pressurise and ventilate the cabin and to control its temperature.

As the ECS is one of the largest power consumer among the non-propulsive systems, it appears clear that toward a More Electrical Aircraft, the electrification of this system will play a key role within the power generation and management and fuel saving, but will also have a big impact on other systems using pneumatic power, for example the Wing Ice Protection System.

This paper describes the main changes, benefits and drawbacks linked to the electrification of the ECS: the deletion of engine bleed air system and the increased needs in electrical power, the positive fuel consumption impact on the engine and increased ECS weight.

1 Introduction

The task of an ECS is to provide conditions for the passenger's physiological comfort and establish sufficient working conditions for the crew. Acceptable conditions shall be ensured to all other lives aboard and sufficient cooling for all equipment e.g. electronic equipment and material. To ensure these tasks the ECS shall be designed in order to control the temperature, to pressurise the relevant compartments and to provide sufficient ventilation and fresh air to passengers, to control the level of humidity inside acceptable limits in the cabin and to remove pollutants. These tasks are today usually divided between different systems on civil aircrafts, however the core system where air is conditioned are the so called packs.

2 Current situation

Currently the ECS Packs of large civil Aircraft uses air bled from the engine compressor to provide conditioned air (flow, pressure, temperature) to the cabin (Fig 1). As the thrust produced by the engines depends on the flight phase, the pressure of the engine bleed air varies so that it is necessary to use two different ports: the Intermediate Pressure port (IP) which is used the port delivering the air during the mean time of the flight, and the High Pressure port (HP) which is used when the engine is operating at low power defined by the flight envelope (especially in landing, hold and descent conditions). The choice of the bleed port (IP or HP) for the supply of the ECS (but also the Wing Ice Protection System (WIPS)) is driven by the available pressure and is controlled by complex laws.

The pressure of the air delivered is limited by the Pressure Regulating Valve (PRV) and its temperature by the Pre-Cooler (PCE) which uses Engine Fan air to cool down the air coming from the core of the engine. The Fan Air Valve (FAV) modulates the coolant flow so that the temperature of the air living the PCE doesn't exceed 200°C.

It appears obvious that the air bleeding from the engine has an impact on the engine fuel consumption. It depends mainly on the following parameters: flow, pressure, engine power.

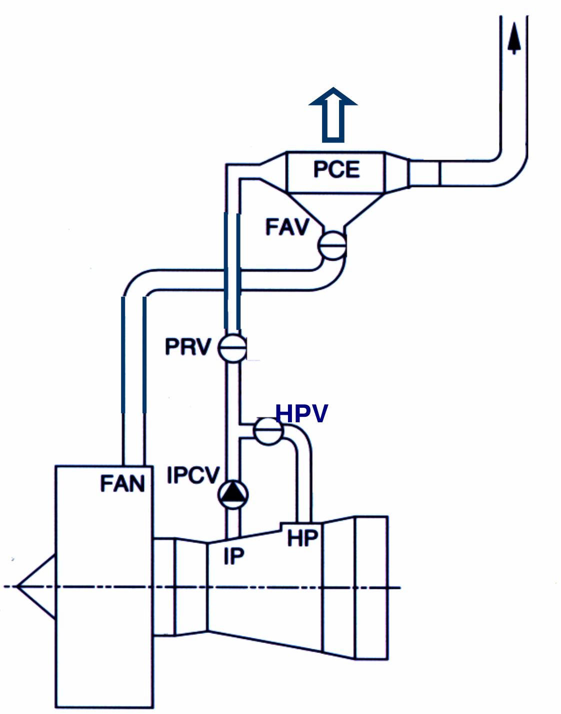

Fig 1: simplified typical engine bleed air system

It is also obvious that the ECS has to match with all energy level supply situations coming from the engine, regardless if the air has a low or high temperature and a low or high pressure: the tasks to be fulfilled remain the same.

It means that the ECS has to be designed for the worst case (low pressure and high temperature), and that when the conditions are not so stringent the ECS is oversized, and use high level energy that it doesn't need (this occurs particularly during the take-off and climb phases): the engine provides air with a high pressure which is reduced by the PRV and Flow Control Valve (FCV) at the inlet of the Packs.

3 Electrification of the ECS

At Aircraft level, the electrification of the ECS will play a key role on the way to a More Electrical Aircraft as it will be one of the major steady state power consumers, but could also allow to save a lot of power, due to its adaptability and the lower impact on the thermodynamical cycle of the engine.

The Fig 2 shows the approximative power consumption to realise the pressurisation and ventilation as well as the cooling of an Aircraft for 100 and 350 Passengers (valid for a Cruise flight at 40,000 ft, HOT Day conditions).

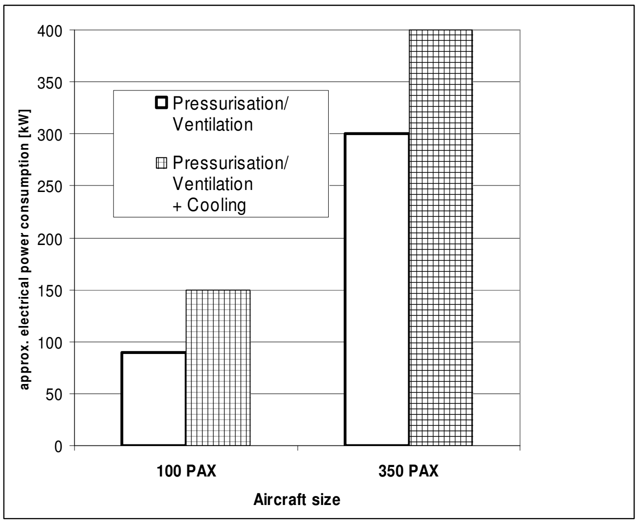

Fig 2: approximate electrical power consumption of an full electric ECS depending on the aircraft size.

The values of electrical power consumption of an full electric ECS are directly linked to the number of passengers, as the number of passengers determines the fresh air flow to be introduced into the cabin. A minimum fresh air flow per passenger is specified in the rules (JAR and FAR).

Although the values reported in the Fig 2 are approximate, they give an order of magnitude of the needed electrical power to be supplied to an electrical ECS. For an aircraft with 350 passengers the electrical power needs will be in the range of 400 kW and will therefore largely influence the sizing of the Electrical Power Generation System (EPGS), the wiring through the aircraft and the power distribution.

4 Benefits of the electrification of the ECS

The benefits of the electrification of the ECS are numerous and some of them are listed below:

- No direct-intervention of the ECS in the thermodynamical cycle of the Engine. Due to the air extraction bleeding from the engine compressor the engine performances are degraded. An electrical ECS will allow to design the engine compressor independently from the needs of the pneumatic systems.
- A high efficiency Engine can only be realised with a high bypass ratio (fan flow divided by core flow), and the impact on the Specific Fuel Consumption (SFc) of the engine air bleeding is higher the lower the core flow (the percentage of bleed air (determined by the aircraft fresh air needs) related to engine core flow is higher for engine with a high bypass ratio as the core flow is reduced to a minimum).
- Other than for a conventional ECS, where the energy source is the engine compressor, and therefore the energy level depending on the flight phase (high energy level during the climb and low level during descent), the electrical ECS will absorb the power needed to perform its tasks and not dissipate power by throttling high pressure in different valves.
- During some flight phases the minimum thrust produced by the engine can be driven by the ECS which require a minimum pressure to fulfil its tasks. This leads to an additional aircraft fuel consumption and avoid to fly the ideal mission profile. An electrical ECS would allow to segregate the engine speed from its power needs.
- Due to the thermal inertia of the complete ECS, it could beneficial at Aircraft level to accept a slight increase of the cabin temperature to allow other systems consuming for a short time a lot of power to be activated. This would allow to reduce the EPGS size.

5 Challenges of the electrification of the ECS

Of course the electrical ECS has not only advantages and some challenges to make it viable are indicated hereafter.

- Due to the high electrical power consumed by the ECS, the size of the generators has to be appropriate. The challenge is much higher for twin engine aircraft and especially for the failure case one engine off, where the half of the generators have to deliver more than half of the of the ECS power consumption in normal operation
- It seems obvious that the deletion of the engine bleed air extraction for the ECS will deliver its full positive potential only if the other system using also a big amount of engine bleed air, the WIPS, will use another power source as currently: the pneumatic power of the WIPS has to be replaced by electrical power, and the current power consumption of this system is tremendous when icing conditions are encountered. Fortunately alternative solutions can be found.
- So as to built a compact, efficient and low weight ECS, it is necessary to realise turbo-machines (Air Cycle Machine (ACM)) working at high speed. These electrically driven ACM’s have to work in the speed range of 50,000 rpm. For the cooling of their motors, it means that a lot heat has to be dissipated over a small surface. Air cooled motors seems to be feasible for the high power motorised ACM needed to realise a full electrical ECS for a 350 passenger aircraft, but the challenge is not easy.

- The realisation of the electrical ECS will probably simplify the engine (deletion of bleed port, of bleed valves and of the pre-cooler) and its control, but will for sure make the ECS more complex, as it will have to produce pressurised air by itself. This higher complexity will result for the ECS in more weight, installation space and costs. This have to be carefully balanced against the benefits mostly on the engine side.

Conclusion

The electrification of the ECS shows some big potentials in order to optimised the power consumption of an aircraft, but they have to be balanced against the drawbacks.

This technological step appeals a lot other changes at engine and aircraft level. Also the EPGS and the voltage of the electrical network play a key role in the electrification of the ECS due to their impact of the total weight of the system and its periphery.