Integrated Design by Optimization of Power Systems for More Electric Aircraft

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More electric aircraft (MEA) has introduced some significant advantages such as weight decrease, reduced maintenance requirements and increased reliability and passenger comfort. However, while aircraft installed electrical power increases, maintaining the advantages of the MEA highly relies on optimized on-board electrical network and power electronic conversion systems. Recent technology progress has largely contributed to improve power conversion systems for MEA. For example wide band-gap semiconductor devices, new magnetic materials, and advance packaging techniques enable high power density power converters. Innovative architecture and energy management, such as merging several functions supplied with a similar power converter, and hybridized power sources with energy storage, further reduce the weight of the aircraft power system. On the other hand, design and integration of the power system still follow the legacy standards. Each component can be optimized according to standards. However, locally optimized individual components may not results an optimum system; integrated optimal design is the future trend. A simultaneous synthesis by optimization of all system components (considering their interaction), architecture and management, is the only way to obtain an optimal design.

As a key link for integrated optimal design, specification of the voltage bus rating and constraints should be investigated. In this paper, the weight of a notional subsystem (Fig. 1) of the MEA power system is studied as a function of dc bus voltage rating, power quality constraints and stability constraints. Increasing the distribution voltages can reduce the current for a given distribution power, leading to smaller wire size. As the power demand in the MEA increases, nominal ac voltage has recently been increased from 115 V to 230 V, and dc voltage from 270 V to ±270 V to reduce weight and size of cables. While the higher voltages are generally beneficial for optimized cables, their impact on power converters is not so clear yet.

The preliminary results of this paper, as shown in Fig. 2, show that weight of passive components in the environment control system (ECS) converter decreases as the bus voltage rating increases. However, power semiconductors (IGBT) and cooling system weight increases, since high voltage rating IGBTs are bigger and produce higher losses. Converter weight can be further reduced by optimizing the circuit topology, and the results will be shown in the full paper.

![Fig. 1. Notional subsystem for study.](image)

Fig. 2. Left: ECS converter circuit; Right: weight distribution and comparison for different bus voltage ratings.

Similar analysis will be also shown for all other subsystem components. Power quality constraints, such as bus voltage ripple, current ripple and harmonic limits, greatly influence the load and source filters size of the converters. Higher frequency ripple and harmonics may reduce the weight of filters while still maintaining the performance of the whole system. The study of this paper will treat the limit of ripple and harmonic as design variables to optimize the whole system weight and performance.

Small-signal stability of the system can be assured by limiting the input impedances of the loads below the output impedance of the given source. This design approach may lead to oversized filter. A better approach is to limit the interaction of source and load impedances with a certain margin. This could be only achieved on system level with integrated design. Issues and design examples for power quality and stability will also be presented in the full paper.