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# A Collaborative Optimization Strategy for the Design of More Electric Aircraft Networks

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**Abstract** Nowadays, embedded aircraft network contains electrical devices which must cooperate in safe and light weight operation. For designing such systems, different local strategies have been developed but no global optimization has been performed so far. In this paper, we present at first two approaches, a classical approach used at the moment and a utopian approach involving all devices in a single optimization loop that should provide the ideal design. Then, a new approach based on collaboration is presented and a particular attention is paid on the data exchanged between subsystem designers. We compare the three strategies applied to the sizing of a whole network of more electric aircraft. A simplified case study with only two components is considered to illustrate methodological issues.

## Introduction

Modern engineering products are becoming increasingly complex, particularly in industries such as railway, aerospace and automotive [1], [2]. Conventionally, expertise and classical analysis methods, especially those based on simulations are used, aided by optimization methods in some part of the process. Each subsystem is designed separately by his manufacturer using his own model and process: this classical approach is called “mechanistic approach”. Another approach called “simultaneous design” may be developed to integrate all the components of a system into a single optimization. This extreme approach requires full cooperation for best results [1], [3]. A new approach called “sequential collaborative approach” is presented. It combines the independence of subsystem designs and a limited collaboration between them for better result. Industrial design imposes other constraints, integration of a large scale multidisciplinary system, privacy issues and decision level are fundamental criteria to elaborate feasible and efficient system design method [3].

## Design of a simplified embedded electric network

Embedded electric networks contain a high number of sources and loads connected to several buses: the issue is then to analyze applicability of optimization methods to this class of complex system. In our study, related to the development of strategies for system design, we initially relied on a “simplified” network, which is voluntary limited to a single load in order to establish and compare optimization methods. It consists of a single generating channel, connected with a unique non-linear load. This channel includes a generator, a rectifier and an output filter. The load comprises an actuator, an inverter and an input filter.

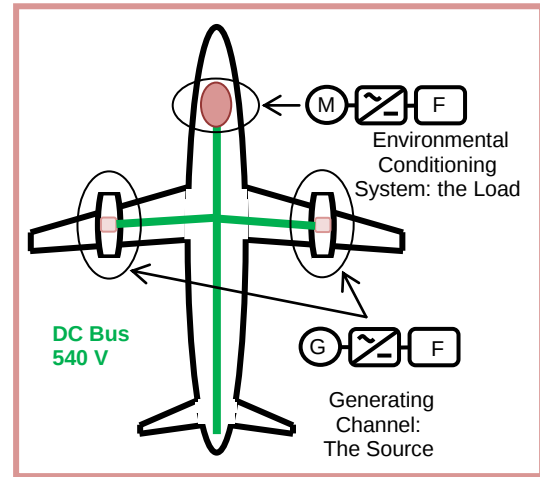


Fig. 1: An example of an aircraft network

We investigate the design of this channel (especially the filtering device sizing) using the three approaches previously presented.

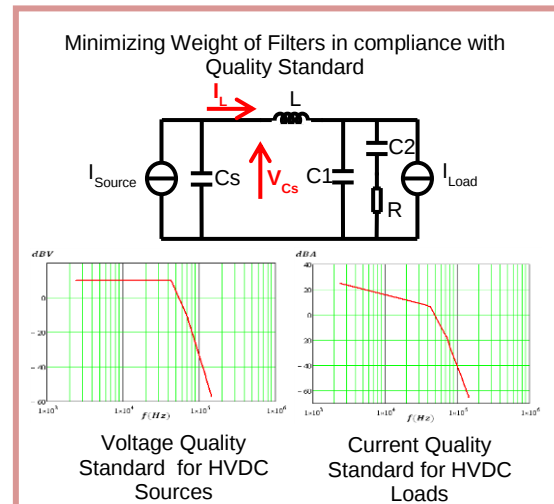


Fig. 2: Design problem of an embedded network

The single optimization goal is to minimize the whole network weight in compliance with quality standards; (current and voltage harmonics are limited to a maximum threshold in a frequency band).

### Classical (mechanistic) approach

In the classical approach, each subsystem is designed separately. Each subsystem manufacturer uses its own model and tools.

In the source design, we may choose the optimal value of the capacitance  $C_s$  (the decision variable) to minimize the weight of the source and fulfill the harmonic constraint. This process is managed by optimization software: CADES [4].

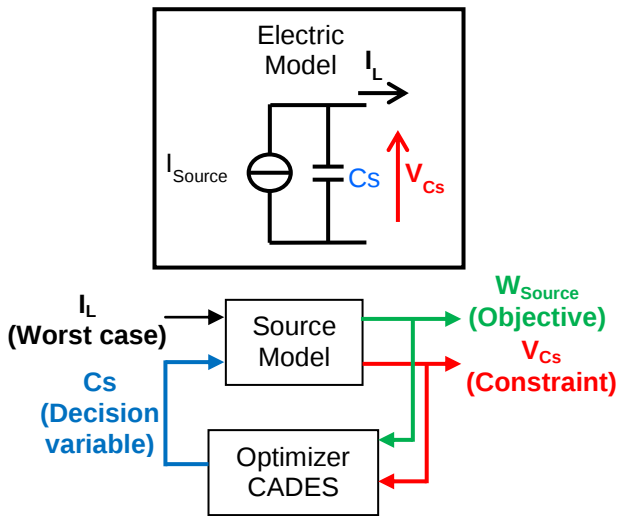


Fig. 3: Classical design of the source

For the load design, we may choose the optimal values of the passive elements:  $C_1$ ,  $C_2$ ,  $L$  and  $R$  (the decision variables) to minimize the weight of the load filter and fulfill the harmonic current constraint. We use the same optimization software to manage this process.

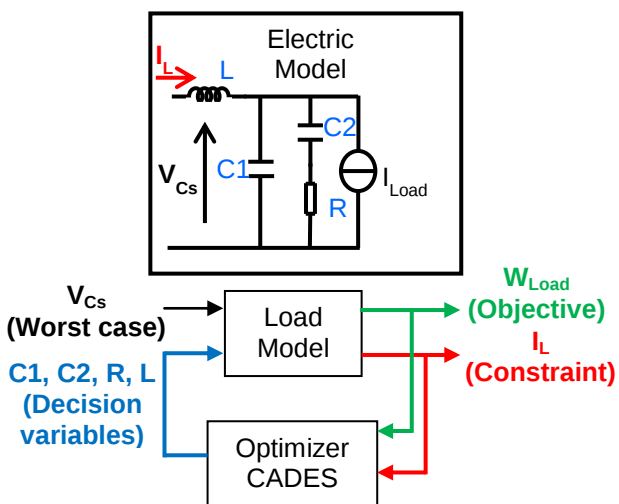


Fig. 4: Classical design of the load

### Simultaneous (global) approach

In this approach, the whole system (source and load) is considered as one. The optimization problem is bigger because it contains the modeling of both source and load, both decision variables and both voltage and current constraint.

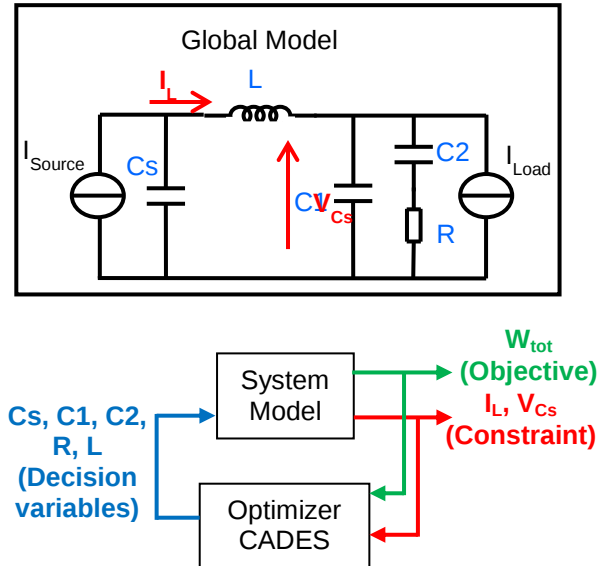


Fig. 5: Simultaneous design of the system

### Sequential Collaborative approach (S. C. A)

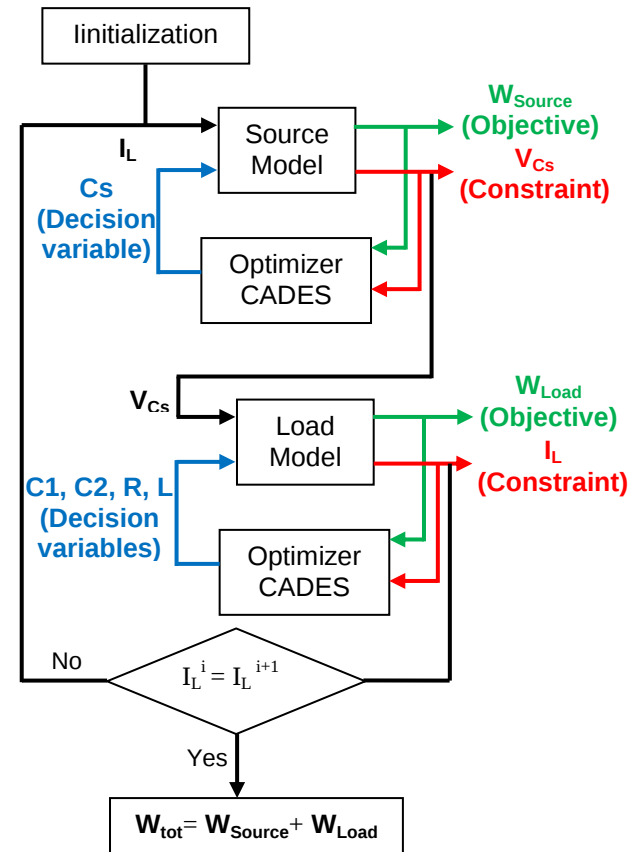


Fig. 6: Sequential collaborative Approach

In this new approach, we share the values of global variables. As shown in the previously approaches, current and voltage of the DC bus are common to the two subsystems. In the classical approach, according to the sub system, they are either overestimated or calculated in the model while they are all exactly calculated in the global approach.

So to share this information, we propose to combine the two design process by making them sequentially. After the optimization of the source, voltage calculated in this step is injected in the design process of the load and the same operation is done after the optimization of the load; we inject the new values of the current in the optimization of the source.

The stop criterion of this method is established by comparing the value of the current of two iterations. When the value of current is the same, the total weight of the system is calculated.

## Results

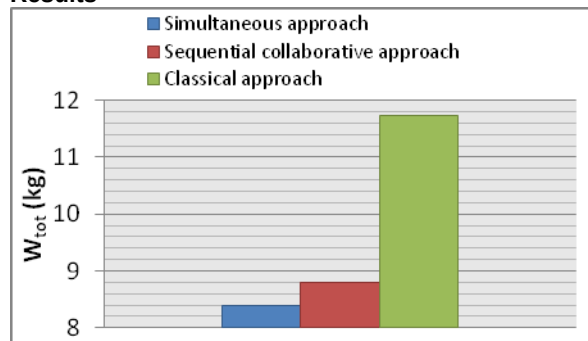


Fig. 7: Comparison of the objective function

First, we notice that there is a difference of 28.4 % between the weight obtained by the classical approach and the ideal design of the system. This oversizing of subsystems is due to two the assumption in the value of external harmonic pollution and the local model which do not consider the system couplings especially those between filters.

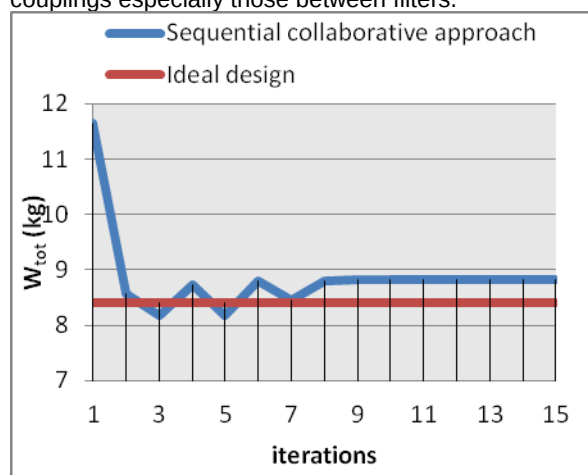


Fig. 8: Convergence of the S.C. A

The sequential collaborative approach takes no longer than 8 iterations to reach a solution. The design obtained by the sequential collaborative approach is far better than the classical approach one (25% of difference) but it is not as the ideal design. When observing the iterations, we notice that the values of global variables are not the same as in the ideal solution. A different choice of initialization values shows that the final solution depends on this first step.

## Conclusions

Through our work, we managed to demonstrate the influence of the couplings on the design of a system. The sequential collaborative approaches we have proposed allowed us to obtain a better solution by sharing a limited amount of data.

An improvement of this approach is planned by adding a hazardous choice of initialization to reach the same solution as in the ideal design of the system.

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