UNICO I+D Project
6G-INTEGRATION-4

E14-6G-INTEGRATION-4

Preliminary 5G comms POD design

Abstract

This deliverable includes the preliminary design for a dedicated POD that will house the 5G and 6G systems, including the equipment necessary for their operation, especially power supply and environmental control systems. This design will be the first step for the design of a functional POD, focusing on the envelope and interior spaces, but without going into the details of the internal systems or communication interfaces with the rest of the aircraft on which it will be embarked.

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List of Acronyms

APU – Auxiliary Power Unit

AC – Alternating Current

ANN – Artificial Neural Network

DC – Direct Current

EMS – Energy Management System

ESS – Energy Storage Systems

FLC – Fuzzy Logic Control

HESS – Hybrid Energy Storage Systems

MEA – More Electrical Aircraft

PEM – Proton Exchange Membrane

PEMFC – Proton Exchange Membrane Fuel Cell

RAT – Ram Air Turbine

RES – Renewable Energy Sources

SOC – State of Charge

MF – Membership Functions

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Executive Summary

This deliverable provides a preliminary design for a POD, specifically engineered to integrate 5G and 6G telecommunications systems onboard High-Altitude Platform Station (HAPS) aircraft.

The POD design ensures the effective integration of antennas, power supplies, and environmental control systems (ECS). Aerodynamic considerations play a crucial role in the POD's design. The streamlined geometry minimizes drag and ensures stable integration on the aircraft's wing. The ECS adopts an air-cooling system with both free and forced convection mechanisms. Inlet and outlet nozzles maintain optimal internal temperatures, ensuring reliable operation of the integrated systems under various flight conditions.

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1 Introduction

The growing demand for ubiquitous, high-speed connectivity has driven the development of next-generation communication technologies, such as 5G and 6G. However, the deployment of these technologies in remote or hard-to-reach areas poses significant logistical and technical challenges.

This paper presents the conceptual design of an aeronautical POD, an external module designed to integrate 5G and 6G telecommunications equipment. The POD efficiently integrates antenna systems, power supplies, and environmental control systems, ensuring optimal equipment performance during in-flight operation.

The pre-design of the POD is based on conceptual 3D models, which allow visualizing and optimizing the layout of the components. Simulations have been performed to evaluate the power consumption simulations to properly size the power supplies and optimize the energy efficiency of the system.

This paper presents the conceptual design of the aeronautical POD, including equipment layout and ventilation systems adapted to flight conditions. The objective is to provide a solid basis for the development of a definitive design that can be integrated into the complete design of a HAPS aircraft, thus contributing to the expansion of next-generation communication networks in remote or hard-to-reach locations.

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2 5G&6G POD design

The design of the specific POD to house the 5G and 6G systems will be based on the study of the different components to be shipped. This design seeks the integration of all the equipment in a compact format, which also allows adequate thermal dissipation and control of the integrated systems.

This POD will be designed so that the housed antennas can emit the signal without any problem. For this purpose, a section of the POD fuselage shall be covered by a surface permeable to the emission frequency. This material does not fall within the design scope of the POD, therefore only the geometry of this part will be designed.

Likewise, in order to perform the preliminary design, use is made of commercial 5G signal emitting equipment, which will serve as a sizer of the space and thermal dissipation requirements of this container.

For the ECS (Environmental Control System) study, we will start from an air cooling approach, visualizing the needs between free and forced convection systems.

2.1 Studies of Aeronautical PODs profiles

PODs (Point Of Dispense) are external containers attached to the wings or fuselage of an aircraft to carry additional cargo, such as weapons, surveillance equipment, or supplies. The aerodynamic design of these PODs is crucial to minimize drag and maximize flight efficiency.

Aerodynamic Profiles An aerodynamic profile refers to the cross-sectional shape of a wing or a POD. Selecting the appropriate profile is essential to determine the aerodynamic characteristics of the object, such as lift, drag, and pitching moment.

Types of Aerodynamic Profiles There are different types of aerodynamic profiles, each with unique characteristics. Some of the most common types include:

- **Symmetrical Profiles:** These profiles have the same shape on the upper and lower surfaces, making them suitable for applications requiring neutral lift, such as horizontal and vertical stabilizers.
- **Asymmetrical Profiles:** These profiles have different shapes on the upper and lower surfaces, allowing them to generate lift even at low angles of attack. They are widely used on aircraft wings.
- **Supercritical Profiles:** Designed to delay the onset of shock waves in transonic and supersonic flights, these profiles reduce drag and improve efficiency.

Application to Aircraft PODs The choice of an aerodynamic profile for a POD depends on several factors, including flight speed, the cargo carried, and its location on the aircraft. In general, profiles offering low drag and good stability are preferred.

Additional Considerations Apart from the aerodynamic profile, other factors influencing POD design include:

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- **General Shape of the POD:** It should be as aerodynamic as possible to minimize drag.
- **POD Placement on the Aircraft:** It must be positioned to avoid interfering with the airflow over the wings and fuselage.
- **POD Attachment System:** It should be strong enough to withstand aerodynamic loads during flight.

Studies and Developments Computational Fluid Dynamics (CFD) has become an essential tool for aerodynamic analysis of PODs, allowing for airflow behavior simulations and design optimization.

Research is ongoing into new materials and technologies to reduce the weight and drag of PODs, such as composite materials and 3D printing.

Additional Resources To deepen your understanding of aerodynamic principles applied to aviation, you can refer to the following flight manual:

- **Flight Manual: Aerodynamic Principles Applied to Aviation.**

For information on aerodynamic analysis of airfoils in the supersonic regime using CFD, check the following document:

- **Aerodynamic Analysis of Diamond-Shaped Airfoils in the Supersonic Regime Using CFD - CORE.**

For information on CFD applications in aeronautical aerodynamics, refer to:

- **CFD Applications for Aeronautical Aerodynamics at FAdeA S.A. - cimec.org.ar.**

For details on the study, simulation, and optimization of an airfoil, you can consult:

- **Study, Simulation, and Optimization of an Airfoil - UPCommons.**

For information on the aerodynamic study of a NACA airfoil, check out:

- **Aerodynamic Study of a NACA Airfoil - UPCommons.**

2.2 Operation conditions

<u>Altitude of 0 Meters (Summer Scenario with High Temperatures):</u>

- **Atmospheric Pressure:** Approximately 101,325 Pa (1.01 bar). This is the standard atmospheric pressure at sea level.
- **Temperature:** 40-45°C.
- **Air Density:** At 45°C, the air density is approximately 1.109 kg/m^3.

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- On a hot and humid day, especially in coastal or tropical areas, the relative humidity could range between 60% and 90%.
- In arid or desert regions, the relative humidity could be much lower, even below 30%.

<u>Altitude of 20,000 Meters:</u>

- **Atmospheric Pressure:** Approximately 5,500 Pa (0.055 bar).
- **Temperature:** Approximately -56.5°C.
- **Air Density:** Approximately 0.089 kg/m^3.
- At this altitude, the atmosphere is extremely dry. The relative humidity is very low, close to 0%. The air contains very little water vapor.

2.3 5G&6G integrated equipment

The first step in defining the sizing is to outline the equipment that needs to be integrated into the POD design. The following components are proposed for this purpose:

- **<u>Baseband 6648:</u>** Baseband 6648 provides switching, traffic management, timing, baseband processing, and radio interfacing. The baseband unit is in the 19-inch format, with 12 Common Public Radio Interface (CPRI or eCPRI) ports, enabling increased connectivity for radio units.
- **<u>Antenna Integrated Radio 3227 (AIR 3227):</u>** AIR 3227 is a 32TR TDD AAS for LTE and NR, operating as standalone or as mixed mode. The AIR unit has beamforming and MU-MIMO technology, capable to fully utilize radio resources in both azimuth and elevation.
    - The main benefits compared to previous macro solutions are improvements in:
        - Enhanced coverage - High gain adaptive beamforming
        - Enhanced capacity - High-order spatial multiplexing and multi-user MIMO
        - Advanced RAN features - Vertical and horizontal beamforming
        - Improved network performance - Low inter-cell interference

The characteristics of the systems to be integrated are as follows:

<u>Baseban 6648:</u>

- Nominal Voltage: -48 Vdc
- Operating Voltage Range: -38.0 to -58.5 Vdc
- Non-destructive range: 0 to 60 Vdc
- Maximum Power Consumption: 340 W

<u>AIR 3227:</u>

- Maximum nominal output power: 200 W (Power of the emitted signal)
- Máximun dissipation: 860 W
- Nominal Voltage: -48 Vdc
- Operating Voltage Range: -38.0 to -58.5 Vdc
- Non-destructive range: 0 to 60 Vdc

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- Maximum Power Consumption (assumption): 200+860 W (1060 W)

The total Consumption Power for both systems is approximately 1400 W.

To power the equipment related to the antenna, we are looking for a lightweight power supply model designed for aeronautical environments, capable of providing more than 1400 W of power to the equipment, in order to propose a power reserve of 25% of the demand. A 1750 W power supply is selected for this purpose.

The system must be connected to a 400 Vdc power bus, which will be the main power bus of the aircraft. It will also provide voltage at 48-50 Vdc, falling within the functional range of both 5G systems.

DC/DC Power Source Vicor BCM4414VD1E5135C02:

- Input Voltage: 260-410 Vdc
- Output Voltage: 32.5-51.3 Vdc
- Output Current: Up to 35 A
- Maximum Power Output: 1750 W

2.4 Preliminary POD 3D Model Design

With the defined equipment to be incorporated into the POD, a first design is proposed, focusing a first iteration on the development of the central body to house a 5G antenna with the necessary equipment for its conditioning.

A first design of the POD is presented to house a 5G antenna with the necessary equipment for its conditioning. An open base is proposed, which will be covered by a material permeable to its emission frequency.

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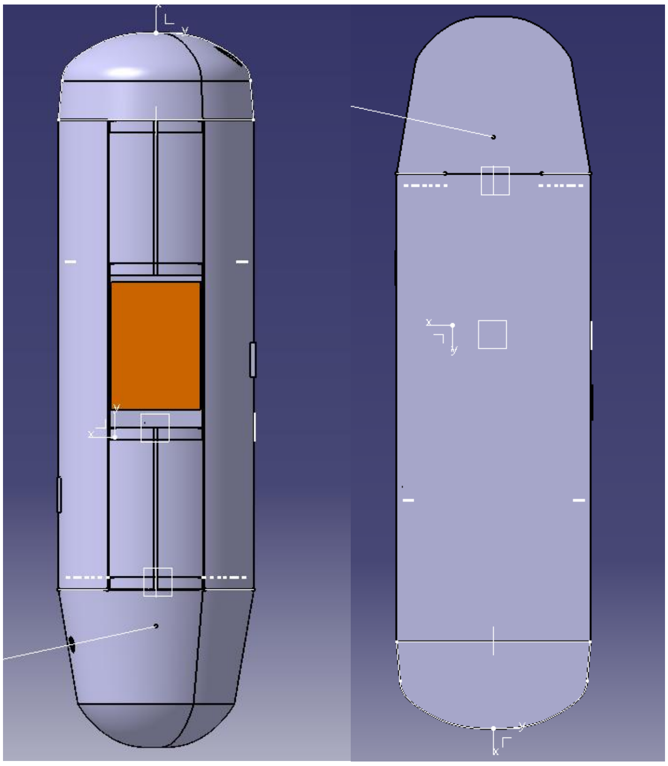

Figure 2.1: Floor plan (right) and Upper plan (left) of the preliminary design of 5G&6G POD

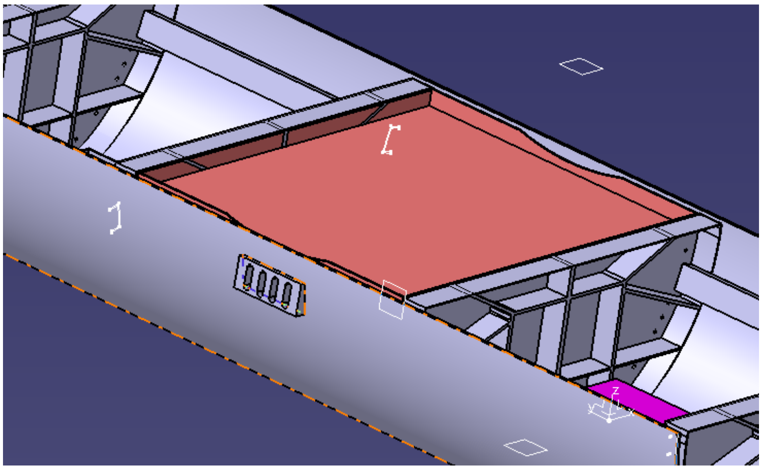

Figure 2.2: POD inside visual detail

The systems included are shown in the following image:

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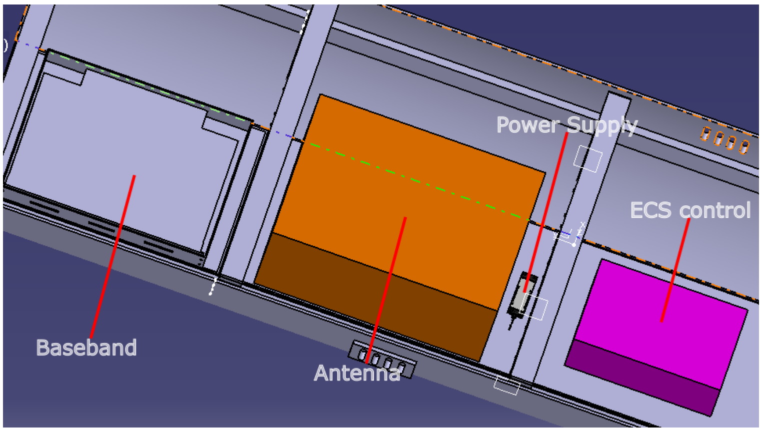

Figure 2.3: Systems included inside POD

The first step in defining the sizing is to outline the equipment that needs to be integrated into the POD design. The following components are proposed for this purpose:

- **5G Antenna:** Orange
- **Baseband:** Gray
- **Common Power Supply**
- **ESC (Electronic Speed Controller):** Pink

2.5 Definition of POD Environmental Control System (ECS)

The POD is designed with an inlet nozzle that will serve as the main access for internal cooling air. In the intermediate separating sections, air flow holes are provided both in the separating layer and near the junction of the separating layer and the POD enclosure.

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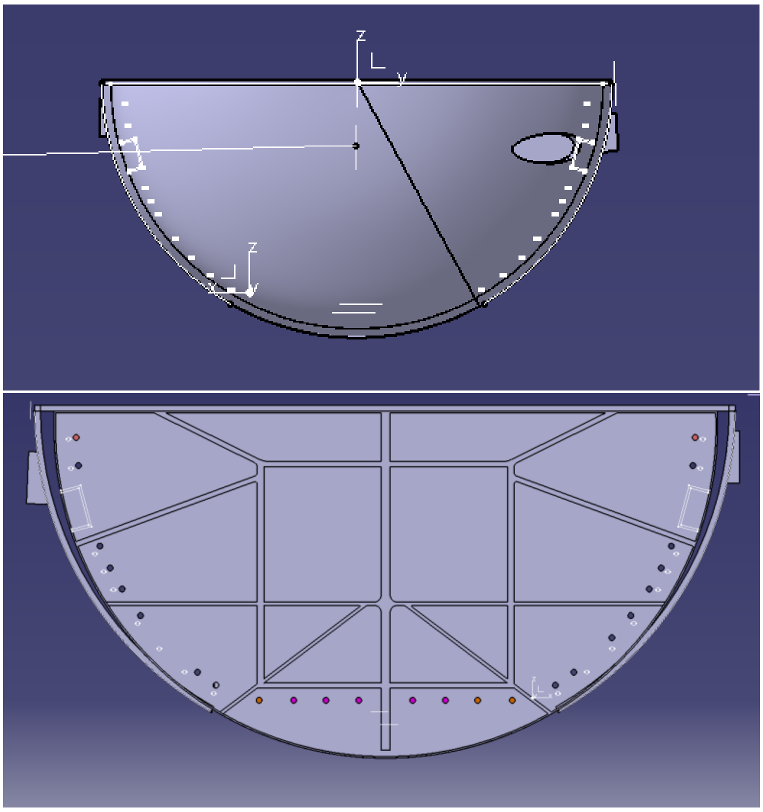

Figure 2.4: Elevation of the POD (upper) and section of the POD (down)

The system must occupy a sufficient length to be attached to the lower part of the wing in question. In addition, air outlets are provided on the sides to evacuate the heat from inside the POD.

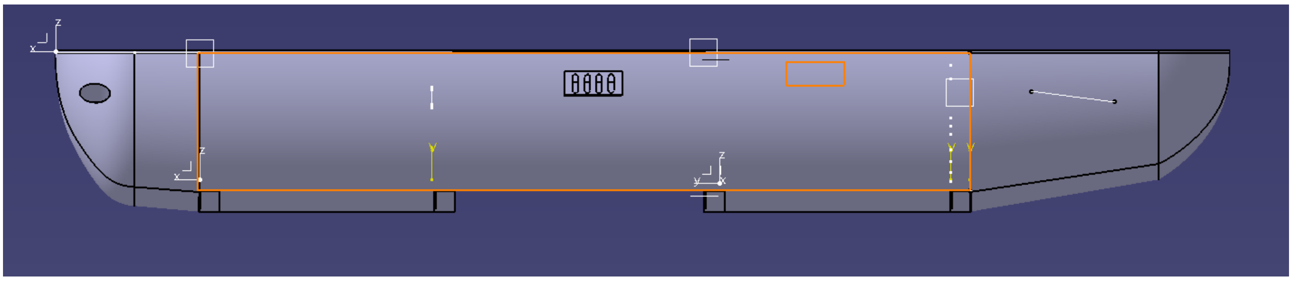

Figure 2.5: 5G&6G POD profile

The upper part will be flat and without roughness, since it will be glued to the wing, and should be as close as possible. The lower part of the POD will continue the curvature, leaving an exit opening for the 5G antenna. This opening will be covered with a continuation of the profile but made of a material permeable to the signal emission frequency.

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2.6 POD Simulations

The POD simulations are performed at two levels, first at the energy level, in order to obtain the consumption profile and the behavior of the appropriate power supply.

2.6.1 Energy Management Simulation

The simulation of the energy management for the power systems of this POD is focused on the development of a consumption profile simulator depending on the 5 and 6G operations to be carried out. For this purpose, the characteristics of the integrated antenna will be used to delimit the simulator and establish the optimal consumption profiles.

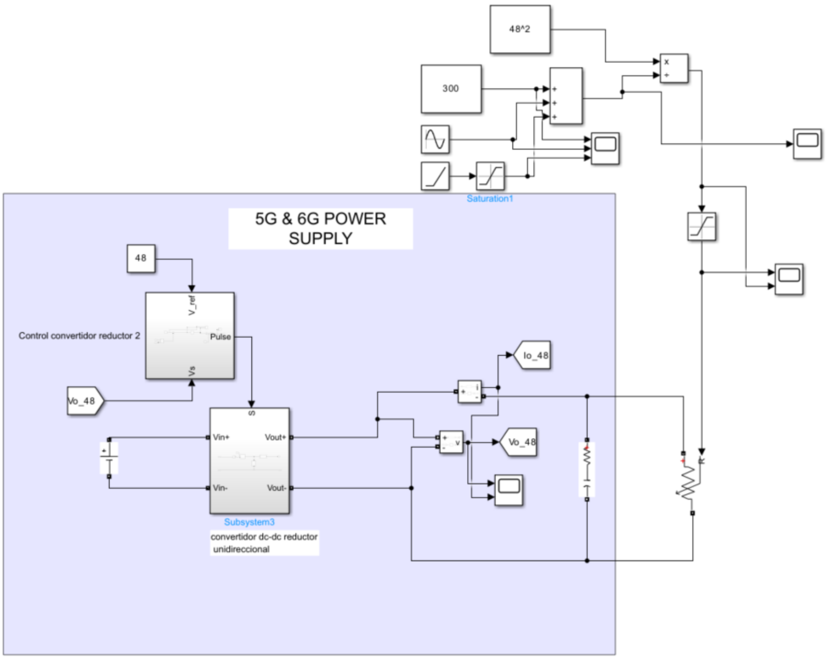

Figure 2.6: Electrical 5G&6G POD simulation model

Two simulations are presented below where the consumption of the equipment is considered for two circumstances, the first in the case of maintaining a variable data flow, so that a very high consumption is not maintained constantly.

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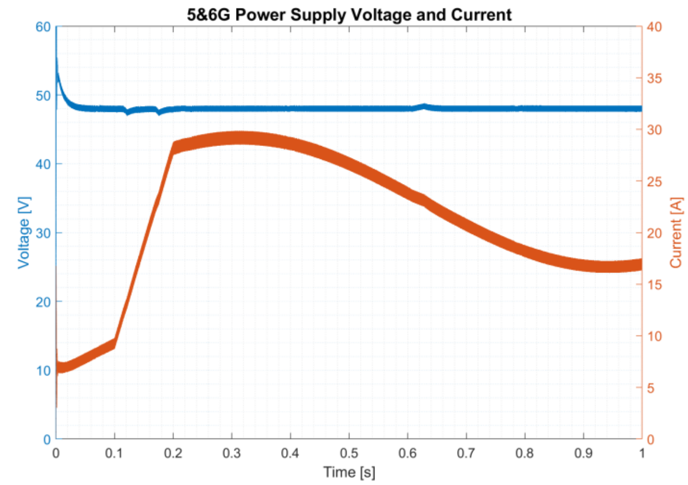

Figure 2.7: Voltage and current temporal behaviour response. 1st Case

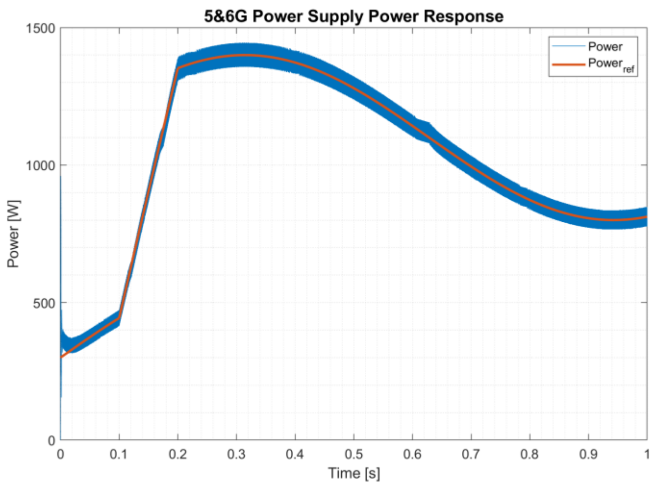

Figure 2.8: Power temporal behaviour response. 1st Case

The second case corresponds to an increasing consumption until reaching the maximum power of the antenna, thus simulating a constant high flow of data transmitted by the antenna.

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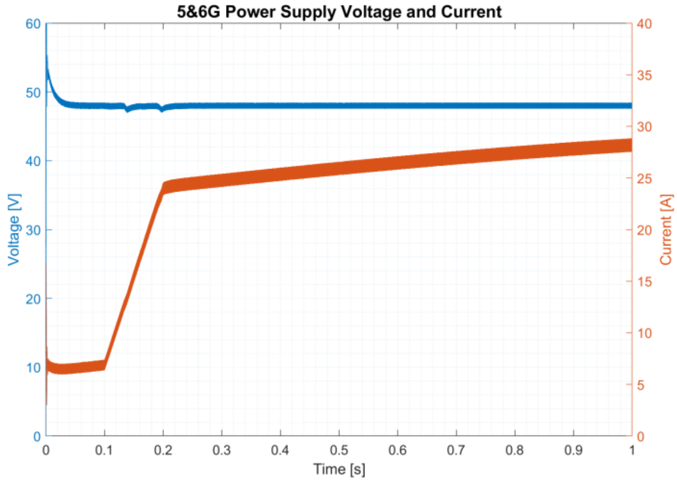

Figure 2.9: Voltage and current temporal behaviour response. 2nd Case

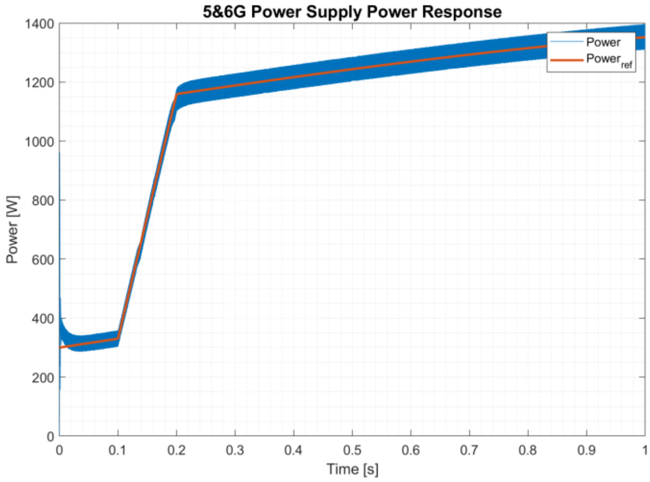

Figure 2.10: Power temporal behaviour response. 2nd Case

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3 Summary and conclusions

This concludes the conceptual preliminary design of the POD for the integration of 5G and 6G equipment on HAPS platforms, with the following key conclusions:

- **Adequate Aerodynamic Design:** A preliminary design with acceptable aerodynamic characteristics has been achieved, balancing reduced drag and structural stability. Its geometry allows for efficient integration on the platform's wings, minimizing the impact on overall aerodynamic performance.

- **Space Optimization:** The POD design prioritizes the efficient use of internal space, enabling the effective arrangement of onboard equipment, including the 5G antenna, baseband, ESC, and common power supply. This approach ensures a robust structural assembly while facilitating maintenance and future upgrades of the components.

- **Positive Energy Assessment:** Based on the performed energy simulations, the selected power supply is confirmed to be sufficient to meet the POD's power demands under operational conditions. This ensures continuous and reliable operation during the intended missions while maintaining the system's energy efficiency.

Overall, the conceptual preliminary design meets the established objectives, providing a solid foundation for further development phases. It is recommended to proceed with more detailed studies, including structural, thermal, and additional aerodynamic analyses, to validate and optimize the design.

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