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Research on Simulation Modelling of Civil Aircraft Power System Logic Architecture

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Abstract. There are many limitations in the traditional text-based design method of aircraft power systems, which makes it difficult to meet the challenges of complex product design. In this paper, a civil aircraft airborne system simulation modelling process based on the Arcadia method is proposed, and a modelling and simulation design process such as system analysis and logic analysis is constructed. Through the modelling and simulation application of the power system, it is shown that this method has great advantages in the early R&D and design of the civil aircraft power system.

Keywords. power system; Arcadia; logic analysis; operation analysis

1. Introduction

In the current field of civil aircraft, higher design requirements are put forward for the comfort, safety, and reliability of aircraft products [1][2], which leads to higher and higher electrification and intelligence of aircraft system products, and product complexity continues to increase. There are many defects in the traditional text-based system design method [3], mainly including the text-based design scheme cannot be simulated and verified; the design scheme cannot be associated with the digital model [4][5]; the design scheme has vague descriptions, and it is difficult to ensure accuracy, etc., which cannot meet the product design needs of current complex systems [6].

In the Arcadia modelling method, functional decomposition is used as a framework for all engineering activities, thereby effectively preventing errors in the development process [7]. We tailored the Arcadia approach to our modelling objectives, primarily using systems analysis [8]. Combined with part of the operational analysis, the analysis of logical architecture is completed [9][10].

Based on previous experience in aircraft development, in the process of aircraft system design, there are problems such as unclear functional logic, incomplete requirements coverage, unclear boundaries, duplication between different requirements, and insufficient evidence for requirements confirmation. The problem occurs repeatedly. We use Arcadia modeling to conduct demand analysis, function analysis/allocation, and design synthesis. Through model-based design synthesis and function analysis, the performance simulation analysis of the system is finally realized.

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2. Airborne System Logic Architecture Modelling Process

Civil aircraft airborne systems can adopt the ARCADIA method modelling tool for system modelling. The ARCADIA method modelling process includes four processes: operation analysis, system analysis, logic analysis, and physical analysis.

2.1. Operational analysis

The purpose of the operational analysis is to understand what the aircraft is trying to do. The Arcadia method combines relevant concepts. First, it defines the tasks that the aircraft needs to be completed by the system, that is, the operational capabilities that the aircraft needs to possess. During the operational analysis phase, only the problems encountered by the aircraft, the needs of the aircraft, and the potential needs of the aircraft are analysed. There is no need to define the boundaries of the system, as the system appears in the operational analysis, defining the solution for the aircraft. The object of operation analysis is the aircraft and the activities completed by the aircraft, such as whether there are problems and deficiencies in the aircraft activities, and whether there is room for improvement. After the operation analysis is completed, the system engineer needs to organize and analyse the needs of different types of aircraft, and obtain a unified aircraft requirement specification after analysis.

2.2. System analysis

During the system analysis phase, it is studied how the system meets the needs of the aircraft. Through the refinement of the operational capabilities, the tasks that the system needs to complete in the aircraft operation analysis are clarified, the capabilities that the abstract system needs to possess are summarized, the activities that the system needs to complete are defined, and the limitations brought by the operational constraints to the system activities are considered. In the system analysis stage, it is also necessary to consider the input conditions required for the completion of system activities, that is, the external interface of the system.

2.3. Logical analysis

Logical analysis is the refinement of system functions, decomposing system functions into sub-functions, and realizing the integration and distribution of system sub-functions at the system level. Logical analysis also solves problems such as internal constraints of the system, internal functions of the system, functional relationships, specific implementation technologies, and potential technologies. At the logical level, detailed system analysis is realized, system constraints are considered, and system performance, security, and reliability indicators are balanced to obtain the best system solution.

2.4. Physical analysis

Physical analysis is to define the specific implementation of the system and consider the physical characteristics of the system to achieve the optimal design of the system in terms of quality, power consumption, and cost. In the process, how the system is implemented is considered, including the selection of system architecture with physical constraints, physical connection form, and the functions realized by each component, etc.

3. Power System Logic Architecture Modelling

In this article, the civil aircraft power supply system is taken as an example, the ARCADIA method is used for system modeling, and operation analysis and system analysis are focused on as examples to show the specific application process.

3.1. Definition of Power System Operating Capability

In this section, the operational capabilities and the relationships between operational capability entities are described. The power system should have the following operating capabilities, described in terms of operational activity order and entity order, as shown in Figure 1.

- Provide and distribute power.
- Provide indication and warning.
- Provide operation and control.
- Support ground operations.

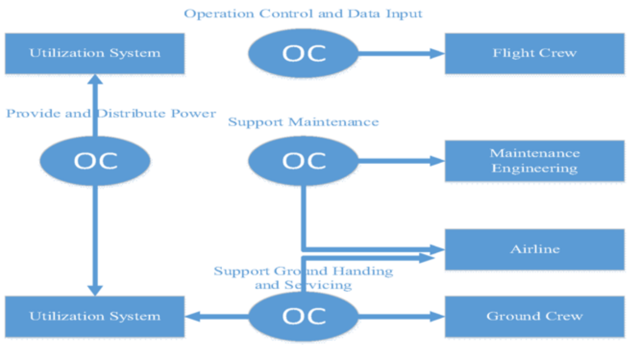

Figure 1. The Power System Operational Capability Definition Diagram

The sequence of power system activities is shown in Figure 2.

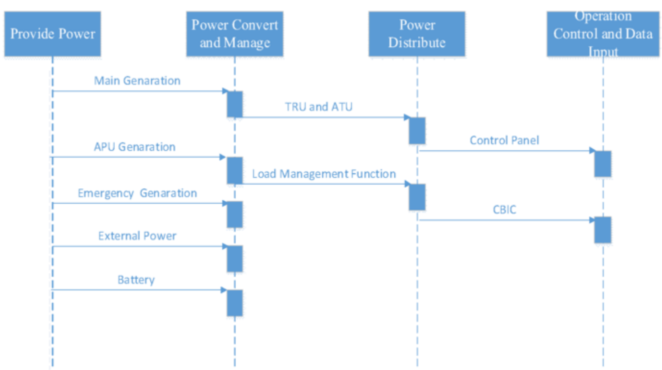

Figure 2. The sequence diagram of power system operation activities

The operating architecture of the power system is shown in Figure 3.

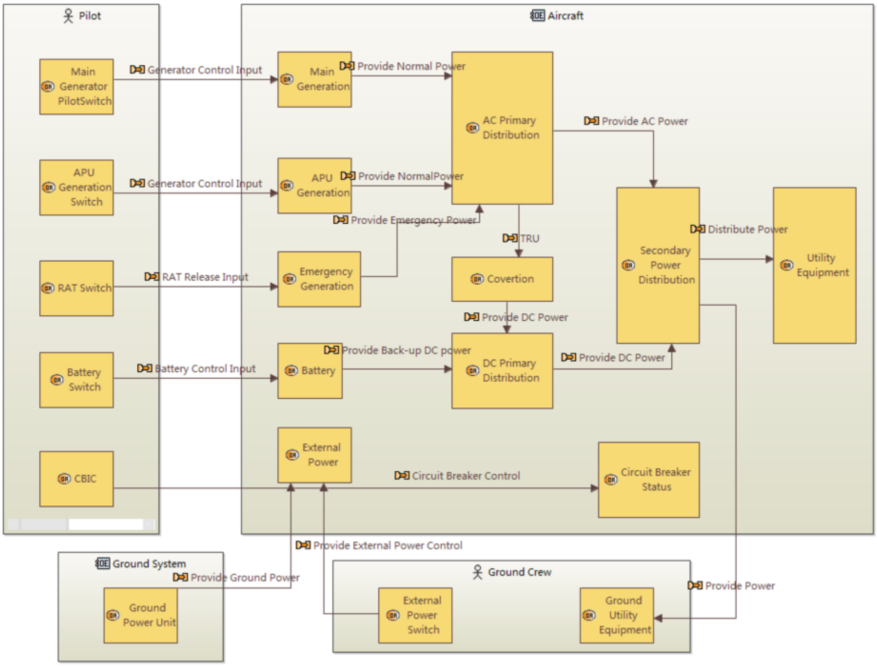

Figure 3. The Power System Operating Architecture

3.2. Power System Modeling Analysis

The functional scene analysis of the power system is shown in Figure 4.

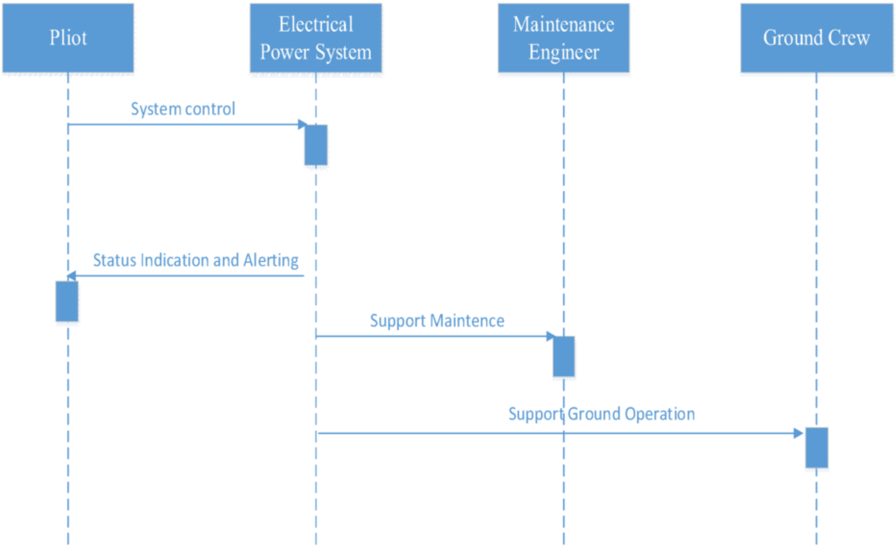

Figure 4. Power System Functional Scenario Analysis

The power system architecture is shown in Figure 5.

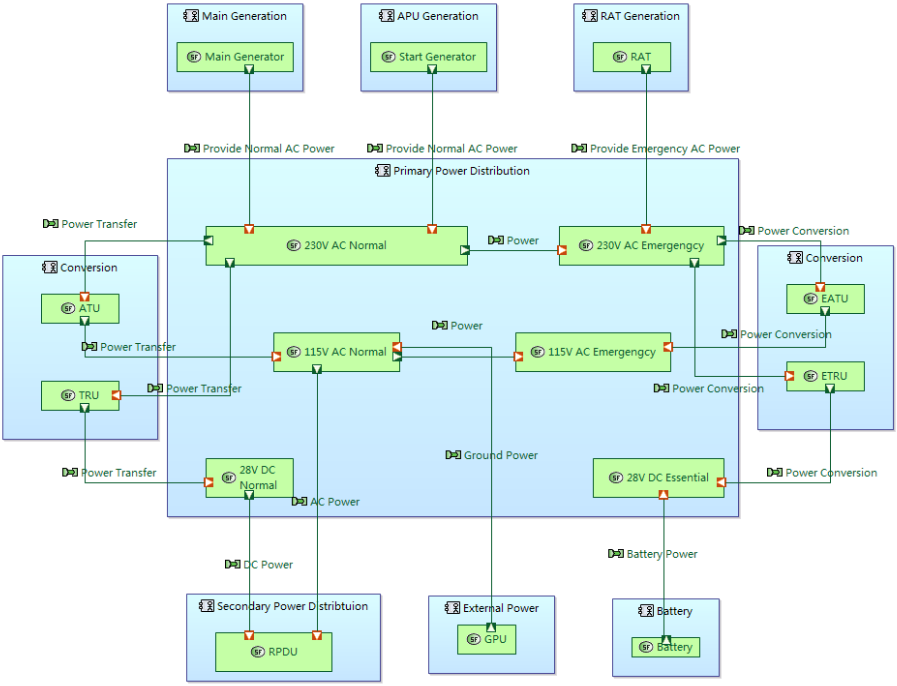

Figure 5. The Power System Architecture

4. Case Application

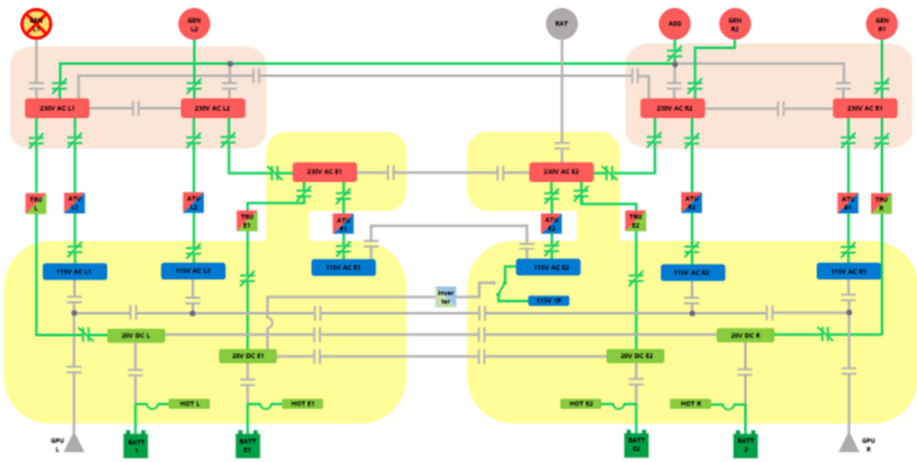

Figure 6. The single point of failure scenario for a civil aircraft power system architecture

Taking a civil aircraft power supply system as an example, a simulation model is established and tested, and some typical scenarios are selected for verification. The power supply system failure scenario to be verified in this paper is: the failure type is generator failure with GEN L1 failure injected. The scenario is described as four GENs supplying power, followed by GEN L1 failure and ASG activation. The single point of failure scenario for a civil aircraft power system architecture is shown in Figure 6. The verification results show the power system simulation model functions and logic as expected.

5. Conclusion

In this paper, a civil aircraft airborne system simulation modelling process is proposed based on the Arcadia method, which uses simulation tools to analyse the early design schemes and eliminate unreasonable schemes in the early design stage, and reduce R&D design costs. It is shown that this method has great advantages in the early R&D and design of the civil aircraft power system.

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