33RD CONGRESS
OF THE INTERNATIONAL COUNCIL
OF THE AERONAUTICAL SCIENCES
STOCKHOLM, SWEDEN, 4-9 SEPTEMBER, 2022

DESIGN OF AERO-ENGINE FADEC POWER SUPPLY CONTROL SYSTEM BASED ON FORWARD DESIGN

Shang Yang
Shanghai Aircraft Design and Research Institute，Shanghai 201210

Abstract

The aero engine FADEC generates heat when it is powered on. When the engine is running, the airflow from the inlet will cool the FADEC. When the engine is not running, the FADEC cannot be cooled by the inlet airflow. At this time FADEC power on for a long time will affect its life. This paper adopts the method of forward design to design the engine FADEC power supply control system through scenario analysis, requirement capture, scheme design to extend the service life of FADEC. In addition, the engine FADEC is closely cross-linked with other systems of the aircraft. When FADEC is powered off, it cannot send signals to other systems. Therefore, other systems need to recognize this scenario when designing to avoid possible failures and warnings.

Keywords: FADEC Power; Forward Design; Scenario Analysis; Requirement Capture

1. Introduction

The FADEC, as the aero-engine controller[1-2], is installed in the engine nacelle. There are special ventilation and cooling channels inside FADEC. When the engine is running, the airflow from the inlet will cool the FADEC. Before the engine is started or after the engine is shutdown, due to the lack of cooling airflow, the FADEC will increase the internal temperature when the power is turned on for a long time, which will affect the life of the FADEC. Especially, the heat soakback after engine shutdown will have a greater impact on the life of FADEC. Therefore, it is necessary to control the power supply of FADEC, not only to ensure that FADEC can perform the corresponding functions normally, but also to extend the service life of FADEC.

2. Scenario analysis

In order to capture the design requirements of the FADEC power supply control system as comprehensively as possible, the scenarios related to the FADEC power supply control function should first be identified.

When performing scenario recognition, all possible scenarios during the entire life cycle of the aircraft, such as different flight phases, ground maintenance, and route operations, should be considered.

Through analysis, the scenarios involved in the FADEC power supply control function are shown in Table 1.

Table 1 Scenarios related to FADEC power supply control function

No.	Scenario
1	Initial cockpit preparation
2	Engine start

No.	Scenario
3	Engine dry motoring
4	Engine wet motoring
5	The aircraft is in the air
6	Engine shutdown
7	Ground maintenance

3. Requirement capture

The following analyzes the scenarios listed in Table 1 one by one to capture the requirements of each scenario.

a) In the initial cockpit preparation scenario, the pilot needs to check some parameters of the engine through the cockpit EICAS screen, such as the oil quantity, to ensure that the oil quantity meets the requirements for aircraft release. Therefore, capture the following requirement: When the aircraft is powered on, FADEC shall be powered on for a certain period of time to check the engine parameters.

b) In the engine start scenario, FADEC needs to be powered on to realize the control function of the engine. Therefore, the following requirement are captured: When the engine starts, FADEC shall remain powered on to realize the engine control function.

c) In the engine dry motoring scenario, FADEC needs to be powered on to realize the control function of the engine. Generally, the time for a engine dry motoring is within 5 minutes. When the engine dry motoring ends, FADEC needs to be powered off to extend its service life. Therefore, the following two requirements are captured: When the engine is dry motoring, FADEC shall remain powered on to realize the engine control function; when the engine dry motoring is over, FADEC shall be powered off to extend the service life of FADEC.

d) In the engine wet motoring scenario, FADEC needs to be powered on to realize the engine control function. Therefore, the following two requirements are captured: When the engine is wet motoring, FADEC should remain powered on to achieve the engine control function; when the engine wet motoring is over, FADEC shall be powered off to prolong the service life of FADEC.

e) When the aircraft is in the air, from the perspective of safety, FADEC needs to be powered on all the time. Therefore, the following requirement are captured: When the aircraft is in the air, FADEC shall be powered on to achieve engine control and air start functions.

f) In the engine shutdown scenario, the heat soakback will be generated after the engine is shut down. If the FADEC is powered on at this time, it will seriously affect the life of the FADEC. However, considering that FADEC needs to transmit data to the aircraft just after the engine is turned off, the power cannot be cut off immediately. Therefore, capture the following requirements: When the engine is turned off, FADEC shall be powered off after 5 minutes (assuming that FADEC completes data transmission within 5 minutes) to ensure that FADEC can transmit in-flight data to the aircraft and extend the service life of FADEC.

g) In the ground maintenance scenario, the maintenance crew often needs to check the engine data and power on the FADEC. After the check, the FADEC needs to be powered off. Therefore, capture the following two requirements: During ground maintenance, FADEC shall be powered on in a certain way; at the end of ground maintenance, FADEC shall be powered off in a certain way.

Through the above analysis, a total of 10 FADEC power supply control system design requirements have been captured, as shown in Table 2.

Table 2 Design requirements of FADEC power supply control system

No.	Requirement
1	When the aircraft is powered on, FADEC shall be powered on for a certain period of time to check the engine parameters.
2	When the engine starts, FADEC shall remain powered on to realize the engine control function.
3	When the engine is dry motoring, FADEC shall remain powered on to realize the

No.	Requirement
	engine control function.
4	When the engine dry motoring is over, FADEC shall be powered off to extend the service life of FADEC.
5	When the engine is wet motoring, FADEC should remain powered on to achieve the engine control function.
6	When the engine wet motoring is over, FADEC shall be powered off to prolong the service life of FADEC.
7	When the aircraft is in the air, FADEC shall be powered on to achieve engine control and air start functions.
8	When the engine is turned off, FADEC shall be powered off after 5 minutes (assuming that FADEC completes data transmission within 5 minutes) to ensure that FADEC can transmit in-flight data to the aircraft and extend the service life of FADEC.
9	During ground maintenance, FADEC shall be powered on in a certain way.
10	At the end of ground maintenance, FADEC shall be powered off in a certain way.

4. FADEC power supply control system design scheme

4.1 FADEC power supply control system design scheme

A permanent magnet generator (PMA) is installed on the engine[3]. When the engine speed is greater than a certain value, PMA can provide power for FADEC. When the engine is not running, the aircraft power supply provides power for FADEC. When the engine is running, PMA provides power for FADEC, and the aircraft power supply provides backup power for FADEC.

The design architecture of the FADEC power supply control system is shown in Figure 1. The cockpit switches involved are: engine start switch, FADEC maintenance power switch, fuel control switch, and the participating control equipment is EICU.

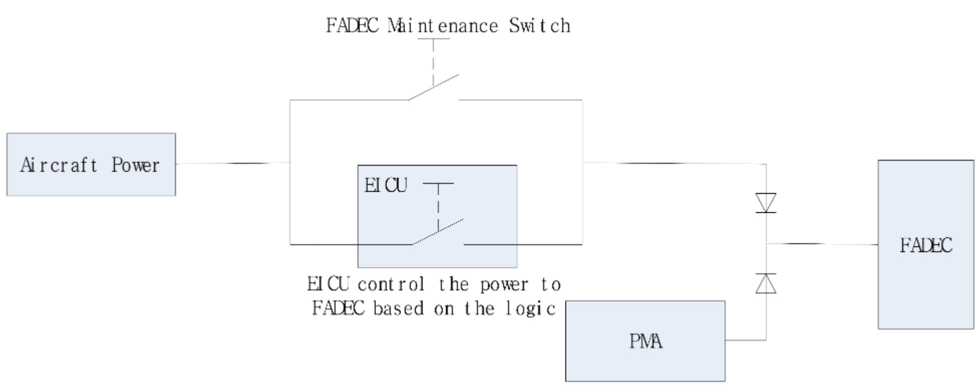

Figure 1 FADEC power supply control system design architecture

The power supply of FADEC is controlled in the following two ways.

a) Control FADEC power supply through the FADEC maintenance power switch: Press in the FADEC maintenance power switch on the top panel of the cockpit, and the aircraft power supply will keep supplying power to FADEC. Press out the FADEC maintenance power switch, the aircraft power supply will stop supplying FADEC.

b) Automatically control FADEC power supply through EICU: EICU automatically controls the aircraft to power on or off FADEC according to the control logic. The control logic is:

1) When the aircraft is first powered on, the EICU controls the aircraft power supply to power on the FADEC for 15 minutes. During this period, if the fuel control switch or engine start switch is not operated, the EICU controls the aircraft power supply to power off the FADEC; during the period, if

the fuel control switch or engine start switch is operated, EICU will control the aircraft power supply to continue powering FADEC until the final power-off logic is executed.

2) Turn the fuel control switch from CUTOFF position to RUN, the EICU controls the aircraft power supply to continue powering on the FADEC. Turn the fuel control switch from RUN position to CUTOFF, EICU controls the aircraft power to power off FADEC after 5 minutes,

3) Press the engine start switch, the EICU controls the aircraft power supply to supply power to FADEC, and after 5 minutes, the EICU controls the aircraft power supply to power off FADEC.

4) When the aircraft is in the air, the EICU continues to supply power to FADEC.

4.2 The compliance check of design scheme to requirements

Analyze the above scheme to determine whether it meets the design requirements of the FADEC power supply control system. The detailed analysis process and results are shown in Table 3.

Table 3 The compliance check of the plan to the requirements

No.	Requirements	Description of the scheme compliance to the requirements	Whether the scheme meets the requirements
1	When the aircraft is powered on, FADEC shall be powered on for a certain period of time to check the engine parameters.	When the aircraft is just powered on, the EICU controls the FADEC to be powered on for 15 minutes to check the engine parameters.	Yes
2	When the engine starts, FADEC shall remain powered on to realize the engine control function.	When the fuel control switch is set to the RUN position, the EICU controls the FADEC to continue to be powered on.	Yes
3	When the engine is dry run, FADEC shall remain powered on to realize the engine control function.	By pressing the engine start switch to control the dry motoring of the engine. When the start switch is pressed, the EICU controls the FADEC to be powered on for 5 minutes.	Yes
4	When the engine dry run is over, FADEC shall be powered off to extend the service life of FADEC.	By pressing the engine start switch to control the dry motoring of the engine. When the start switch is pressed, the EICU controls the FADEC to be powered on for 5 minutes.	Yes
5	When the engine is wet motoring, FADEC should remain powered on to achieve the engine control function.	Manually disconnect the igniter circuit breaker, and execute the engine wet motoring by operating the fuel control switch. When the fuel control switch is turned from CUTOFF to RUN position, EICU controls FADEC to be powered on continuously.	Yes
6	When the engine wet run is over, FADEC shall be powered off to prolong the service life of FADEC.	Manually disconnect the igniter circuit breaker, and execute the engine wet running by operating the fuel control switch. When the fuel control switch is turned from RUN to CUTOFF position, EICU controls FADEC to be powered off after 5 minutes.	Yes
7	When the aircraft is in the air, FADEC shall be powered on to achieve engine control and air start functions.	When the aircraft's WOW signal is in the air, the EICU controls the FADEC to be powered on continuously.	Yes

No.	Requirements	Description of the scheme compliance to the requirements	Whether the scheme meets the requirements
8	When the engine is turned off, FADEC shall be powered off after 5 minutes (assuming that FADEC completes data transmission within 5 minutes) to ensure that FADEC can transmit in-flight data to the aircraft and extend the service life of FADEC.	When the engine fuel control switch is turned from RUN to CUTOFF, EICU controls FADEC to be powered off after 5 minutes.	Yes
9	During ground maintenance, FADEC shall be powered on in a certain way.	By pressing in the FADEC maintenance power switch, the aircraft can power on the FADEC.	Yes
10	At the end of ground maintenance, FADEC shall be powered off in a certain way.	By pressing out the FADEC maintenance power switch, the aircraft can power off the FADEC.	Yes

Through the analysis, the FADEC power supply control system design scheme can realize all the requirements of the FADEC power supply control function, so the scheme meets the requirements.

5. Cross-linking system design considerations

The engine FADEC has a cross-linking relationship with many aircraft systems. When the FADEC is powered off, it cannot send signals to the cross-linking system. Therefore, the cross-linking system needs to consider the scenario of FADEC power off when designing.

Take the flight control system as an example, when the FADEC signal is not received, it will trigger the flight control no dispatch EICAS message. Therefore, when designing the flight control system EICAS messages, this type of EICAS message caused by the expected power off of FADEC should be suppressed.

Take the flight management system as an example, in the cockpit preparation phase, the pilot needs to enter data such as flexible temperature through the CDU and send it to FADEC. In the airlines, the engines will be started after the passenger boarding and aircraft push back is completed. It may take more than 15 minutes before the aircraft is powered on, and the FADEC will lose power. When FADEC is powered on again, it needs to re-enter data such as flexible temperature, which will increase the workload of the pilot or even fail to input flexible temperature data again. Therefore, the flight control system shall be able to record data such as the flexible temperature of the current flight, and sent it to FADEC after FADEC is powered on.

Therefore, when designing the aircraft, the FADEC power supply control requirements and solutions should be passed to the FADEC cross-linked system for evaluation, and corresponding designs should be adopted to avoid problems such as failures and warnings due to FADEC's expected power off.

6. Conclusion

This paper adopts the method of forward design to design the FADEC power supply control system in accordance with the process of scenario analysis, requirement capture, scheme design, etc., to improve the design quality and reduce a series of problems caused by incomplete requirement capture. At the same time, FADEC cannot send out signals after power off, which will cause related problems in the cross-linking system. This paper also gives some suggestions on the design of the cross-linking system.

References:

[1] Zhang Shaoji. A Review of Aeroengine Control System[J]. Journal of Aerospace Power. 2004, 19(3):375-382.

[2] Wang Xi,Cheng Yin. Development of Thrust Control Technology for Foreign Aeroengine[J]. Aeroengine. 2009, 35(3): 4-7.

[3] Jin Yamei. Research on Optimization Design of High-Speed Permanent Magnet Generator Applied to Micro Turbojet Engine[M]. Nanjing University of Aeronautics and Astronautics. 2019.