



“APISAT2014”, 2014 Asia-Pacific International Symposium on Aerospace Technology,
APISAT2014

Research on Probabilistic Safety Analysis Approach of Flight Control System based on Bayesian Network

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Abstract

Traditional probabilistic safety analysis methods are not suitable for modern flight control system with multi-state probability. In this paper a Bayesian Network based probabilistic safety model is built according to the state relationship between flight control system and its constituting components. A safety probability algorithm is proposed by using Universal Generating Function (UGF) combined with Clique Tree Propagation. The probability of system top failure condition and the importance of each constituting component are acquired efficiently, the safety level of the flight control system can be assessed and the role of each component in the system safety can be determined. The probabilistic safety analysis approach based on Bayesian Network provides a simple and intuitive measure to deal with the safety analysis of flight control system with multi-state property, which overcomes the deficiencies of traditional approach.

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Peer-review under responsibility of Chinese Society of Aeronautics and Astronautics (CSAA)

Keywords: Flight control system; Bayesian network; Universal Generating Function; Multi-state System

1. Introduction

Safety analysis is an important method to demonstrate compliance with airworthiness requirement in type certification. At present, Fault Tree Analysis, Markov Analysis and Dependence Diagram Analysis are the most widely-used methods of probabilistic safety analysis for civil airborne system [1]. All these methods are based on

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traditional binary model allowing for only two possible states for a system and its components: perfect functionality and complete failure. However, flight control system of modern civil aircraft is a typical integrated and complex system that consists of mechanical, electronic, electrical, and hydraulic components; and the diversity of these constituting components cause the system to have different performance levels and several failure modes with various effects on the entire system performance. Therefore, all of the above mentioned probabilistic safety analysis methods are not suitable for modern flight control system. The probabilistic safety analysis approach proposed herein can be applied to the safety analysis of flight control system with multi-state property.

We will establish a probabilistic safety model based on Bayesian Network to describe the multi-state property of modern flight control system [2]; and then, in terms of the model, we will present a safety probability algorithm which can be used to calculate the probability of system top failure condition and importance of each component constituting the system.

2. General architecture and failure feature of flight control system

The flight control system is commonly composed of three types of subsystem: Sensor subsystem, control computer subsystem and actuator subsystem. In the Fig. 1, the general architecture of flight control system is shown.

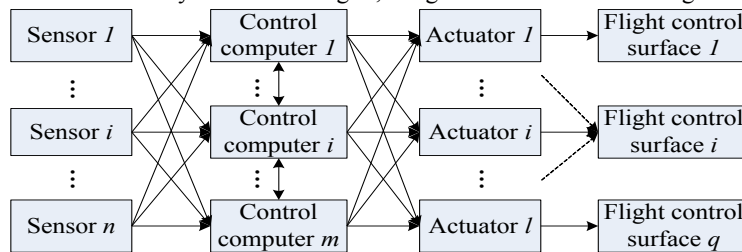


Fig. 1. General architecture of flight control system.

- Sensors collect the signals that are available to the flight control progress and provide these signals to the control computers. The failure features of sensors can be divided two modes: mistake signals output and the function of output signals get failed.
- Control computers receive the output signals of sensors and output the control signals to the actuators to the flight control surface. The failure feature of control computers can be divided two modes: mistake signals output and computing control signals function fail. While failure feature of the control computers' power is that providing power function fail.
- Actuators receive the signals from control computer and move the surfaces to the corresponding position. The failure feature of actuators can be divided two modes: part of actuating function lost, full actuating function lost. While the failure features of hydraulic pressure system that provide hydraulic pressure to the actuators can be divided two modes: part of providing pressure function fail, full providing pressure function fail.

3. Bayesian Network based probabilistic safety model of flight control system

In this paper UGF is used to describe the multi-states and series-parallel structures to build the Conditional Probability Table (CPT) of the Bayesian network. The UGF polynomial expression of the multi-state units or systems like [3,4]:

$$U_s(z) = \sum_{j_s=0}^{k_s} p_{s_j} z^{g_{s_j}} \quad (1)$$

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