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OPTIMAL NAVIGATION SATELLITE CONSTELLATION SPARE STRATEGY BASED ON PETRI NET

Abstract

Purpose

Satellites spare strategy is essential to global satellite navigation system. It can provide assurance for position, navigation, and timing services, in case of satellite failure, satellite maintenance, etc. Nowadays, GPS and GLONASS are in the phase of modernization, BDS and Galileo will be set up. This paper investigates on the optimal spare strategy for Walker constellation in the medium Earth orbit.

Approach

Firstly, the up-to-date spare statuses of GPS, GLONASS, Galileo and BDS are summarized, and the main spare models are analyzed, including on-orbit spare model, parking orbit spare model, and ground spare model. Then, a new satellite reliability model based on dynamic fault tree is put forward. The dynamic fault tree model of three subsystems of satellite power, attitude and orbit control and propulsion is established by combining Markov chain and binary decision diagram. The random fault model of satellite is given, and the reliability model of satellite is established by considering the depletion fault. Monte Carlo simulation is used to evaluate and analyze the random fault model, and its performance is compared with Weibull distribution model. Thirdly, the system availability model is established by using Petri Net, which can reflect the constellation operational status during ten years. Different scenarios are analyzed, including the scenario with no spare satellite, only with ground spare and both on-orbit spare and ground spare. Finally, the on-orbit spare satellite phases are optimized for different cases, including one on-orbit spare satellite per plane, two on-orbit spare satellites per plane. A combined objective function is put forward, including the maneuvering time and maneuvering fuel comsumption. Genetic algorithm is adopted to solve the problem.

Practical implications

One aim of this research is to provide theoretical basis for satellite spare issue of global satellite navigation system, the other is to provide important technical support for engineering practice.

Results

Simulations show that the new satellite reliability model based on dynamic fault tree is effective, which is beneficial for predicting the weakest aspects of navigation satellite. The Petri Net model can be used to establish the various constraints during navigation satellite operational time, and the on-orbit spare satellite phase optimization model is effective.