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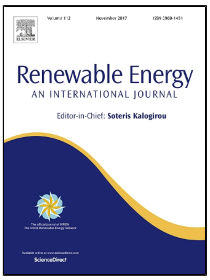

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Renewable Power System Simulation and Endurance Analysis for Stratospheric Airships

Xixiang Yang*, Duoneng Liu

Abstract: Composition of renewable power system for stratospheric airships is introduced, curved paving model of solar array is established, the high accuracy calculation method for output power of solar array is proposed, and operation process of renewable power system is simulated. On basis of this, endurance of the stratospheric airship is evaluated, and the influence of some important factors on endurance is analyzed, including wind resistance strategy, photoelectric transformation efficiency of solar array and the specific energy of lithium battery. Simulation results show that, 1) endurance of the stratospheric airship can be improved by adjusting power sequential during day and night with maneuverable wind resistance strategy, for the case in this paper, endurance increases 24.2 hours compared with fixed point wind resistance strategy, 2) endurance can be greatly improved in a certain range through increasing photoelectric transformation efficiency of solar array and the specific energy of lithium battery, for cases in this paper, endurance increases 73.5 hours and 47.5 hours respectively, 3) to realize closed cycle of renewable power system during day and night, attenuation of radiation flux with the change of date must be considered in design of renewable power system, and sufficient redundancy should be designed for solar array.

Keywords: Stratospheric airship; renewable power system; solar array; endurance; wind resistance strategy

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1 Introduction

Stratospheric airships are lighter-than-air (LTA) controllable flight vehicles flying around the altitude 20 km, where wind speed is less intense and the wind direction is relatively stable[1,2]. Stratospheric airships can provide wide-area observation and surveillance for months at a time, neither satellites nor aircrafts have this ability. In recent years, many countries all over the world have attempted to develop stratospheric airships or associated systems, including the HAA and Hisentinel project in USA [3,4], SPF project in Japan[5], Stratobus project in France[1], and so on.

Renewable power system is one of the most critical subsystems for stratospheric airships, because it has major impact on flight duration, wind resistance ability and payload capacity. Renewable power system mainly consists of solar array, power storage system and power management system, in which the solar array often uses thin film solar cell, and the power storage system selects lithium batteries or hydrogen/oxygen fuel cells.

For both renewable power system design and stratospheric airships conceptual design, it is important to evaluate endurance based on the operation process simulation of renewable power system, in which the relation among solar energy, energy storage and energy consumption is simulated. The thin film solar array is placed on the curved shape of the stratospheric airship, output power of it varies with the latitude, season, time of day and attitude angle during flight, meanwhile, power consumption of propulsion and flight control system depends on environmental wind field and wind resistance strategy. As a result, the simulation of renewable power system and analysis of endurance for stratospheric airships become very complex, and some studies have been performed on related problems in recent years. Lobbia researched conceptual design of a high-altitude/long-endurance airship using a solar/battery power system, in which the power generation of solar array was calculated taking into account the effect of season, latitude and type of solar panel[6], Ozoroska performed similar studies[7]. Colozza analyzed the effect of renewable power system technologies on sizing and capabilities of stratospheric airships, where the solar array was assumed to be on the upper surface of the cylinder portion of the airship, and output power was calculated[8]. Bents studied conceptual design of long-duration low-to-medium-altitude solar electric airships, in which power requirement and mass of lightweight photovoltaics and fuel cells were approximately determined[9]. Lubkowski investigated five different solar power technologies for stratospheric airships using simple analysis model[10]. Zheng et al proposed both an approximation analytical method and a numerical method to compute power generated by the cylindrical solar array of a stratospheric airship, and analyzed effects of latitudeand attitude on the output power[11], Shi et al conducted similar studies[12]. Zhang et al researched the simulation and design of renewable power system of a stratospheric airship, developing a method to estimate area of solar array and mass of lithium batteries[13]. Li et al analyzed the output performance of solar array on stratospheric airships considering the thermal effect, and established thermal model, incident solar radiation model on the solar array, and power output model[14]. During the research on conceptual design of a solar-powered hybrid airship, Zhang et al developed a photovoltaic array model on the curved envelope[15]. Lv et al. designed the optimal solar array layout on stratospheric airships, in which a numerical method for calculating the output power of solar array on curved envelope[16]. Meanwhile, many studies haved been performed on solar powered aircrafts which also adopt renewable