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Invited Paper

A novel design project for space solar power station (SSPS-OMEGA)

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ABSTRACT

The space solar power station (SSPS) capable of providing earth with primary power has been researched for 50 years. The SSPS is a tremendous design involving optics, mechanics, electromagnetism, thermology, control, and other disciplines. This paper presents a novel design project for SSPS named OMEGA. The space segment of the proposed GEO-based SSPS is composed of four main parts, such as spherical solar power collector, hyperboloid photovoltaic (PV) cell array, power management and distribution (PMAD) and microwave transmitting antenna. Principle of optics, structure configuration, wired and wireless power transmissions are presented.

1. Introduction

The SSPS concept was firstly introduced by Dr. Peter Glaser in 1968 [1]. The basic idea is that sunlight is collected and converted into electricity in space, and then transmitted to the ground-receiving antenna via wireless power transmission (WPT). It is a promising methodology to provide earth with primary power.

Since the invention of SSPS concept, there have been numerous research activities. As far as design project of SSPS is concerned, a few innovative design concepts, such as Reference model, Sun tower, Sun sail, JAXA models, Tethered SPS, etc., have been proposed by the scientists and engineers from the US, Japan and Europe [2,3,4,5]. Typical SSPS concepts can be divided into three kinds according to their difference on focusing methodologies: such as non-focusing, point-focusing and distributed focusing. The NASA/DOE reference model [6], put forward in 1979, is a typical one of non-focusing. The model consists of a single large solar array about 50,000 m^2 in area, a microwave transmitting antenna, and a high-power rotary joint mechanism. The shortcoming is the excessive initial investment. Another one is the Tethered Solar Power Satellite [7,8], proposed by Japanese government METI and USEF, a concept to reduce the system complexity and mass. It is composed of a power generation/transmission panel of 2.0 km × 1.9 km suspended with multi-wires deployed from a bus system. The panel consists of 400 subpanels of 100 m × 95 m. However, low efficiency and large fluctuation on energy collecting curve are the obvious disadvantages. Typical concepts of point-focusing are Integrated Symmetrical Concentrator (ISC) and Symmetrical Two-stage Flat reflected Concentrator (STFC) [4]. ISC utilizes large, symmetrically placed off-axis parabolic reflectors whilst receiving surface being placed on the focal plane. By integrating the PV cell array, microwave devices and transmitters into sandwich structure and making use of secondary reflectors, an improved concept named STFC was proposed which is good for receiving a high degree of distribution uniformity and a suitable condensation ratio by adjusting the parameters of the main reflectors, secondary reflectors and receiving plane [9]. However, high-power rotating mechanism and complicated control strategies are

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Table 1
Typical SSPS concepts.

	Reference model [11]	Sun tower [12]	Solar disc [4]	ISC [4]	Sun Sail [4]	Tethered- SSPS [8]	ALPHA [13]
Year	1979	1995	1997	1998	1999	2001	2012
Organization	NASA/ DOE	NASA	NASA	NASA	ESA	METI/ USEF	Artemis
Orbit	GEO	LEO	GEO	GEO	GEO	GEO	GEO
Power (GW)	5	0.1–0.4	1–10	1.2	0.275	0.75	2
Frequency (GHz)	2.45	5.8	5.8	2.45	2.45	5.8	2.45
Mass (MT)	30,000–50,000	2000–7000	8000–70,000	35,000	3750	3800	25,260*
Focus	Non	Point	Non	Point	Non	Non	Distributed
Modularity	Monolithic	Modular	Monolithic	Modular	Modular	Modular	Modular

* The data is from the ALPHA DRM 5/Case_4B, a mature full-scale SSPS with 2 GW power for commercial markets, which might to be realized at least 30 years.

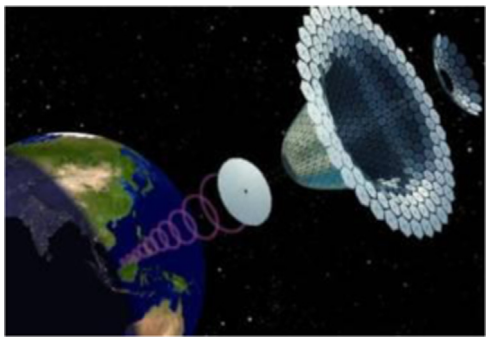

Fig. 1. Basic architecture of the ALPHA concept.

needed for both ISC and STFC. The ALPHA (Solar Power Satellite via Arbitrarily Large Phased Array) [10], proposed by John C. Mankins, is a hyper-modular design of distributed focusing. Thousands of individually pointed light weight thin-film mirrors redirect sunlight to a high-efficiency photovoltaic array. Typical concepts are summarized and compared in Table 1.

2. SSPS-ALPHA concept

Biomimetic and hyper-modular design have been introduced in the architectural design of the ALPHA, a concept which is thought to be the first practical and one of the most advanced SSPS. The basic concept is to form an exceptionally large space platform from an extremely large number of small, high modular elements using the idea of cooperative behavior.

2.1. Architecture

Fig. 1 shows the basic architecture of the space segment of the ALPHA, which is comprised of three major functional elements: (1) a large sandwich structure with antenna surface toward earth. (2) a solar energy collecting system involving a large number of individually reflectors mounted on a non-moving primary structure; and (3) a truss structure that connects these two.

2.2. Principles of optics

Operating in the GEO, the sandwich structure is always pointing toward earth. A large number of flat reflectors that act as individually pointing “heliostats” [14] are steered to reflect the sunlight into the PV cell array. Fig. 2 illustrates the structure of the reflectors and its operational principle.

Some schemes of the ALPHA have been proposed varying from the different approaches to the primary structure configurations, the newest one among which is the 2013 version [10]. The main reflector is created by

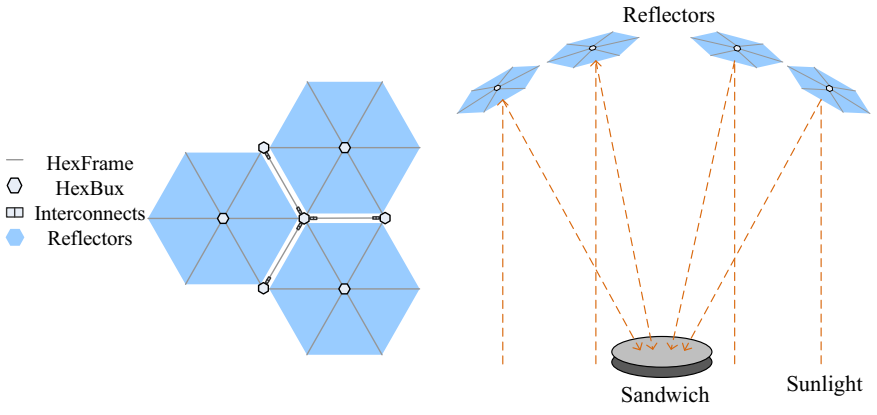

Fig. 2. Structure and adjustment of the reflectors.