Space Based Solar Power (SBSP): An Emerging Technology

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Abstract—This study presents Space Based Solar Power, an emerging technology which is under a heavy research phase. Here geosynchronous satellites are used for collecting sunlight, harnessing it to produce solar power and transmitting the generated power back to Earth using Wireless power transmission (WPT), safely and reliably. The advantage of placing solar cells in space is the 24 hour availability of sunlight. Also the urgency of finding an alternative energy source due to the depleting energy resources on earth calls for Space Based Solar Power. Here we study the concept of Solar Power Satellites (SPS), investigate the feasibility of implementation, the overall architecture & the underlying components. The results highlight the effectiveness of this system as an environment friendly, low-loss and large-scale method of energy transfer.

Index Terms—DCRF-DC Radio Frequency, MPT-Microwave Power Transfer, MW-Microwave, RFID-Radio Frequency Identification, SPS-Space Power Satellites, TWT-Travelling Wave Tube, WPT-Wave Power Transfer

1 Introduction

A recent survey conducted on consumption of the existing oil reserves on earth revealed shocking facts that if we keep consuming oil at the current rate, the oil wells might dry up within the next 65 years. This situation certainly demands for an alternative energy source for future generations. The advent of solar cells gave an impetus to harnessing the solar power as a renewable energy resource. But the drawback of solar cells on earth is non-availability of sunlight at night. Another disadvantage of solar panels on earth is the obstruction of sunrays due to the clouds. The solution to these difficulties in producing solar power on Earth is the use of Solar Power Satellites (SPS) .The solar power satellites are an integral part of Space Based Solar Power (SBSP) .The SPS are illuminated by the Sun for 99% of the time in a year except for a short duration during equinox. Also the microwave power can pass through the clouds and other barriers and thus is an unobstructed source of energy

2 Solar Power Satellite (SPS) concept

The idea of the Solar Power Satellite energy system is placing giant satellites, with wide arrays of solar cells embedded on them, 22,336 miles above the Earth's surface in the geosynchronous orbit. Every satellite thus will be illuminated by sunlight 24 hrs a day for most of the year. Because of the 23" tilt of the Earth's axis, the satellites pass either above or below the Earth's shadow. The equinox period in both spring and fall is the only time that they will be cast by the shadow. They will be shadowed for less than 1% of the time during the year [1]. Dr. Peter Glaser of Arthur D. Little Inc., was the pioneer in introducing the concept of placing huge SPS in the GEO (Geostationary Earth orbit) which can harness the sunlight, turn it into a electromagnetic beam, and transmit this energy to the Earth in form of microwaves. After establishment of this concept in 1968, NASA supported a research project undertaken by Department of Energy of the United States of America, in the years following 1976 [2].

3 Wireless power transmission

In the year 1893, World Columbian Exposition in Chicago witnessed a demonstration by Nikola Tesla which involved the illuminating vacuum bulbs without the use of wires [3]. William C. Brown, the pioneer in wireless power transmission technology, had designed, developed a unit and demonstrated to show how power can be transferred through free space by microwaves. Brown published the first paper proposing wireless power transmission in 1961. And later in the year 1964 he demonstrated a microwave-power driven model helicopter that entirely received the power needed to fly from a microwave beam at 2.45 GHz [4] which lies in the ISM band. Point-to-point power transmission is typical characteristic of WPT. It was shown that the power transmission efficiency can reach almost near to 100% [5].

4 Wireless power transmission system

4.1 Microwave Generator

The Microwave generator converts the DC power produced by the solar cells and to radiated RF output. It consists of a DCRF conversion oscillator, which is typically low-power and followed by a gain stage and finally a power amplifier (PA) [6]. Typically the microwave generating devices are classified as microwave tubes (e.g. klystron, magnetron, TWT etc) or semiconductor MW devices. But generally a Phase and Amplitude Controlled Magnetron is preferred. 2.45GHz or 5.8GHz of ISM band are the microwave transmission frequencies that are most often used. The other choices of frequencies are 8.5 GHz [7], 10 GHz [8] and 35 GHz [9]. The highest efficiency over 90% is achieved at 2.45 GHz among all the frequencies [9].

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4.2 Transmitting Antenna

The antenna elements might be dipoles [12], slot antennas, or any other type of antenna, even parabolic antennas [13]. We need highly efficient amplifiers and generator for the MPT system than that for the wireless communication system. For higher efficiency of beam collection on rectenna array, highly stabilized and accurate phase and amplitude of microwave are required when using the phased array system for the MPT [14]

4.3 Rectenna

The concept and the name 'rectenna' were conceived by W.C. Brown of Raytheon Company in the early of 1960s [16]. A RECTENNA is a Rectifying ANTENNA, a specially designed antenna that is used to convert microwave energy into DC electricity directly. A multi- element phased array fashion with mesh pattern reflector elements is generally used to make it directional. Recentness are being designed as the receiving elements in proposed microwave power transmission (MPT) schemes that use microwaves to transmit electric power to distant locations. Recentness is used in RFID tags; the energy to power the computer chip in the tag is received from the querying radio signal by a small rectenna. One possible future application is a receiving antenna for solar power satellites. A basic rectenna element consists of a dipole antenna with a Scotty diode placed across the dipole elements. The diode does the rectification of the AC current in the antenna induced by the microwaves, resulting the production of DC power. Scotty diodes are preferred due to the lowest voltage drop and highest speed. They thus waste the least amount of power for conduction and switching. Large recentness are formed by an array of numerous similar dipole elements [17]. Retina's are highly efficient at converting microwave energy to electricity. In laboratory environments, efficiencies of over 85% have been observed.

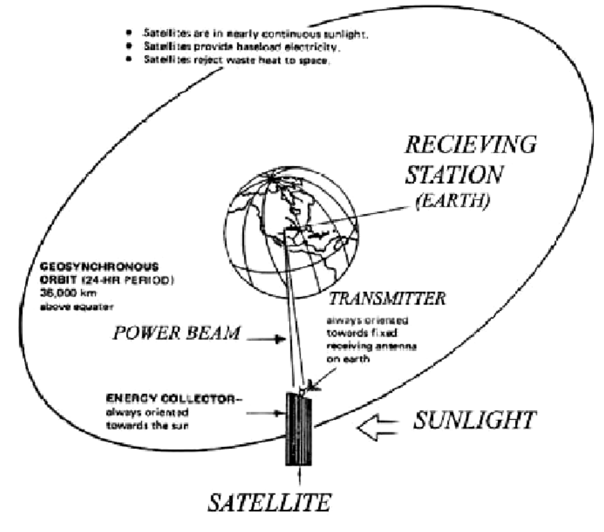

Fig.1. SPS system generates and transmits solar power back to Earth.

5 Advatages & Disadvantages of SPS

5.1 Advantages

Compared to natural gas, oil, coal plants and ethanol, space based solar power does not result into by-products like greenhouse gases. Also like nuclear power plants, space solar power will not produce hazardous waste, which needs to be stored and guarded for hundreds of years [20]. The following figure also shows that in future the cost of producing electricity using coal will go on increasing. Whereas, that using Solar Satellites, if implemented, will keep reducing over the years. Another major advantage of space based solar power is that it is a renewable source of energy. Also the losses in wireless transfer of electricity are much less than Transmission lines.
Differences in Total Plant Cost Over 40 Years

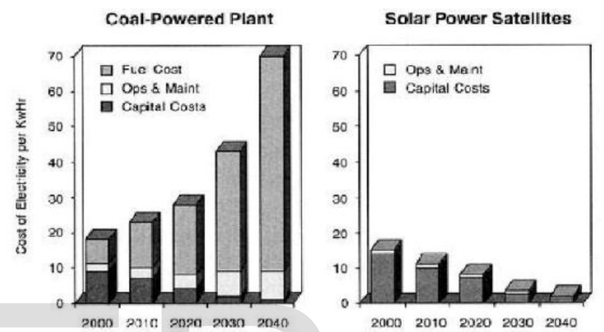

Fig.2.Production costs of electricity by using Coal vs. Solar Satellites.

The SPS can produce solar power continuously as there is no day-night effect in space. The presence of clouds does not hamper the efficiency of SPS as transmitted microwave power can pass through clouds. As a geosynchronous satellite is used, the position of the satellite wrt. the Receiving Station on the Earth remains the same.

5.2 Disadvantages

One of the disadvantages of Solar Power Satellites is the high cost of development. Another disadvantage is the interference of microwaves with present communication systems.

5.3 Impacts on Environment and Biodiversity

Wireless power transmission through SPS has no major impacts on Environment or life on Earth. Studies reveal that the microwave radiations used are not higher than that experienced while opening a kitchen microwave oven. The microwave radiations are well within the prescribed safety guidelines. Thus SPS might provide a large scale, clean, green and efficient source of power.

6 Conclusion

From the above considerations it can be inferred that SBSP can prove to be a promising alternative to fossil fuels .We also came across the fact that the losses in Wireless power transfer are much less compared to the transmission lines. Microwave Power Transmission (MPT) also has no harmful effect on the biodiversity and the environment on the Earth. But the major hurdle in the implementation of Solar Power Satellites is not technology but economical factors. A large scale research is ongoing to overcome the high cost of fabrication and launching of these satellites

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