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Purpose of Satellite Solar Power Station

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ABSTRACT: Throughout the entire 20th century, radio and its applications have been among the essential technologies of the century. It has widened the scope of human activity to include modern lifestyles, and it is now a necessary form of media for human existence. These days, telecommunications is its primary use, particularly radio connectivity and mobile communications between different computers and computer-controlled systems. But while considering the wellbeing of people, radio can serve other functions as well. It is generally acknowledged that in order to preserve human welfare during this century, the topics of energy, food, and the environment need to be carefully considered, guided, and managed. A promising initiative to address the severe shortage of energy for the next three decades is the Space Solar Power Station (SSPS), a space-based power plant.

I. INTRODUCTION

There is a vitality emergency around the world. The unstable increment in the populace of developing nations like "India" requires an exponential increment in the utilization of vitality, sustenance, assets. Like this, the circumstance in creating nations is getting poorer because of the absence of vitality assets. In India, power plants maintained of conventional assets which give 80% of the aggregate essential vitality supply. This kind of electrical vitality transformation strategy has worldwide issues like an unnatural weather change, natural change and quick diminishing of fossil supply. With time, India is turning out to be more industrialized and modernized, so more electrical power prerequisite than other vitality frames. We are searching for efficient power vitality advances which don't discharge carbon dioxide to the environment, or they are renewable. Such practical vitality innovations incorporate earthbound sun oriented vitality, hydropower vitality, wind vitality, and other vitality frameworks given characteristic resources. The sun based vitality is a clean vitality source. Sun oriented vitality falling on the earth every hour is sufficient to supply world vitality yearly request. Along these lines, research is in advance for expanding change productivity from sun-powered illumination and sunlight based thermal to electrical power. There are additionally monetary and area condition issues in commercializing sun based power plants. Sun powered illuminations lessen while coming to on earth. It debilitates on overcast or stormy days additionally sun based vitality is not accessible in the evening.

II. PRINCIPLES OF A SATELLITE SOLAR POWER STATION

Figure 1 shows the concept and Figure 2 the design principles for an SSPS. Two symmetrically arranged solar collectors are used to convert solar energy directly to electricity by the photovoltaic process, while the satellite is maintained in a synchronous orbit around the Earth. The electricity is then fed to microwave generators incorporated in a transmitting antenna located between the two solar collectors. The antenna accurately directs the microwave beam to a receiving antenna on Earth where the microwave energy is efficiently and safely converted back to electricity. The solar collector is pointed toward the sun to within ± 1 degree while the antenna maintains a pointing accuracy of ± 1 minute. Electronic phase shifting provides beam control to 1 arc-second at the receiving antenna. There are no moving parts, except for joints which allow the antenna to rotate with respect to the solar collector to maintain the required attitude. An SSPS can be designed to generate electrical power on Earth at specific levels ranging from about 2,000 to 15,000 megawatts. Over this range of power output, the orbiting portion of the SSPS exhibits the best power-to-weight characteristics. Reaction control systems will be required for attitude control purposes to overcome orbiting influences such as the gravitational effects of the sun and the moon, solar pressure, and the eccentricity of the Earth. A space transportation system based on a reusable space shuttle and an ion engine-propelled space tug will be required to place the SSPS into synchronous orbit at orbital locations of 123° West and 57° East. The microwave beam permits all-weather transmission so that full use can be made of the nearly 24 hours of available solar energy. Power can be delivered to most desired geographic locations with the receiving antenna placed on land or on platforms over water near major load centers.

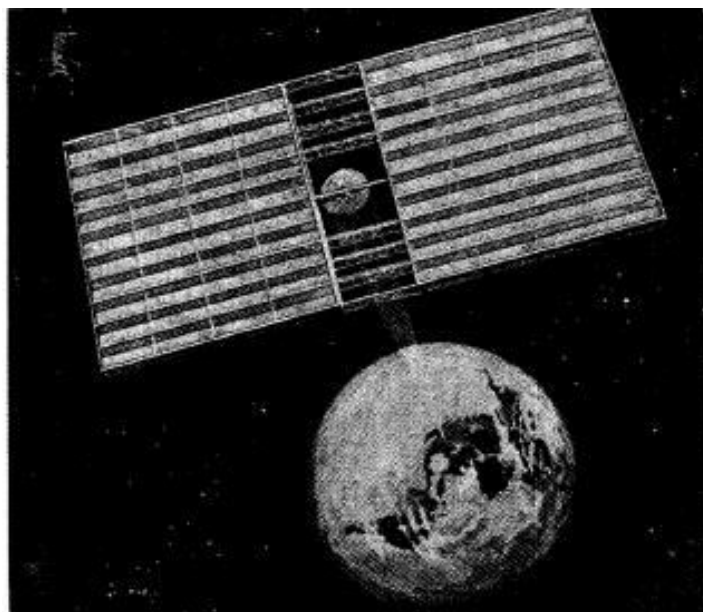


FIGURE 1
CONCEPT FOR A SATELLITE SOLAR POWER STATION

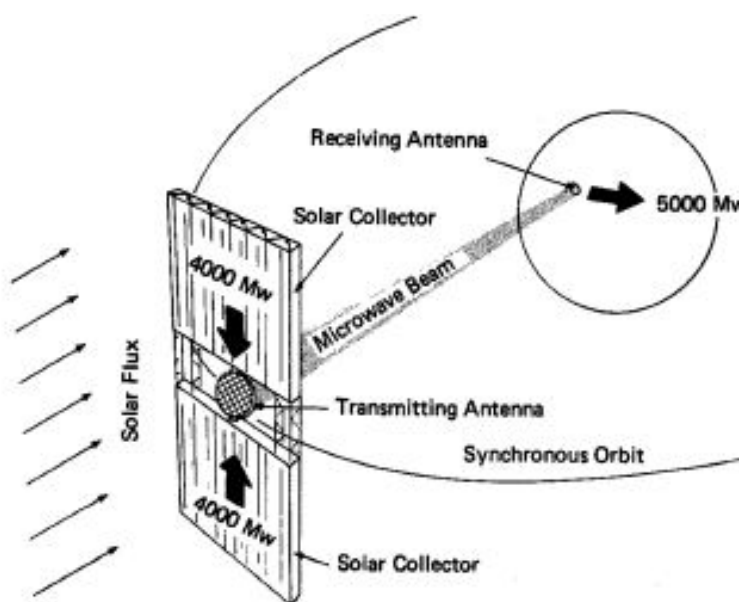


FIGURE 2
PRINCIPLES OF A SATELLITE SOLAR POWER STATION

Single-crystal, silicon solar cells can be used for photovoltaic conversion of solar energy into electricity.² Such cells have already reached efficiencies of 16% for use in communication satellites and efficiencies of 2070 appear to be achievable. A solar cell array can be produced from 50-micron thick silicon solar cells assembled in a blanket between thin plastic films with electrical interconnection 186 between individual cells obtained by vacuum-depositing metal alloy contact materials. Solar energy-concentrating mirrors are arranged to form troughs, with the solar cells forming the bottom part of the trough. Thus, a smaller area of solar cells is required to achieve the same electrical power output leading to substantial weight and cost reductions. Major cost reductions for the silicon solar cells can be projected, based on the continuous production of ribbons of single-crystal silicon. With improved assembly techniques and mass production, the solar collector costs for the SSPS are projected to be about \$310 per kilowatt. Solar radiation damage will cause a logarithmic decay of solar self-effectiveness. Improvements in radiation-resistant solar cells indicate that a

30-year minimum operation lifetime for the SSPS can be achieved. After this period, normal operational effectiveness can be restored by adding a small area of new solar cells. Thus, there is no absolute time limit on effective SSPS operation. In synchronous orbit, the solar collector will be subjected to the impact of micrometeoroids leading to an estimated 1% loss of solar cells during a 30-year period. At about 3.3 GHz, radio frequency interference can be limited so that an appropriate internationally agreed-upon frequency could be assigned to an SSPS. The ionosphere attenuation of the microwaves will be less than 0.1 YO at this frequency and at the low power flux densities occurring within the beam.

III. CONCEPT AND BLOCK DIAGRAM

A Space satellite (SUNSAT) The Sunsets are required to produce radio frequency power at a constant rate with minimum interruptions. The main components of the system include: the solar cell arrays, the power conversion hardware, and a battery backup system. The solar arrays will be paired with a reflector array to help concentrate solar energy onto the photovoltaic cells. The DC power produced by the Sunsets will be transmitted to Earth at a frequency of 5.8 GHz. This frequency compared to 2.4 GHz has less attenuation by atmospheric conditions. The higher frequency of 5.8 GHz instead of 2.4 GHz, increases the gain of the antennas used in the design and thereby the efficiency of the system. The elements of the system are given in Fig.1.

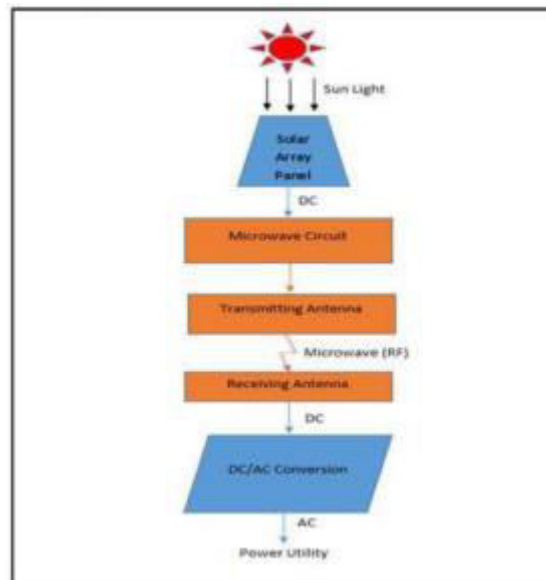


Fig. 1: SSPSS Block Diagram

B. Telemetry and Control system the telemetry system will be used to deploy the Sunsets into their proper orbits. The system will communicate with the earth station under any condition and must be persistent throughout all weather conditions. S-band frequencies of 3.2/3.5 GHz will be used as the carrier frequencies for the link. A. Space satellite (SUNSAT) the Sunsets are required to produce radio frequency power at a constant rate with minimum interruptions. The main components of the system include: the solar cell arrays, the power conversion hardware, and a battery backup system. The solar arrays will be paired with a reflector array to help concentrate solar energy onto the photovoltaic cells. The DC power produced by the Sunsets will be transmitted to Earth at a frequency of 5.8 GHz. This frequency compared to 2.4 GHz has less attenuation by atmospheric conditions. The higher frequency of 5.8 GHz instead of 2.4 GHz, increases the gain of the antennas used in the design and thereby the efficiency of the system. The elements of the system are given in Fig. I. C. Power Transmission system Transmitters used for microwaves includes klystron, magnetron and travelling wave tube. Magnetrons are mostly used since they are efficient and cheaper. Magnetrons can convert power into electron beam and transmit it within a microwave frequency range. Space-based solar power system design depends on the ability to effectively transmit power from space back to earth. This transmission system must be very efficient so that large percentage of the energy harvested can be recovered on Earth. Therefore, an efficiency of 85% is determined for the retina to harvest the transmitted power.

TABLE I. PARAMETERS FOR POWER TRANSMISSION SYSTEM [23].

Parameter	Value
Transmitter Antenna Efficiency (η_t)	90%
Main Lobe Efficiency (η_L)	84%
Transmitter Antenna Power (Pt)	10 GW
Magnetron Efficiency (η_m)	86%
Rectenna Harvest Efficiency	50%
Rectenna Efficiency	82.7%
Frequency	5.8 GHz

D. Ground Antenna For the ground station, a parabolic antenna with the ability to track the satellite will be used. This antenna will have the ability to transmit maximum power using a travelling wave tube amplifier. Space-based solar power system design is mainly dependent on the ability to transmit power from space to earth as efficiently so that a large percentage of the power harvested is recovered on earth. The retina should be able to harvest approximately 85% of the transmitted power and convert the RF energy back into DC power. The type of retina to be used will be determined by its efficiency. The retina developed by Such and Chang which is cable of converting RF to DC at 5.8 GHz with 82.7% efficiency will be used for experiments. The design will be based on the use of a printed dipole antenna attached to a series of filters that block the re-radiation of higher order harmonics. After passing through the filters, the signal is then directed through a Scotty diode, capacitor and load-matched resistor where it is rectified into DC power.

E. Ground Retina the 2, 45 GHz Reference System by DOE/NASA, placed a space solar power system into GEO orbit within a transmitter array diameter of 1 km to deliver 5 GW of power to Earth. The system proposed a peak power density of 23 mW/cm² at the center-of-beam on the rectenna on Earth. The reference systems calculations are used to determine the power irradiance levels and the beam diameter for different orbits that satellites pass through. Three diameters of 342 m, 319 m, and 226 m of the transmitters are chosen to analyse the irradiance levels. The frequency of 5.8 GHz is chosen as opposed to 2.45 GHz, since researchers in the SSPS suggested that 5.8 GHz is cost effective and provides high efficiency. $P_d = \frac{P_t A_p}{4\pi D^2}$ (I) This formula is used to determine the power, where A_p is the total area of the transmitter, P_t is the total power radiated from the transmitter, λ is the wavelength, and D is the separation distance between the apertures.

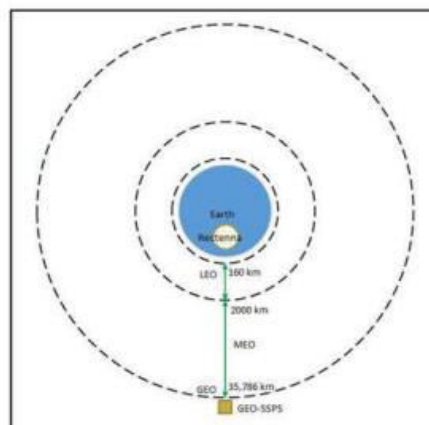


Fig.2 LEO, MEO and GEO altitude from Earth

Fig. 2 shows the distance between the different orbits from Earth. The area for the microwave beam at different orbits is determined by the spot diameter. The diffraction pattern, which constitutes the Airy diffraction disk, is produced from a uniformly illuminated circular aperture whose area contains 84% of the beam energy as seen in Fig. 3.

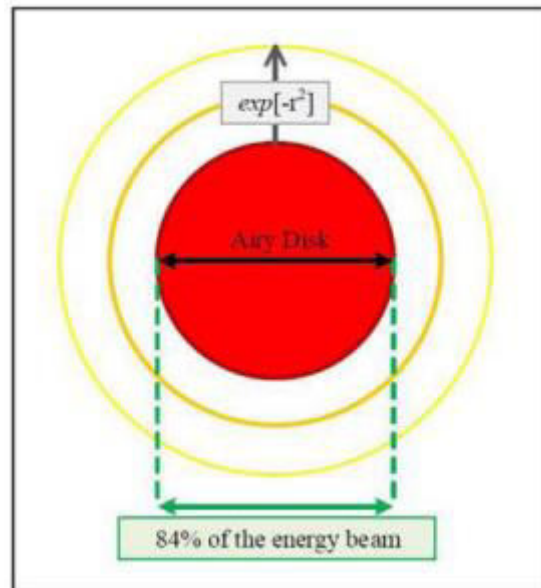


Fig.3 Airy diffraction disk

The diameter of the Airy diffraction pattern is calculated from: where, transmit is the diameter of the transmitting aperture. The distances for transmitter diameter of 342 m, 319 m, and 226 m are 4531 km, 3940 km, and 1970 km respectively at 5.8 GHz. $Disport = 2.44 \lambda D / d$ transmit. The exposure time experienced by a satellite has to be calculated to determine the total accessible solar energy and the required radio frequency. The velocity of the satellite is divided by the beam diameter to give the transit time. If low earth orbit is considered as circular, then the velocity of the satellite can be determined from the formula below: $v = \sqrt{\mu / r}$ where, μ and R are the gravitational constant and mean radius of the Earth respectively including the altitude of the orbit from Earth's surface in kilometer. Elliptical orbits require additional orbital parameters to determine the velocity of the satellite. Table II shows data for power irradiance and Airy disk (diameter) for MEOs.

Altitude (km)	Power Density (W/m ²)	Airy Disk (km)	Average Velocity of Satellite (km/s)	Maximum Time of Exposure (s)
0 (at Earth)	200	14.14	N/A	N/A
500	205	13.95	7.62	1.83
1000	211	13.75	7.35	1.87
1500	217	13.55	7.11	1.90
2000	224	13.35	6.90	1.94
20200 (GPS)	1054	6.16	4.96	1.24

IV. FUTURE SCOPE

It's obvious that the Satellite Solar Power Station not only represents a major challenge to technology but also an unparalleled opportunity to apply space technology for the benefit of mankind. No fundamental breakthroughs are required to achieve the objectives identified with the SSPS but rather major advances and improvements over existing technology. The questions that need to be answered are not only whether the required technology can be developed—because the answer most likely will be yes—but rather whether the development of an SSPS to meet future energy demands is an option that should be pursued. In the face of uncertainties associated with other approaches for generating power with minimal environmental impact, the efforts to explore this option, which is projected to be cost competitive with other energy production methods, should fit within the framework of an integrated energy development program.

V. CONCLUSION

The decline of available resources of fossil fuels and the persistent rise in the prices of oil and gas solidly inspires consumers to hunt for alternative sources of energy. Space solar power is the most productive and attractive source s of free, constant and reliable power. SBSP, at the present trend, uses solar mirrors or panels to collect the available sun's energy and deflect it to earth through wireless power transfer. This paper demonstrates the past research, methods and devices designed. The SPSS will be a central attraction of space and energy technology in future. Space-based solar power transmissions are yet to be proving n in Africa to alleviate the constant energy crises and needs further developments around the world.

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