Issue 9 vol 3 ISSN: 2321-8134

IJFEAT

INTERNATIONAL JOURNAL FOR ENGINEERING APPLICATIONS AND TECHNOLOGY

REVIEW ON SPACE BASED SOLAR POWER

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Abstract

In this paper, we are presenting the concept of an approaching reality i.e. Spaced Based Solar Power. This study presents Space Based Solar Power, an emerging technology which is under a heavy research phase. The concept of Space based solar power (SBSP) is very simple. It is totally based on collecting solar power in outer space and distributing it to Earth. Potential advantages of collecting solar energy in space includes a higher collection rate and a longer collection period. In SBSP, satellites are placed in geosynchronous orbit (GEO) for collection of solar energy in space, harnessing the energy and transmitting to Earth using wireless power transmission. Space based solar power systems convert sunlight to microwaves outside the atmosphere, avoiding losses but at great cost. The expense of launching material into orbit is very large. Various SBSP proposals have been researched but none are economically viable with present-day space launch infrastructure. SBSP is considered as a form of sustainable or green energy, renewable energy. The urgency and need of finding an alternative energy source due to the depleting energy resources on earth calls for Space Based Solar Power. It is attractive to those seeking large-scale solutions to changing climate condition and fossil fuel depletion.

Index Terms: *SBSP, GEO.*

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1. INTRODUCTION

The concept of solar power in space has been discussed during this past four decades. The concept of the Space Based Solar Power is very simple. In this paper we are going to see the designing part of solar power satellites, and the fundamental components used. Many programs and studies are taken into consideration. The concept of space solar power is presented in a very large scale, as it is considered as an environment clean base power. In space there is an uninterrupted availability of huge amount of solar energy. So the use ofsatellites in space, primarily aimed at collecting the solar energy and beam it back to the earth. The concept of the Solar Power Satellite (SPS) is very simple. SBSP can be described as a gigantic satellite designed as an electric power plant orbiting the earth which uses wireless power transmission.

In geosynchronous orbit, i.e. 36,000 km (22,369 miles), a Solar Power Satellite (SPS) would be able to face the sun over 99% of the time. Unused heat is radiated back into the space. Power can be beamed to the location where it is needed, need not have to invest in as large as a grid.

The major loss of power occurs during transmission, from generating stations to the end users. The resistance of the wire in the electrical grid distribution system causes a loss of 26% to 30% of the energy generated. Therefore, the loss implies that our present system of electrical transmission is 70% to 74% efficient. Now a days, the generation is done primarily based on fossil fuels, which will not last long (say by 2050).

2. LITERATURE SURVEY

2.1 DR. PETER GLASER

The concept of a large solar power satellite system placed in high GEO, for collection and conversion of sun's energy into an electromagnetic microwave beam to transmit usable energy to receiving antennas on earth was invented by Peter Glaser.

The SBSP concept, originally known as satellite solar-power system (SSPS), was first described in November 1968. In 1968, PeterGlaser presented the concept, and in 1973 was granted the US patent on, the Solar Power Satellite to supply power from space for use on the Earth.

2.2 1970S DOE-NASA

Various studies of the Solar Power Satellite were conducted during 1970s.During 1970s, the National Aeronautics and Space Administration (NASA) and U.S. Department of Energy(DOE) jointly investigate the concept.

The aim to this concept was a creation of about 60 SPS, each delivering 5GW of power to U.S. National Grid. This DOE-NASA project is considered as the best time ever remembered. This joint effort was funded more than

55 million and resulted in a wide range of useful research.However, due to lack of technical, environmental, economical aspect and high price tag the SPS efforts were terminated.

2.3 FRESH LOOK STUDY

In 1995, NASA undertook a challenge of large scale SSP system. In simple "Fresh Look Study" was a question to all, "What has changed?"The Fresh Look Study was to examine that the modern advanced technology since 1970s might enable new SSP concept. The study aimed at developing, emphasizing systems and architectures for terrestrial markets. The study concluded that the prospects for power from space is technically more reliable, although still exceptionally challenging.

2.4 CONCEPT DEFINITION STUDY

During 1998, NASA conducted the SSP "Concept Definition Study". The project was a one year study that tested the result of "Fresh Look Study".The SSP Concept Definition Study resulted in some of the specific architecture concepts that did not appear more viable than in the past. The overall product of the efforts was the new roads that maps towards the development of SSP technologies.

2.5 SPACE SOLAR POWER EXPLORATORY RESEARCH AND TECHNOLOGY PROGRAM (SERT)

NASA conducted a SSP SERT program in 1999. This program was completed at the end of December 2000.This SERT program led by NASA involved many technologists around the world, many external and internal organizations and included some small and large companies.

SERT's conclusions:

- The environmental impact of conventional power plants and their impact on world energy supplies and geopolitical relationships can be problematic.
- Renewable energy is a compelling approach, both philosophically and in engineering terms.
- Space solar power systems appear to possess many significant environmental advantages when compared to alternative approaches.

3. DESIGN

The concept of the Solar Power Satellite is very simple. It is a gigantic satellite designed as an electrical power plant orbiting around the earth which uses wireless power transmission.

Space-based solar power essentially consists of three functional elements:

1. Collecting solar energy and converting into DC
2. Large antennas to beam power to ground.
3. Rectennas for receiving power on earth.

The portion in space will be in a vacuum, freefall environment and will not need to support itself against gravity other than relatively weak tidal stresses. It needs no protection from terrestrial wind or weather, but will have to cope with space hazards such as micro meteors and solar flares. The major advantages of SBSP are, 100% replacement for fossil fuels in the near future, they are pollution free, elimination of transmission lines, overhead lines and cables as the power can be beamed directly to a particular spot all over the world. No water or air pollution is created during generation.

4. SOLAR POWER SATELLITE (SPS) SYSTEM

4.1 SOLAR ENERGY COONVERSION

Two basic methods of conversion have been studied:

1. Photovoltaic (PV)
2. Solar dynamic (SD)

4.1.1 Photovoltaic (PV)

Most analyses of spaced based solar power have focused on photovoltaic conversion using solar cells that directly convert sunlight into electricity.Photovoltaics is a term which relates the conversion of light into electricity using semiconducting materials (like silicon or arsenide) that shows the photovoltaic effect. Semiconductors are used to convert photons into electrical power via quantum mechanical mechanism. A photovoltaic system consist of several solar cells, which generates electricity. PV system may be ground mounted, rooftop mounted or wall mounted. PV installation may me fixed or may be track based (which track the moment of sun).

PV has specific advantages; its generates no pollution and no greenhouse gas emissions once installed, it is a simple system in respect of power needs and the semiconductor used for production of PV i.e. silicon has large availability in the Earth's crust. The major disadvantage that the PV systems have that the power output is dependent on direct sunlight. About 15-25% of power is lost if a tracking system is not used, this is because the cell will not be directly facing the sun at all times. Dust, clouds, and other things in the atmosphere also affects the power output.

4.1.2 Solar dynamic (SD)

Solar thermal energy is mostly used for generating thermal energy or electricity. Solar dynamic uses mirrors to concentrate light on a boiler. Solar Dynamic in space would use heat collectors and thermal storage.The use of solar dynamic could reduce mass per watt.

4.2 COVERTING INTO MICROWAVE POWER

Oscillator are used for the purpose of generating a signal. They provide the signal source for all microwave systems, including both transmitters and receivers. They can generate a frequency source such as wave or square wave. Microwave oscillators are useful in applications like audio signal generation, reference signals for different applications and in measurement applications.To convert the DC power to microwave for the transmission through antenna towards the earth's receiving antenna, microwave oscillators like Klystrons, Magnetrons can be used.A klystron is a specialized linear-beam vacuum tube, which is used as an amplifier for high radio frequencies, from Ultra High frequency (UHF) up into the micro wave range.Unlike other vacuum tubes such as a klystron, the magnetron cannot function as an amplifier in order to increase the intensity of an applied microwave signal. The magnetron serves solely as an oscillator, generating a microwave signal from direct current electricity supplied to the vacuum tube.Dc power converted into microwaves power at transmitting end of system is done by using microwave oven magnetron.

4.3 TRANSMITTING ANTENNAS

At the transmitting antennas, microwave power tubes (such as magnetrons and klystrons) have been studies as primary RF power source.The key transmitter requirement is the ability to efficiently convert the dc power to RF power and radiate the power in low loss manner. Transmitter in small WPT application consist of single high power RF source feeding mechanical steered antennas. But large scale WPT application, such as SPS, require a phased array antenna to distribute RF power source to control beam power. Any heat generated during DC to RF conversion must be removed for long life and reliable operation.

In SERT program a 5.8 GHz, 500m diameter phased array transmitter was selected. In DOE/NASA study 2.45 GHz, 10db amplitude tapered beam was used.Klystron and magnetron devices were extensively studied in reference system study for 2.45 GHz beam (as shown in table 4.3).Although klystron operated at higher power level, magnetron was preferred due to its efficiency, reliability.

Table 4.3.1 RF Tube Comparison

Parameters	Klystron [19]	Magnetron [20]
Amplifier output power	50W	4.39kW
DC-RF efficiency	74%	87.5%
Life time	25 years*	50 years*

Power transmission using radio waves are more directional, allowing longer distance power beaming, having shorter wavelength and typically in microwave range. Hence power beaming using microwave has been proposed for transmission of energy from space to Earth. Microwaves power beaming is considered rather than Laser beaming, because it is less prone to atmospheric attenuation. Microwave transmission often use 2.5GHz to 5.8GHz. The highest efficiency is obtained at frequency of 2.45GHz. Other than microwave power tubes (magnetron and klystron), typical semiconductor devices are FET (Field Effect Transistor), HBT (Hetero junction Bipolar Transistor), and HEMT (High Electron Mobility Transistor) can also be used. But microwave tubes are preferred over semiconductor amplifiers. The microwave tube is lighter in weight than that of the semiconductor amplifier. The microwave tube can generate/amplify higher power microwave than that by the semiconductor amplifier.

Table 4.3.2 Microwave element comparison

Element	Parts	Efficiency	Power level
Microwave generator/ amplifier	Electronic tubes	70-80%	Several 100W Several MW
	Semiconductor	60-70%	Less than 100w
Microwave beam controller	Phase shifter	Loss 1db/bit	Less than 10W

4.4 RECTIFYING ANTENNA (RECTENNAS)

Rectennas is a special type of antenna that is used for converting electromagnetic energy into DC. They are used in wireless power transmission systems that transmit power by radio waves A rectennas can be constructed from an antenna, a diode rectifier, and a DC bypass filter. The final output of the rectenna is DC

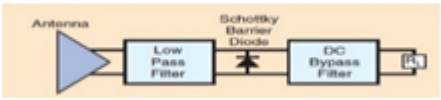

Figure 4.4.1 Rectennas circuit.

power.

The microwaves transmitted from a satellite would be received by a large group (array) of rectennas. The received microwave frequencies are in a range from 2.88 GHz. The diodes would be used to absorb and convert the high power frequencies into low frequency DC power. This DC power is then collected by a DC voltmeter. There have been many experiments in which the RF-DC conversion efficiency was above 85%. The efficiency of the RF-DC conversion depends on the amount of power input and connected load

The energy transmitted by antennas is very diffusive in nature. Therefore the receiving antennas area must be very large compared to antennas. Most of the microwaves receives interference with the atmosphere. Still there are some frequency windows in which this interaction are minimized. The frequency window in which the interaction is minimized is between range of 2.45-5.8GHz and also 35-38GHz. And in this two ranges we might expect losses of about 2-6% and 8-11%.

5. MICROWAVE POWER TRANSIMMSION

Due to the research programs, such has NASA's SERT, has led to wireless revolution.System supporting wireless power transmission has been advanced over the past 15 years.The purpose of this section is to discuss the key components required in WPT system: transmitter, beam control, and rectifying antennas. The ability to efficiently delivering electrical power is dependent upon the component efficiency used in transmitting and receiving. And also the efficiency also depend upon the ability to focus the electromagnetic beam onto rectennas. The microwave WPT is achieved by unmodulated continues wave signal with a bandwidth of above 1GHz.But for SPS, the historical frequency choice for wireless power transmission it has been 2.45GHz. The use of this frequency id due its low cost components and extremely low attenuation through atmosphere.The alternate frequency, the next higher ISM band, is of 5.8 GHz, which has drawn attention of WPT. The study of SERT program was based on 5.8 GHz system. Other frequency studied at SERT were 8.5GHz, 10GHz, and 35GHz.

6. ORBITAL LOCATION

The concept of spaced based solar power was totally based on placing the SPS in GEO for collecting sunlight, and use it to generate electromagnetic beam and then transmit it to Earth. A geostationary earth orbit or geosynchronous equatorial orbit (GEO) is a circular orbit approximately 36,000km (22,236 mi) above the Earth's equator. An object in such an orbit has an orbital period equal to the Earth's rotational period and thus appears motionless, at a fixed position in the sky, to ground observers. Communication satellites and weather satellites are often placed in geostationary orbits, so that the satellite antennas (located on Earth) that communicate with them do not have to rotate to track them, but can be pointed permanently at the position in the sky where the satellites are located. All geosynchronous satellite can be located in this GEO. The main advantage of locating a space power station in geostationary orbit is that the antenna geometry stays constant, and so keeping the antennas lined up is simpler.

7. LAUNCH COST

The major problem with SPSP is the cost for launch and the amount of material that would be required to be launched. High efficient engines are used to move the satellites from LEO to GEO but those engines are quite slow. It is concluded that a very large size of rectennas are required for a total space based power system. This in total increases the cost of system.

The cost for a single satellite launch can range from a low of about $50 million to a high of about $400 million. Launching a space shuttle mission can easily cost $500 million dollars, although one mission is capable of carrying multiple satellites. Designs for microwave transmitting satellites are massive, with solar reflectors spanning up to 3 km and weighing over 80,000 metric tons.

In Yuma County, Arizona, covers almost precisely 1 square kilometer of land (2400 acres), and generates around 600 GW every year. It was completed in 2014 and it cost more than $1.8 billion to build. So we can just have an idea of how much the cost of SBSP will be, many billions.

8. ADVANTAGES AND DISADVANTAGES

8.1 ADVANTAGES:

1. Spaced solar power does not emit greenhouse gases.
2. Does not compete for valuable farm land.
3. Space solar power will not produce hazardous waste.
4. Space solar power is available 24 hours a day.
5. Unlike nuclear power plants, space solar power does not provide easy targets for terrorists.
6. Does not require problematic mining operations.
7. It eliminates a major source of national competition for limited Earth-based energy resources.

8.2 DISADVANTAGES:

1. Maintenance of SPS is expensive and challenging.
2. Geosynchronous orbit is already in heavy use.
3. Size of construction for the rectennas is very massive.
4. Transportation of all the materials from earth to space and installation is highly challenging.

9. CONCLUSION

The increasing global energy demand is likely to continue for many decades, may be till the earths end. New power plants will be built in future. Fossils fuels will run off in next 3-4 decades. However solution is something only Space based solar power can deliver.

SBSP concept is attractive because it is much more advantageous than ground based solar power. It has been predicted that by 2030, the world needs 30TW power from renewable energy sources to meets the ongoing requirement and solar energy alone has the capability of producing around 600TW. The increasing global energy and CO2 gas emission can be minimized and brought under control. The problem of global warming will be solved to a great extent that has never been achieved. Though the success of space solar power depends on successful development of key technology, it is certain the result will be worth the effort. Space solar power can completely solve our energy problems in long term. The sooner we start and the harder we work, better the future.

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