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ENERGY HARVESTING FROM SPACE BASED SOLAR POWER SATELLITE

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ABSTRACT

The outer space is the field of huge amount of uninterrupted solar energy, available in the form of light and heat. The future technologies of space based solar power satellites (SBSP) are capable to collect 99% of solar radiation in 24hx7days. In space the collection of solar energy is unaffected by the day/night cycles, seasonal changes and the filtering effects of earth's atmospheric gases. SBSP system has huge solar panels which are consistently exposed to a high amount of solar radiation rather than earth's ground based solar power stations, in which solar panels are facing towards the sun and it collects solar energy during the day-time only. SBSP technology consistently provides clean, renewable and constant energy; it is capable to complete displacement of fossil fuels, nuclear energy and biological energy sources in near future. Energy harvesting from SBSP system, we need to establish it into geosynchronous orbit of the earth that converts the solar energy into DC power and DC power to microwave signal for the transmission through antenna towards the earth based receiving antenna. The ground based rectennas are able to convert microwave signals into DC electricity. Energy harvesting from space based solar power satellite is most useful and effective.

Keywords: Magnetron, Microwave power transmission, Space based solar power satellite (SBSP).

I. INTRODUCTION

Our outer space contain uninterrupted and huge amount of renewable source of energy, we obtained this without expanding anything. The exploration of non-renewable energy sources like nuclear energy, fossil fuels (coal and petroleum products) are deteriorated our environment and creating the problem of global warming. The future energy demand cannot be fulfilled by the non-renewable sources; we need to explore sustainable and reliable renewable energy sources like solar energy, wind, hydro and biomass. Solar energy has been recognized as an ideal source of energy for mankind. It is naturally available and plentiful, does not disturb the environment. The utilizing solar energy to generate electricity on a 24-hour continuous basis was proposed by Dr. Peter Glaser in 1968, introduced the concept of a space based solar power satellite system of square miles of solar collector in geosynchronous orbit i.e. 36,000 km (22,369 miles above the equator of the earth, illustrated in figure 1. Solar power satellite (SPS) would be able to face the sun over 99% of the time and no need for any costly storage devices when sun is not in view. Only a few days at spring and fall equinox would the satellite be in shadow [3]. SBSP system converts solar energy into direct current (DC) electricity and DC to an electromagnetic microwave

beam to transmit usable energy to large receiving antennas on earth, which are able to covert microwave energy to DC electricity.

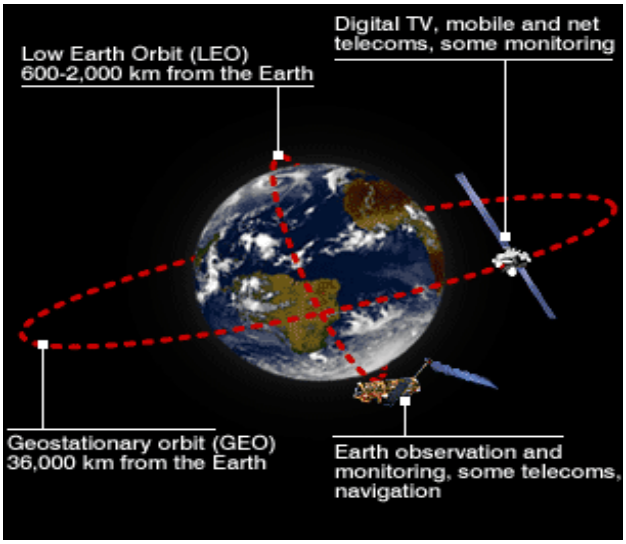

Figure 1: The principle of space based solar power satellite system in geostationary orbit.

II. SPACE BASED SOLAR POWER SATELLITE SYSTEM

The principle technical feasibility study was conducted by NASA during the period of 1973 to 1977 about solar energy harvesting in the space for use on earth. This study created a reference system consists of following units:

(a) Solar energy collector and converter to solar energy into DC electricity.

(b) Direct current to Microwave converter and beamed antenna array towards the Earth.

(c) Microwave power receiving antenna to the ground.

(d) Space transportation system.

2.1 Solar Energy Conversion into DC Electricity

Photovoltaic cells (PV) and concentrated photovoltaic cells (CPV) are widely using for direct conversion of solar photons into DC electricity in ground based solar energy generation. It is consist of a semiconductor cell (e.g. Si, GaAs, InGaAs, InGaP). The efficiency of CPV cell (~ 44%) is more than the PV cell (~ 36%), many researchers and scientists are currently working for developing new technology to obtaining greater efficiency (more than 70%) PV cells of lighter weight, less expensive and tolerant to space radiation environment used in SBSP system. Figure 2.1 illustrate the basic principle and ground based solar energy harvesting technique [1], [2],[5], [7].

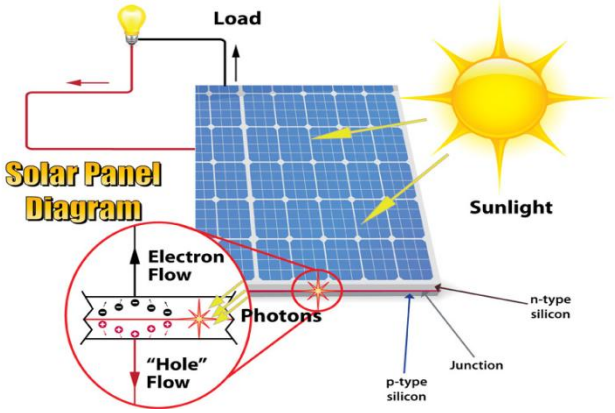

Figure 2.1 Illustrate the basic principle and construction of photovoltaic cell.

2.2 Direct Current to Microwave Power Converter

The solar power satellite initially converts the sunlight into the DC electrical energy; this energy will be converted into microwave power through microwave oscillator like klystrons and magnetrons. In figure 2.2 represent the basic structure of cavity magnetron which is capable to generate microwave signals in the order of 10 GHz. This microwave power signals are transmitted through antenna towards the earth based receiving antennas [2], [3], [4]. The magnetron is diode type electron tube, which uses the interaction of magnetic and electric field in the complex cavity to produce oscillation of very high peak power. When there is no magnetic field applied on cavity magnetron, the path of the electron is straight towards anode but in the effect of strong magnetic field the path of the moving electron becomes curved shaped instead of a straight one. As the electron passes the cavities, the cavities resonate and emit microwave radiation just like flute producing sound wave after blowing in the open end. The microwave radiations are collected up and channeled by a kind of funnel called a wave guide and beamed out into the air by an antenna.

III MICROWAVE POWER TRANSMISSION SYSTEM

Space based solar power satellite is orbiting in geosynchronous orbit (the special case of geostationary orbit) i.e. 36,000 km above the Earth surface. The wire based transmission and distribution systems from one electrical grid station to another grid station are 70% to 74% efficient. The resistance of wire causes a loss of 26% to 30% of the energy generated. The microwave source consists of microwave oven magnetron with electrons to control the output power ranges from 50w to 2.45GHz. The recent research about microwave power transmission efficiency is found up to 85-90% for the 2.45GHz frequency range, which is greater efficient than wire-based power transmission system[9], [10], [11].

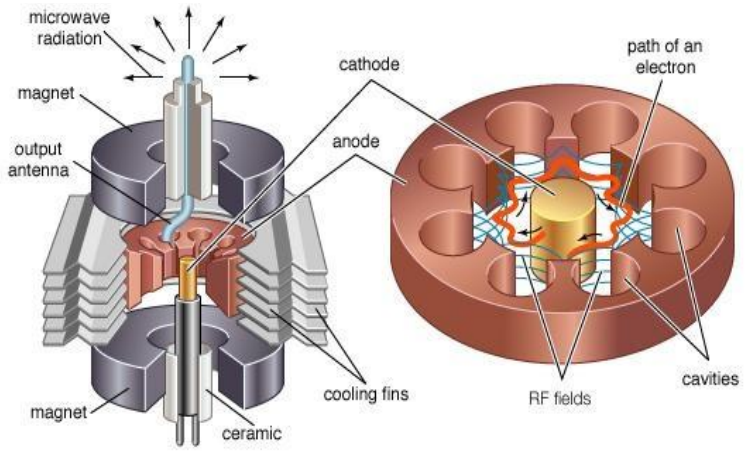

Figure 2.2 Schematic design of cavity magnetron as high energy microwave signal generator.

IV. RECTENNA AS MICROWAVE POWER RECEPTION SYSTEM

In SBS system once DC is converted into microwave signal and transmitted from space towards Earth, a system required to receive microwave signals and converts it back into DC. The device can be used for reception and conversion is called a Rectenna. It was created by W. C. Brown in 1960 which consists with antenna, low pass filter, matching filters, and rectifying circuits microwave radiation passes into it and finally converts into DC electricity. The dipole antenna system achieves the maximum efficiency (85%) for conversion to DC from received microwave radiation of 2.45GHz frequency [8], [9].

V. ADVANTAGES OF SBSP SYSTEM

1. Unlike oil, gas, ethanol and coal plants, space solar power does not emit greenhouse gases.
2. Unlike nuclear power plants, space solar power will not produce hazardous waste, which needs to be stored and guarded for hundreds of years.
3. Unlike terrestrial solar and wind power plants, SPS is available 24 hours a day, 7 days a week, in huge quantities. It is not affected by cloud, rain and wind speed.

4 Unlike fossil fuels, SPS does not need mining operation.

5. SPS will provide true renewable energy.

5.1 Disadvantages of SBSP System

1. Maintenance of SPS is expensive and challenging.
2. Geosynchronous orbit is already in heavy use, could be endangered by space debris.
3. The size of construction of the rectenna is massive.
4. Transportation of all the materials from earth to space and installation is highly challenging and very expensive.

VI. CONCLUSION

The global energy demands increases day by day and likely to continue for many decades. The most of the power plants are running by using fossil fuels will be run off in another 3-4 decades. It creates the problem of global warming by producing green house gases. SBSP concept is more attractive and much more advantageous than ground based solar power station. The technology of SBSP system is capable to completely solve our energy problems in near future.

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