Evaluation of Wireless Solar Power Transmission through Satellite (SPS)

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Abstract - In this paper we are going to propose an idea of Solar Power Generation and Transmission Via Satellites (SPS) -The solar cells in the satellite will receive the sunlight and convert the sunlight into electricity in the method of DC (Direct Current), which will further transformed into microwave energy, then it is beamed to a receiver site on the earth and reconverted back into electricity by using transmitting and receiving antenna's with the technology of wireless power transmission (i.e., transmitting power as microwaves signals in order to reduce the transmission and distribution losses). This concept is also can be known as Microwave Power Transmission. The advantages, drawbacks, biological impacts and applications of Wireless Power Transmission are also presented.

I. INTRODUCTION

This paper aims to linkage several disciplines in an attempt to define an application of solar power generation via satellite communication. The Solar Power Satellite energy system is about to place the satellites covered with many arrays of solar cells in geosynchronous orbit. The orbit is about 36,000 miles above the Earth's surface. Each satellite will be illuminated by sunlight for almost 24 hours in a day for most of the year, this is due to the 23" tilt of the axis of earth's rotation, and satellites will pass either below or above the Earth's shadow region. The sunlight will be fall on satellite for about 99% in the year [1]. The solar cell's will convert the sun light into electrical energy in the form of Direct Current and it is converted into a form of microwave beams and which can be directed to any location on earth surface were required. This beam is collected in the earth surface as power signal and convert it back to the electrical energy would then be used for our normal electric distribution network here on the Earth. This method of power production is more advantageous other than all conventional methods [1]. The losses occurs due to the transmission and distribution of electrical power is one of the major issue in power system. Due to day by day usage increment the demand of power is increased, the power generation increases and the power dissipation is also increased. There is almost as 26 to 30% all losses due to transmission. Effectiveness of the system is only up to 70-74%. The main reason for power loss while transmission and distribution is the resistance of wires used for grid. The efficiency of power transmission can be improved to certain level by using high strength underground cables and overhead cables that use high temperature super conductor. Even thou, the transmission is still inefficient [1].

II. SPS –THE BACKGROUND

The concept of large SPS was invented in 1968 by Peter Glaser which has to be placed in geostationary orbit [2]. 1970 DOE and NASA examined keenly about SPS concept in 1970's. In 1978 both organizations analysed about SPS system and forwarded the study and investigate to next step [3]. Power creation and broadcast of 60 SPS can deliver a total power of 300GW which can be useful for providing better infrastructure in space. It is the main feature of this SPS concept. They have given the most extensive performed to date that was to begin the concept it take around $50 million But because of its huge price and prevailing energy crisis, the US terminated this concept. On NOV 2, 2012, china and India collaborated this concept as SBSP. 12 MARCH 2015 Japan Aerospace Exploration Agency (JAXA) announced a research proposal to generate and transmit a 1.8 Kw wireless power [1]. Within all the proposal from researches as noted in the IEEE Spectrum magazine on May 2014 "It's Always Sunny in Space" [4].

III. CONCEPT OF SATELLITE POWER SYSTEM (SPS)

The concept of the Solar Power Satellite (SPS) is very simple. SPS can be positioned in geosynchronous orbit. By comparing to existing satellites, SPS will generate much more power than it needs for its own operation. The solar energy in the atmosphere is collected by solar panels placed in SPS would be converted into electricity then the electricity is further converted into microwaves. Huge array of antennas is used to transfer microwave beams to earth surface and then it is again reconverted into electricity with the help of rectenna called rectifying antenna. Each SPS would have been gigantic, measuring with an average area of 56 sq. km or 5.3km wide and 10.5 km long. There are around 400 million solar cells placed in the surface of each satellite. The Receiving antenna have about 10 km in diameter and The Transmitting antenna have about a diameter of 1 kilometre [5]. Microwave signals also have additional features such as smaller size of antenna, larger band width, and it have sharp radiated beam signals which can be propagate through straight lines. Have planned to transmit the microwave signals in a frequency of (2-3) GHz [6]. Microwaves have other features such as larger band width, smaller size of antenna, sharp radiated beams and they transmit along straight lines. An average of 5GW power can be available to the consumers from one SPS. SPS has a major merits of power generation in night times, cloudy days and poor weather times. In other words solar array operation is almost similar to SPS receiver. It receives

power from space satellite and convert back it into electricity. It can be reduce the complexity and size of the satellite [7]. The figure 3.1 shows the total model of SPS.

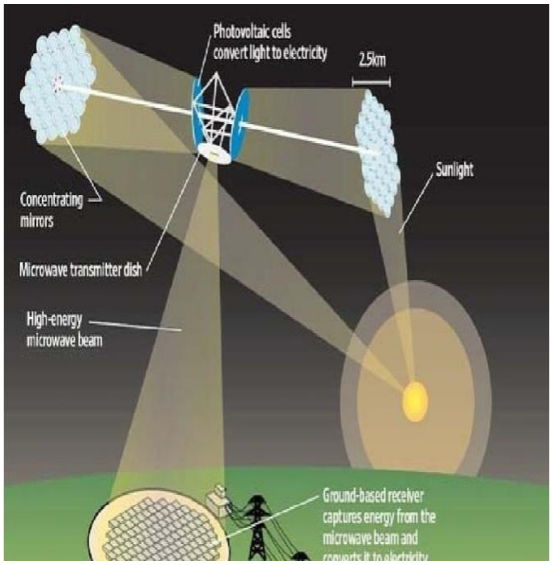

Fig: 3.1 Concept of Solar Power Satellite System

Space-based solar power basically consists of three major practical units:

1. A Solar energy collector to convert the solar energy into DC (Direct current) electricity and a DC to Microwave converter.
2. Large array of antenna to beam the Microwave power to the ground.
3. Receiving power station on earth, for example microwave antennas (Rectenna).

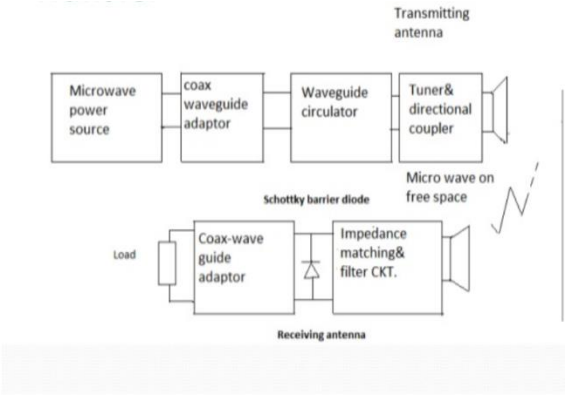

Fig 3.2 Block diagram of Solar Power Satellite System

IV. COMPONENTS OF SPS SYSTEM

The Primary components of SPS through Wireless Power Transmission are

1. Microwave Power Generator,
2. Transmitting array antenna and
3. Receiving rectifying antenna (Rectenna).

The components are described in the below chapters.

A. Microwave Generator

The UV rays from sunlight are converted into electrical power signal by help of solar panels. In the solar panels solar dynamic (SD) conversion or photovoltaic (PV) conversion are the two methods used. Comparing with this two most analyses of solar power satellites are focused on photovoltaic conversion process (commonly known as "solar cells"). Photovoltaic alteration method uses semiconductor cells like gallium arsenide or silicon to directly convert photons into electrical power via a quantum mechanical mechanism and then the electrical power is to be converted into microwave beams then it is amplified by use of suitable amplifier circuits.

Fig 4.1.1 Generation of Electricity in Space Satellite.

B. Transmitting antenna

To transmit converted electrical power to the ground surface array of antennas is used.

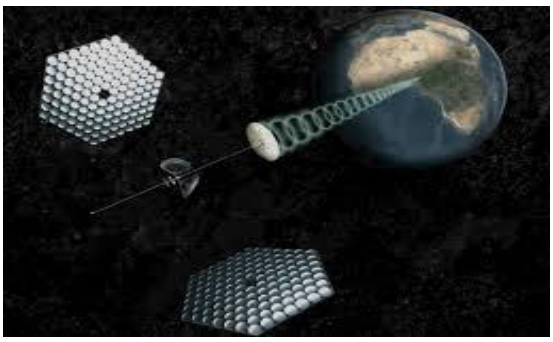

Fig 4.2.1 Transmitting array of antenna in satellite.

The transmitter needs a requirement of its ability to convert dc power to RF power effectively and radiate the power to a skilful manner with lower loss. The transmitter's efficiency drives the end-to-end efficiency as well as thermal management system. The main components of a transmitting antenna include direct current to radio frequency converter and array of transmitting antenna. Power distribution at the transmitting antenna= $(1-r^2)$, where (r) is the radius of antenna.
There are mainly three DC-to-RF power converters:

1. Solid state amplifiers.
2. Magnetrons.
3. Klystrons.

By using any one of this method the power is radiated to the ground surface.

C. Receiving antenna (Rectenna)

The pioneer in developing the first (2-3) GHz rectenna was by Brown [9]. Rectenna is the microwave to DC power converting device and is mainly composed of a receiving antenna and a rectifying circuit in single block. It consists of a receiving antenna and an input low pass filter as a rectifying circuit and an output smoothing filter. The input filter is needed to decreased radiation of high harmonics that are generated by the non-linear characters of rectifying circuit. Because it is an extremely non-linear circuit harmonic power levels must be undeveloped.

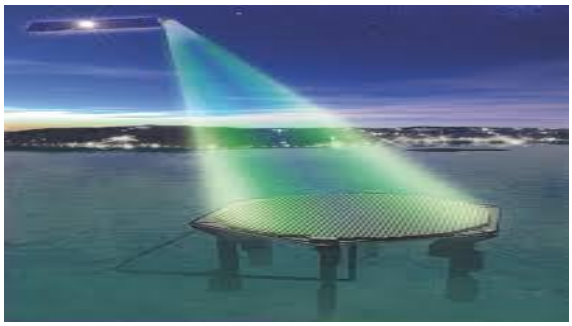

Fig 4.3.1 Ground level receiving station.

V. WHY SATELLITE POWER SYSTEM (SPS)

In day to day life global energy demand is rapidly increasing if it continue many decades will happen. Were ever, almost many renewable energy sources are limited in their ability to affordably offer the base load power necessary for global industrial development and affluence, because of intrinsic land and water requirements. Due to burning of fossil fuels availability of it is abruptly decreased. It may cause many other environmental issues and also led to the greenhouse effects, and also other assets also have some demerits and environmental issues. A solution for global warming is power generation through nuclear power but it may cause many concern in case of any terrorist attacks on nuclear power plants.

To overcome all drawbacks solar power generation is the best method but earth based solar power generation receives only an amount of the solar energy due to reflection and absorption of clouds and different layers, also due to night time in earth surface. So it is looked-for to place the solar panel in the gio-synchronising orbit itself where the solar energy is available for long durations compare to earth based, energy is collected and converted in to DC power which is then converted into microwave beam for transmission. This microwave beam can be directed to any desired place on the Earth surface which can be collected through rectenna and then converted back to electricity. This idea has more advantageous than current methods. The microwave energy is chosen for transmission of generated power which cannot be restricted by clouds and different layers.

The space-based SPS will be in a free-fall, and it will not need to support itself against gravity. The major advantages of SPS are fossil fuels can be replaced by 100%, they are pollution free, in future transmission lines like overhead lines and cables can be totally eliminated, as the power can be radiated directly to a certain place all over the world we needed. Air and Water pollution can be rapidly decrease.

VI. RECENTLY DEVELOPED MPT SYSTEMS

SPORTS (Space Power Radio Transmission System) it is a system developed by Kyoto University [2]. It consists of units like solar panel, microwave transmitter, transmitting array antennas, a near field scanner, microwave receiver. In the dc power to microwave power transmitter (MPT) system an 8.4kW power can be provided by the solar panels. By using SPORTS we can simulate power generation technique for the whole conversion process. Another MPT team of Kyoto University developed SPRITZ (Solar Power Radio Integrated Transmitter) mission in the year 2000 [2]. This unit contains many components like solar panel, microwave generators, transmitting antennas in one package itself.

VII. ADVANTAGES AND DISADVANTAGES

The idea collecting solar energy in space and returning it to earth using microwave beam has many attractions. The full solar irradiation be available in space expect when the sun is eclipsed by the earth [11]. The solar power can be directed to anywhere on the earth's surface we needed. In space due to high vacuum condition and zero gravity it allows much light for more power generation and low maintenance structures and collectors [11]. The earth based solar power density would be interrupted by precipitations, darkness, clouds etc. The space based solar energy generation has its essential drawbacks also. Here listed down some of major draw backs:

Storage of electricity generation during off peak demand hours is the main draw backs of this concept [12]. Approximately at 2.45 GHz frequency is planned to beam the radiation but this same frequency is used for many applications and communication satellites also. A whole structure is too gigantic it takes high cost and it require more time for designing and implementing. System can associated with some radiation hazards. Percent of malfunction of system is high. To deliver a powerful burst of energy to a targeted place a high gain antenna is to be used and it can be used as a weapon [12].

VIII. BIOLOGICAL IMPACTS

Effect of microwave radiation is the common belief fear. But studies in this domain constantly proves that the microwave radiation level is lesser than the amount received in the microwave oven door which means it is slightly higher than the radiations created by mobiles, cellular towers and some other devices that operates in mi-

crowaves. This proposed plan will be designed by reduced densities at or below the ANSI/IEEE exposure standards, and also be below existing safety guideline standards provided for wireless power transmission. However many experiments and test have also shown that the energy density in the radio-frequency beam is limited to safe levels [1].

IX. APPLICATIONS

By the year 2030 SPS is realize and expected one. Before the realization of the SPS we can expect many other application in the wireless power transmission. In modern years mobile devices are getting advance quickly and it require low power consumption. It means that we can use the dispersed weak microwave power as a power source of the mobile devices with low power consumption such as RF-ID. A radio IC-tug with wireless power information and transmission is known as RF-ID. This is a different wireless power transmission application like broadcasting.

X. CONCLUSION

The concept of Solar Power Satellite and Microwave Wireless Power Transmission system were discussed in the above chapters. The developments and technological in Wireless Power Transmission (WPT), along with their background, recent development biological impacts, applications, merits and demerits of Solar Power Satellites are also discussed. This concept provide easy way of transmission with minimum amount of losses. Additionally, the solar power is the major supplier and that will be a replacement of non-renewable energy sources. Even though Space based Solar Power Satellite may seem ultramodern at present, but it is scientifically possible.

XI. REFERENCE

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