International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 3, Issue 12, December 2014

Wireless Power Transmission By Using Solar Power Satellite

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Abstract— **A wireless power transmission using microwave is a system which contains satellite based solar power system (SPS), microwave generator, microwave transmitter and microwave receiver. The DC power received on earth is converted into AC for various useful purposes. This paper contains an analysis of wireless power transfer with an assessment of its practical applicability in terms of power range and efficiency. Their advantages, disadvantages and economical consideration will also be presented. This paper concentrates mainly on (i) Tesla Theory, (ii) Solar power satellite. Solar Power Satellites (SPS) will converts solar energy in to microwaves and sends that microwaves in to a beam to a receiving antenna which is on the Earth for conversion to ordinary Electricity. SPS is a large scale, stable power electric source. For SPS Wireless power transmission is essential. WPT contains microwave beam, which can be directed to any desired location on Earth surface. This beam collects Solar Energy and converts it into Electrical Energy. This concept is more advantageous than any other conventional methods. The SPS will be a central attraction of space and energy technology in coming decades.**

Index Terms— **Microwave power transmission, Rectenna, Transmitting antenna, Solar Power Satellites (SPS), Tesla theory, Wireless transmission**

I. INTRODUCTION

In our present electricity generation system we waste more than half of its resources. About 20 to 30% energy is lost during the distribution of the electricity. The present electricity generation system is not very efficient in terms of energy transfer. Therefore to improve the ultimate electricity supply the scientists are working on the projects. They look for efficient and alternate technologies to provide 100% electricity transfer. Therefore the wireless transmission of electricity power is also on move [1], is a means of delivering power to use device without wires. One of the oldest known power transmission technologies, WPT is seeing a reanimation of interest. Wires typically allowed devices to receive both power and communicate with other devices. To carry data wireless data transmission eliminates the need of wires. With the explosive growth in wireless data applications, the market potential for wireless power transfer technologies has seen a dramatic increase [3]. Basic idea of SPS is to collect the solar energy in orbit and send it to ground by microwave or some other way. The concept of the Solar Power Satellite energy system covered with vast arrays of solar cells, 22,300 miles above the Earth's equator in geosynchronous orbit. Sunlight illuminated each satellite 24 hours a day for most of the year. The satellites pass either above or below the Earth's shadow due to 23" tilt of the Earth's axis. During the equinox period in the spring and fall that satellite will pass through the shadow. Sunlight will be converted into electricity with the help of solar cells, which will then be converted into to radio frequency energy by a transmitting antenna on the satellite and beamed to a receiver site on Earth. Then it will be again converted into to electricity by using receiving antenna, and the power would be feeded into our normal electric distribution network for use here on the Earth. As the demand increases day by day the power generation as well as the power loss is increased. The efficiency of power transmission can be improved to certain level by using high strength composite over head conductors and underground cables that use high temperature super conductor.

Manuscript received Nov 25, 2014.

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II. WHY SPS

The burning of fossil fuels resulted in an abrupt decrease in their availability. It is also led to the greenhouse effect and many other environmental disorders. Earth based solar panels receives only a part of the solar energy. So it is advantageous to place the solar panel in the space, where, the solar energy is collected and then converted in to electricity which is later converted to a highly directed microwave beam for transmission. This microwave beam, which is directed to particular location on Earth surface, can be collected and then converted to electricity. This concept is more desirable than various conventional methods.

III. SPS –THE BACKGROUND

The concept of a large SPS that would be placed in geostationary orbit was invented by Peter Glaser in 1968

ISSN: 2278 – 909X

[4].The SPS concept was examined extensively during the late 1970s by the U.S Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA). The DOE NASA put forward the SPS Reference System Concept in 1979 [2]. The main feature of this concept was the creation of a large scale power structure in space, which consist of 60 SPS, and delivering a total of about 300GW. But due to high price tag, the subsiding energy crisis and lack of evolutionary concept in 1980-1981, all U.S SPS efforts were terminated. At that time international interest in SPS emerged which led to WPT experiments in Japan.

IV. SPS-A General Ideas

The great advantage of placing the solar cells in space instead of on the ground is that the energy is available 24 hours a day, and the total solar power energy available for satellite is between four and five times more than is available anywhere on Earth. Wireless energy transmission to the Earth can be accomplished at very high efficiencies was demonstrated by testing. Tests have also shown that the energy density in the radio-frequency beam for all life forms can be limited to safe levels [5][6]. The SPS is a gigantic satellite designed in the Geostationary Earth Orbit (GEO). It consists of mainly three segments; solar energy collector to convert the solar energy into DC (direct current) electricity, large antenna array to beam down the microwave power to the ground and DC-to-microwave converter. The first solar energy collector can be either solar thermal turbine or photovoltaic cells. The second segment is a gigantic antenna array. In order to increase the beam collection efficiency and to decrease side lobe level in almost all SPS design, amplitude tapering on the transmitting antenna is adopted. The third DC-to-microwave converter of the SPS can be either microwave tube system or semiconductor system. A typical amplitude taper is called as 10 dB Gaussian in which the power density in the center of the transmitting antenna is ten times larger than that on the edge of the transmitting antenna. Power will be transmitted over a 1-1/4 mile range to a receiving antenna (rectenna) and then fed into a commercial utility power grid. Table 1 shows some typical parameters of the transmitting antenna of the SPS, with a typical radius of approximately 2 km, is an important element of the radio technology for which high efficiency is essential. For the SPS system, the efficiency depends on input power and the input power flux density is not constant over the entire rectenna site.

V. Typical parameters of the transmitting antenna of the SPS

Model	Old JAXA Model	JAXA1 model	JAXA2 model	ASA/DOE MODEL
Frequency	5.80 GHz	5.80 GHz	5.80 GHz	2.45 GHz
Diameter of Transmitting antenna	2.6 kmφ	1 kmφ	1.93 kmφ	1 kmφ
Amplitude taper in Gaussian	10 dB	10 dB	10 dB	10 dB
Output power (beamed to earth)	1.3 GW	1.3 GW	1.3 GW	6.72 GW
Maximum power Density at center	63 mW/cm^2	420 mW/cm^2	114 mW/cm^2	2.2 W/cm^2
Antenna spacing	0.75 λ	0.75 λ	0.75 λ	0.75 λ
Efficiency	96.5 %	86 %	87 %	89 %

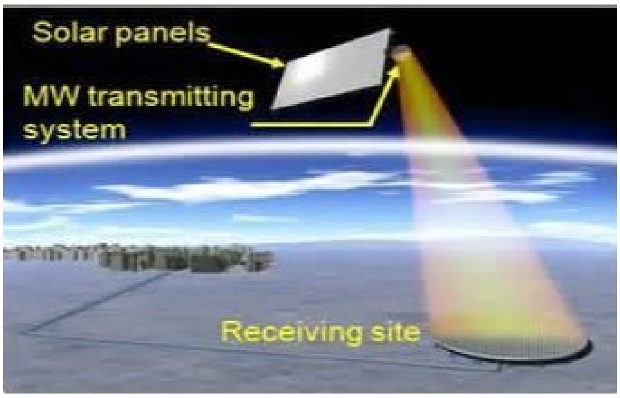

Fig1. Components of Solar Power Satellites & Basic Conversion Process

VI. Wireless Power Transmission

Fig2. WPT

By using mathematical model in 1864, James C. Maxwell was predicted the existence of radio waves. In 1884, John H. Poynting realized that the Poynting Vector would play a key role in quantifying the electromagnetic energy. In 1888, experimental evidence of radio waves by his spark-gap radio transmitter was shown by Heinrich Hertz. In the early 1900s,

ISSN: 2278 – 909X

Nikola Tesla first started experiments with WPT, conclude with the construction of a tower for WPT on Long Island in New York. Tesla's main objective was to develop the technology for transmitting electricity to anywhere in the world without wires. He filed several patents, which describing wireless power transmitters and receivers. However his knowledge about electrical phenomena was largely empirical and he did not achieve his objective of WPT, in 1940 he was awarded the patent for wireless radio. In 1965 a successful demonstration of a microwave beam-riding helicopter was performed. This demonstration proved that a WPT system could be designed and that effective microwave generators and receivers could be developed for efficient conversion of microwaves power into DC electricity. In the 1960s the increasing interest in solar energy conversion methods and solar energy applications and the limitations for producing cost-effective base load power caused by adverse weather conditions and diurnal changes led to the solar power satellite concept in 1968 as a means to convert solar energy with solar cell arrays into electricity and feed it to a microwave power generator forming planar, phased-array antenna. The antenna would direct a microwave beam of very low power density precisely to one or more receiving antennas at particular locations on Earth, in geosynchronous orbit. At a receiving side antenna, the microwave energy would be very efficiently reconverted into electricity and then transmitted to users.

VII. Microwave Power Transmission In SPS

The key microwave components in a WPT system are the transmitter, beam control and the receiver called rectenna. At the transmitter, magnetrons and klystrons which are called as microwave power tubes are used as RF power sources. Rectenna is a component unique to WPT systems. The following section describes these components in detail.

A. Transmitter

The key requirement of a transmitter is its ability to convert dc power to RF power efficiently and radiate the power to a controlled manner with low power loss. The transmitter's efficiency defines the end to-end efficiency as well as thermal management system [2]. Power distribution at the transmitter= $(1-r^2)$, where r is the radius of antenna [7]. There are mainly three dc-to RF power converters: solid state amplifiers, magnetrons, klystrons.

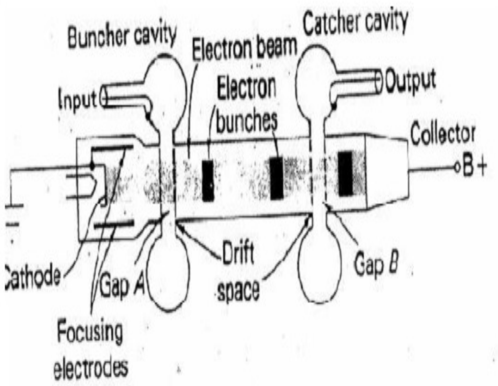

Fig3. Klystron amplifier schematic diagram

B. Klystron

Fig. 3 shows the schematic diagram of a klystron amplifier [8]. Here a high velocity electron beam is formed, focused and then send down a glass tube to a collector side electrode which is at high positive potential than the cathode. As the electron beam which is having constant velocity approaches gap A is velocity modulated by the RF voltage. Thus the bunching of electrons takes place as the beam progress further down the drift tube. This variation in current enables the klystron to have significant gain. Thus at its resonant frequency the catcher cavity is excited into oscillations and a large output is obtained.Fig.4 shows a klystron transmitter [2]. The tube body and solenoid operate at 300°C and the collector operates at 500°C. The overall efficiency is 83%. The microwave power density at the transmitting array will be 1 kW/m² for a typical 1 GW SPS with aperture of 1 km diameter in a transmitting antenna. If we use MPT of 2.45 GHz, the number of antenna elements per square meter is on the order of 100.

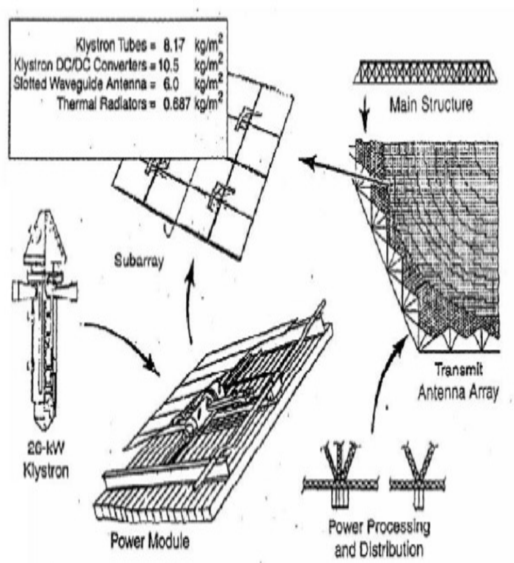

Fig4. Klystron Transmitter

2.45 GHz rectenna [2]. Rectenna is the microwa

ISSN: 2278 – 909X

C. Rectenna

Brown was the pioneer in developing the first 2.45GHz rectenna [2]. Rectenna is the microwave to dc converting device and is mainly composed of a receiving antenna and a rectifying circuit. Fig .5 shows the schematic of rectenna circuit [2]. It consists of an input low pass filter, a receiving antenna, a rectifying circuit and an output smoothing filter. The input low pass filter is needed to suppress radiation of high harmonics that are generated by the nonlinear characteristics of rectifying circuit. Because of its highly nonlinear circuit harmonic power levels must be suppressed.

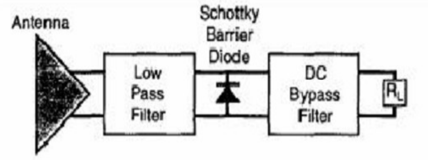

Fig5. Schematic of rectenna circuit

Diode selection is dependent on the input power levels. The power handling capacity is limited by the breakdown voltage and is directly related to series resistance and junction capacitance through the intrinsic properties of material and diode junction. The diode cut off frequency should be approximately ten times the operating frequency, for the efficient rectification. Diode cut off frequency is given by f=1/ [2_RsCj], where f is for the cut off frequency, Rs is for the diode series resistance, Cj is for the zero –bias junction capacitance.

VIII. Advantages

i. Unlimited energy resource
ii. Energy delivering anywhere in the world.
iii. Zero CO2 emission.
iv. Minimize long range environmental impact
v. Zero fuel cost.

IX. Disadvantages

i. Launch cost.
ii. Would require a large network of satellites.
iii. Possible health hazard.
iv. In Geosynchronous satellites the antennas and rectennas would take up large sections of space.
v. Interference to the communication satellites takes place

X. Applications

Around 2030 the SPS is expected to realize. Before the realization of the SPS, the other application of the WPT can considered. In recent years, mobile devices advance quickly and less power consumption is required. So we can use the diffused weak microwave power as a power source of the mobile devices with less power consumption.

XI. Biological Impacts

Common beliefs fear the effect of microwave radiation. But the studies in this domain proves that the level of microwave radiation would never be higher than the those received while opening the door of microwave oven, it means that it is slightly higher than the emissions created by cellular telephones. However Tests have also shown that the energy density in the radio-frequency beam can be limited to safe levels for all life forms.

XII. Conclusion

A wireless power transfer system is capable of transferring the required amount of power which studied successfully with resonance. The technological improvement in Wireless Power Transmission (WPT), advantages, disadvantages, biological impacts and applications of WPT are also discussed in this paper. This concept offers greater possibilities for transmitting power with negligible losses in case of transmission. This paper provides basic idea and development for solar power satellite which is the best option for present energy demand related problems. The proposed system can be effectively used for Farm-Houses, Industrial site for their power requirement purpose.

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