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Future Power Systems

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Abstract: Energy is the concept of energy retrieving from the sun via solar power satellites , transmit as the radio frequency waves and beamed to a receiver site on earth and reconverted to electricity by using transmitting and receiving antenna with the technology of wireless power transmission. In this paper, I present the concept of transmitting power without using wires i.e., transmitting power as microwaves from one place to another is in order to reduce the transmission and distribution losses. I also included merits, demerits and applications of this concept.

Keywords: Ubiquitous,Solar Power Satellites(SPS),Rectenna,Transmitting antenna,Microwave Power Transmossion.

I. INTRODUCTION

SPS is a gigantic satellite designed as an electric power plant orbiting in the Geostationary Earth Orbit (GEO), covered with vast arrays of solar cells, in geosynchronous orbit 22,300 miles above the Earth's equator. Each satellite will be illuminated by sunlight 24 hours a day for most of the year. Because of the 23"tilt of the axis, the satellites pass either above or below the Earth's shadow. It is only during the equinox period in the spring and fall that they will pass through the shadow. They will be shadowed for less than 1% of the time during the year. The solar cells will convert sunlight to electricity, which will then be changed to radio-frequency energy by a transmitting antenna on the satellite and beamed to a receiver site on Earth. It will be reconverted to electricity by the receiving antenna, and the power would then be routed intoour normal electric distribution network for use here on the Earth It consists of mainly three segments; solar energy collector to convert the solar energy into DC (direct current) electricity, DC-to-microwave converter, and large antenna array to beam down the microwave power to the ground.

The problematic thing in existing power system was power loss and Power thieft. As the demand increases day by day, the power generation increases and the power loss is also increased. The major amount of power loss occurs during transmission and distribution. The percentage of loss of power during transmission and distribution is approximated as 26%. The main reason for power loss during 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 composite over head conductors and underground cables that use high temperature super conductor. But, the transmission is still inefficient. According to the World Resources Institute (WRI), India's electricity grid has the highest transmission and distribution losses in the world – a whopping 27%. Numbers published by various Indian government agencies put that number at 30%, 40% and greater than 40%.

The stated problem can be compensated by choose an alternative option for power transmission which could provide much higher efficiency, low transmission cost and avoid power theft. Microwave Power Transmission is one of the promising technologies and may be the righteous alternative for efficient power transmission.

HISTORY OF WPT

Nikola Tesla he is who invented radio and shown us he is indeed the "Father of Wireless". Nikola Tesla is the one who first conceived the idea Wireless Power Transmission and demonstrated "the transmission of electrical energy without wires" that depends upon electrical conductivity as early as 1891. In 1893, Tesla demonstrated the illumination of vacuum bulbs without using wires for power transmission at the World Columbian Exposition in Chicago. The Wardenclyffe tower shown in Figure 1 was designed and constructed by Tesla mainly for wireless transmission of electrical power rather than telegraphy .

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In 1904, an airship ship motor of 0.1 horsepower is driven by transmitting power through space from a distance of least 100 feet . In 1961, Brown published the first paper proposing microwave energy for power transmission, and in 1964 he demonstrated a microwave-powered model helicopter that received all the power needed for flight from a microwave beam at 2.45 GHz from the range of 2.4GHz – 2.5 GHz frequency band which is reserved for Industrial, Scientific, and Medical (ISM) applications. Experiments in power transmission without wires in the range of tens of kilowatts have been performed at Goldstone in California in 1975 and at Grand Bassin on Reunion Island in 1997 . The world's first MPT experiment in the ionosphere called the MINIX (Microwave Ionosphere Non-linear Interaction Experiment) rocket experiment is demonstrated in 1983 at Japan .

Similarly, the world's first fuel free airplane powered by microwave energy from ground was reported in 1987 at Canada. This system is called SHARP (Stationary High – Altitude Relay Platform). In 2003, Dryden Flight Research Centre of NASA demonstrated a laser powered model airplane indoors. Japan proposed wireless charging of electric motor vehicles by Microwave Power Transmission in 2004. Powercast, a new company introduced wireless power transfer technology using RF energy at the 2007 Consumer Electronics Show . A physics research group, led by Prof. Marin Soljačić, at the Massachusetts Institute of technology (MIT) demonstrated wireless powering of a 60W light bulb with 40% efficiency at a 2m (7ft) distance using two 60cm-diameter coils in 2007 .. Recently in 2008, Intel reproduced the MIT group's experiment by wirelessly powering a light bulb with 75% efficiency at a shorter distance .

WIRELESS POWER TRANSMISSION

William C. Brown, the pioneer in wireless power transmission technology, has designed, developed a unit and demonstrated to show how power can be transferred through free space by microwaves. The concept of Wireless Power Transmission System is explained with functional block diagram shown in Figure 2. In the transmission side, the microwave power source generates microwave power and the output power is controlled by electronic control circuits. The wave guide ferrite circulator which protects the microwave source from reflected power is connected with the microwave power source through the Coax – Waveguide Adaptor. The tuner matches the impedance between the transmitting antenna and the microwave source. The attenuated signals will be then separated based on the direction of signal propagation by Directional Coupler. The transmitting antenna radiates the power uniformly through free space to the rectenna.

In the receiving side, a rectenna receives the transmitted power and converts the microwave power into DC power. The impedance matching circuit and filter is provided to setting the output impedance of a signal source equal to the rectifying circuit. The rectifying circuit consists of Schottky barrier diodes converts the received microwave power into DC power.

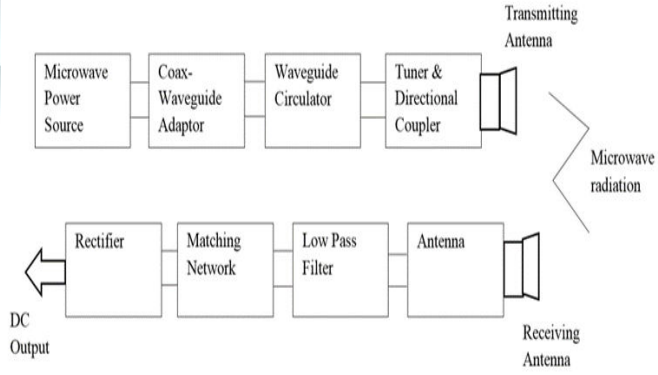
SEGMENTS OF SPS & MPT/WPT:

- Microwave Generator
- Transmitting antenna
- Receiving antenna (Rectenna)

A. Microwave Generator

There are two types of microwave generators/amplifiers. One is a microwave tube and the other is a semiconductor amplifier. The microwave transmitting devices are classified as Microwave Vacuum Tubes (magnetron, klystron, Travelling Wave Tube (TWT), and Microwave Power Module (MPM)) and Semiconductor Microwave transmitters (GaAs MESFET, GaN pHEMT, SiC MESFET, AlGaN/GaN HFET, and InGaAS). Magnetron is widely used for experimentation of WPT.

These have electric characteristics contrary to each other. The microwave tube, such as a cooker-type magnetron, can generate and amplify high power microwave (over kW) with a high voltage (over kV) imposed. Especially, magnetron is very economical. The semiconductor amplifier generate low power microwave (below 100W) with a low voltage (below fifteen volt) imposed. It is still expensive currently. Although there are some discussion concerning generation/amplifier efficiency, the microwave tube has higher efficiency (over 70%) and the semiconductor has lower efficiency (below 50%) in general.



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i) MAGNETRONS

The magnetron is self-oscillatory device in which the anode contains a resonant RF structure. magnetron is suitable device for the MPT because of high efficiency and low cost and unsuitable device because of its unstable frequency and uncontrollable phase. some types of magnetrons are

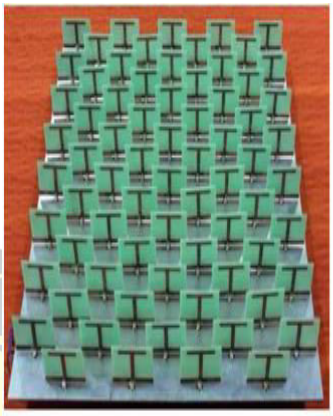
1.Negative resistance type
2.Cyclotron frequency type
3. Cavity type

The microwave transmission often uses 2.45GHz or 5.8GHz of ISM band. The other choices of frequencies are 8.5 GHz , 10 GHz and 35 GHz . The highest efficiency over 90% is achieved at 2.45 GHz among all the frequencies .

B. Power Transmitting Antennas

All antennas can be applied for both the MPT system and communication system, for example, Yagi-Uda antenna, horn antenna, parabolic antenna, microstrip antenna, phased array antenna or any other type of antenna. To fixed target of the MPT system, we usually select a large parabolic antenna.

However, we have to use a phased array antenna for the MPT from/to moving transmitter/receiver which include the SPS because we have to control a microwave beam direction accurately and speedy. The phased array is a directive antenna which generate a beam form whose shape and direction by the relative phases and amplitudes of the waves at the individual antenna elements. It is possible to steer the direction of the microwave beam. The antenna elements might be dipoles, slot antennas, or any other type of antenna, even parabolic antennas. In some MPT experiments in Japan, the phased array antenna was adopted to steer a direction of the microwave beam . All SPS is designed with the phased array antenna



C.Rectenna

The concept, the name ‘rectenna’ and the rectenna was conceived by W.C. Brown of Raytheon Company in the early of 1960s.. The rectenna is a passive element consists of antenna, rectifying circuit with a low pass filter between the antenna and rectifying diode. The antenna used in rectenna may be dipole, Yagi – Uda, microstrip or parabolic dish antenna. The patch dipole antenna achieved the highest efficiency among the all. The performance of various printed rectenna is shown in Table I. Schottky barrier diodes (GaAs-W, Si, and GaAs) are usually used in the rectifying circuit due to the faster reverse recovery time and much lower forward voltage drop and good RF characteristics.

CASE STUDIES

A 1 GW SPS power plant has the following typical dimensions. The area of a solar cell panel is approximately 10 km2 (2km x 5km) for production of 2GW DC power with the solar cell conversion efficiency of 15%. The transmitting antenna array will typically be 1km in diameter. The aperture distribution of the transmitting antenna is determined such as uniform profile or Gaussian profile based on the required beam collecting efficiency. Assuming an antenna element spacing of 0.75λ =3.8cm at 5.8GHz, a radiator weight density of 2.69g/cc, and 160 antenna elements, one could get 9.6 kg/ m2 with this design approach.

A typical rectenna site is 4 kmin diameter for a transmitting antenna diameter of 1km operating at 5.8 GHz. Under these conditions, 93% of the transmitted power is

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collected. The peak microwave power density at the rectenna site is 27 mW/cm2 if a Gaussian power profile is assumed for the transmitter. The beam intensity pattern has a non-uniform distribution with a higher intensity in the center of the rectenna and a lower intensity at its periphery . The safety requirement for the microwave power density for humans is set to 1mW/cm2 in most countries, which is satisfied at the periphery.

MERITS

Wireless Power Transmission system would completely eliminates the existing high-tension power transmission line cables, towers and sub stations between the generating station and consumers and facilitates the interconnection of electrical generation plants on a global scale. It has more freedom of choice of both receiver and transmitters. Even mobile transmitters and receivers can be chosen for the WPT system. The cost of transmission and distribution become less and the cost of electrical energy for the consumer also would be reduced. The power could be transmitted to the places where the wired transmission is not possible. Loss of transmission is negligible level in the Wireless Power Transmission; therefore, the efficiency of this method is very much higher than the wired transmission. Power is available at the rectenna as long as the WPT is operating. The power failure due to short circuit and fault on cables would never exist in the transmission and power theft would be not possible at all. The development of Solar Power Satellites gain the benefits of abundant, low-cost, nonpolluting energy. 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 energy available to the satellite is between four and five times more than is available anywhere on Earth and 15 times more than the average location.

DEMERITS

The Capital Cost for practical implementation of WPT seems to be very high and the other disadvantage of the concept is interference of microwave with present communication systems. Heat reduction is most important problem in space. All lost power converts to heat. We need special heat reduction system in space. If we use high efficient microwave transmitters, we can reduce weight of heat reduction system. We should aim for over 80 %efficiency the

microwave transmitter, which must include all loss in phase shifters, isolators, antennas, power circuits.

BIOLOGICAL IMPACTS

Common beliefs fear the effect of microwave radiation. But the studies in this domain repeatedly proves that the microwave radiation level would be never higher than the dose received while opening the microwave oven door, meaning it is slightly higher than the emissions created by cellular telephones Cellular telephones operate with power densities at or below the ANSI/IEEE exposure standards . Thus public exposure to WPT fields would also be below existing safety guidelines. However Tests have also shown that the energy density in the radio-frequency beam can be limited tosafe levelsfor all life form

ENVIRONMENTAL ISSUES

1.Interferences to Existent Wireless System
2. Interaction with Atmosphere
3. Interaction with Space Plasmas
4. Safety on Ground

APPLICATIONS

The SPS is expected to realize around 2030. Before the realization of the SPS, we can consider the other application of the WPT. In resent years, mobile devices advance quickly and require decreasing power consumption. It means that we can use the diffused weak microwave power as a power source of the mobile devices with low power consumption such as RF-ID. The RF-ID is a radio IC-tug with wireless power transmission and wireless information. This is a new WPT application like broadcasting.

CONCLUSIONS

The concept of Microwave Power transmission (MPT) and Wireless Power Transmission system is presented. The technological developments in Wireless Power Transmission (WPT), the advantages, disadvantages, biological impacts and applications of WPT are also discussed. This concept offers greater possibilities for transmitting power with negligible losses and ease of transmission. Furthermore, it appears almost certain that there will be a shift towards renewable sources and that solar will be a major contributor. It is asserted that if the energy system of the world is to work for all its people and be adequately robust, there should be several options to develop in the pursuit of and expanded supply. While the option of Space Solar Power may seem futuristic at present, it is technologically feasible and, given appropriate conditions, can be come economically viable

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