

Wireless Power Transmission via Solar Power Satellites

V.Srinath¹, K.Deepa²

UG Scholar, Department of ECE, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India¹

Asst. Professor, Department of ECE, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India²

ABSTRACT: In this paper, we present the idea of production of electricity by means of solar power satellites (i.e., SPS) and transmission of power wirelessly in the form of microwaves from space to earth and for domestic use as well (i.e., transmitting power as microwaves in order to reduce the transmission and distribution losses). This concept is also known as Microwave Power Transmission. The working of the system, advantages and applications of microwave power transmission are also discussed.

KEYWORDS: Grid, Microwaves, Microwave generator, Rectenna, Solar Power Satellites (SPS), Transmitting antenna, Wireless Power transmission (WPT), Wireless Electricity Transmission (WET).

I. INTRODUCTION

The concept of power production via solar power satellite is that placing satellites which are covered up with huge amount of solar cells (panels) at geostationary earth orbit. The main purpose of placing satellites covered with solar cells is that the sun rays illuminates the solar cells (24*7). The solar cells convert the solar energy into electricity. The microwave converter present in the space segment of the solar power satellite converts the electricity into microwaves and the large Antenna array present in the satellite beams down the microwaves to the receiver site (grids) present in the earth and from the grids the power is transmitted wirelessly to the consumers in the form of microwaves. Through the process of WPT we can eradicate the constraints present in the wired transmission. When the power is transmitted via wires over a long distance transmission loss occurs. This transmission loss is mainly due to the internal resistance of the wire used in the transmission and also due to grids inefficiency, power theft, hazardous overhead current carrying conductors are other reasons which makes the process of wired transmission cumbersome. In India, the transmission loss is around 40% as per the recent researches.

II. SEGMENTS OF SPS

The SPS is a gigantic satellite designed as an electric power plant orbiting 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, DC-to-microwave converter, and large antenna array to beam down the microwave power to the ground. The first solar collector can be either photovoltaic cells or solar thermal turbine. The second DC-to-microwave converter of the SPS can be either microwave tube system and/or semiconductor system. It may be their combination. The third segment is a gigantic antenna array. An amplitude taper on the transmitting antenna is adopted in order to increase the beam collection efficiency and to decrease side lobe level in almost all SPS design. A typical amplitude taper is called 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. The rectenna array, with a typical radius of approximately 2 km, is an important element of the radio

technology for which high efficiency is essential. The efficiency depends on the input power, and the input power flux density is not constant over the entire rectenna site for the SPS system.

Table 1 Typical parameters of the transmitting antenna of the SPS

| Model | Old JAXA Model | JAXA1 model | JAXA2 model | NASA/DOE MODEL |
|--|----------------------------|-------------------------|----------------------------|-------------------------|
| Frequency | 5.8 GHz | 5.8 GHz | 5.8 GHz | 2.45 GHz |
| Diameter of Transmitting antenna | 2.6 km ϕ | 1 km ϕ | 1.93 km ϕ | 1 km ϕ |
| Amplitude taper | 10 dB Gaussian | 10 dB Gaussian | 10 dB Gaussian | 10 Db Gaussian |
| 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 |
| Minimum power Density at center | 6.3 mW/ cm ² | 42 mW/ cm ² | 11.4 mW/cm ² | 0.22 W/ cm ² |
| Antenna spacing | 0.75 λ | 0.75 λ | 0.75 λ | 0.75 λ |
| Powerperone Antenna (Number of elements) | Max. 0.95 W (3.54 billion) | Max. 6.1W (540 million) | Max. 1.7 W (1,950 million) | Max. 185 W (97 million) |
| Rectenna diameter | 2.0 km ϕ | 3.4 km ϕ | 2.45 km ϕ | 1 km ϕ |
| Maximum power Density | 180 mW/cm ² | 26 Mw/cm ² | 100 mW/cm ² | 23 mW/cm ² |
| Efficiency | 96.5 % | 86 % | 87 % | 89 % |

JAXA : Japan Aerospace Exploration Agency, NASA : National Aeronautics and Space Administration,

DOE : U.S. Department Of Energy.

III. WIRELESS ELECTRICITY TRANSMISSION

Wireless power transmission is a process that takes place in any type of system in which electrical current is conveyed from a source to an electrical load. The main advantage of WET is that there is no usage of any type of wires to connect the source and device. Wireless electricity (power) transmission is basically is the transmission of electricity with the help of microwaves and there is no need to use cables, towers, and grids. The long range application of wireless power transmission via microwaves is production of power through solar power satellites which are placed at geostationary earth orbits. These sps contains two parts 1.Space segment & 2 Ground segment.

3.1 SPACE SEGMENT

At the space segment the solar power satellites converts the solar energy into DC electricity with the help of solar cells (photovoltaic cells) which are present in the satellites. The produced dc energy is converted into microwave signals with the help of DC to microwave converter which is composed of microwave tube /

semiconductor system (generally magnetron). This microwave energy is transmitted to earth with the help of large Antennas arrays.

3.2 GROUND SEGMENT

The microwave energy transmitted by the antennas present in the satellites is received by the receiving antennas at the main grid station present in the ground (earth). This power is then transmitted to the power hubs / substations. The power is transmitted wirelessly to the each home / consumer site in the form of microwaves. There will be energy receiver box in each home which consists of simple rectenna / rectifying circuit . The rectifying circuit have schottky barrier diodes to convert the received microwaves into DC electricity for the energy consumption / use. The information of electricity or power required for each home will be available with the grid station and the energy that is transmitted from the transmitter will reaches the energy box present in the receiver site according to the power requirement data for the corresponding consumers present in the grid station and thus in this process only the authenticated receiver receives the power signal.

IV. WIRELESS POWER TRANSMISSION

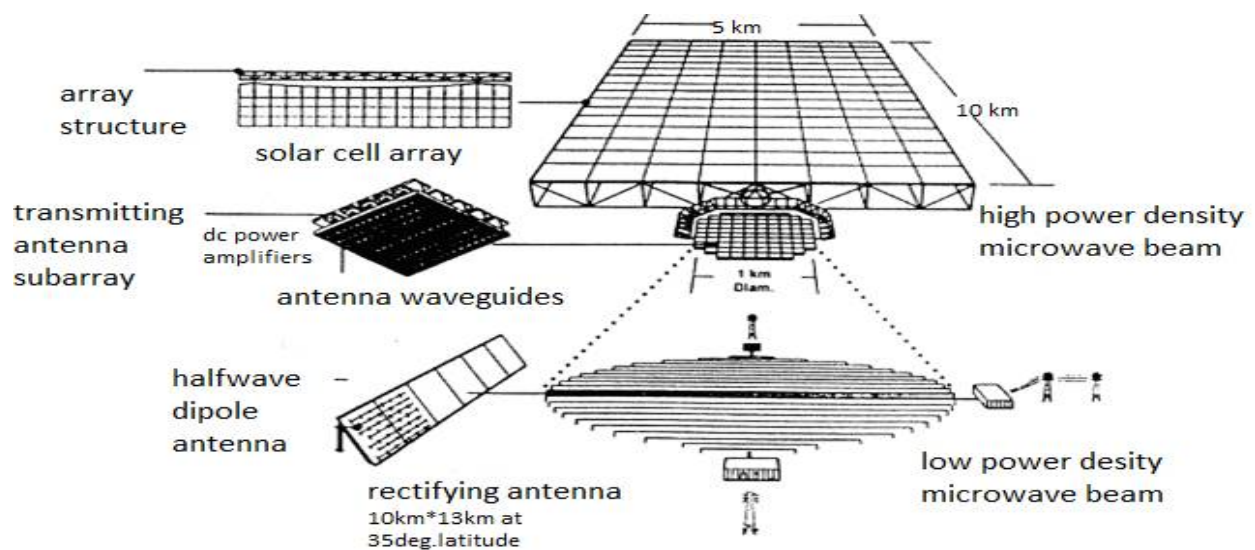


Fig .4 Block Diagram of WPT via SPS

Nicola Tesla he is who invented radio and shown us he is indeed the “Father of Wireless”. Nicola 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.

V. COMPONENTS OF WPT SYSTEM

The significant components of Wireless (Microwave) Power Transmission are Microwave Generator, Transmitting antenna and Receiving antenna (Rectenna).

5.1 Microwave Generator

The microwave transmitting devices are classified as Microwave Vacuum Tubes (magnetron, klystron, Travelling Wave Tube (WT), and Microwave Power Module (MPM)) and Semiconductor Microwave transmitters. Magnetron is widely used for experimentation of WPT. The microwave transmission often uses 2.45GHz of ISM band over which 90% efficiency is obtained.

5.2 Transmitting Antenna

The slotted wave guide antenna, microstrip patch antenna, and parabolic dish antenna are the most popular type of transmitting antenna. The slotted waveguide antenna is most suitable for power transmission because of its high aperture efficiency (> 95%) and high power handling capability.

5.3 Rectenna

The rectenna is a passive element which consists of antenna, rectifying circuit with a low pass filter and the rectifying diode. The antenna used in rectenna may be dipole antenna or patch antenna, and the patch dipole antenna achieved the highest efficiency among the all. 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.

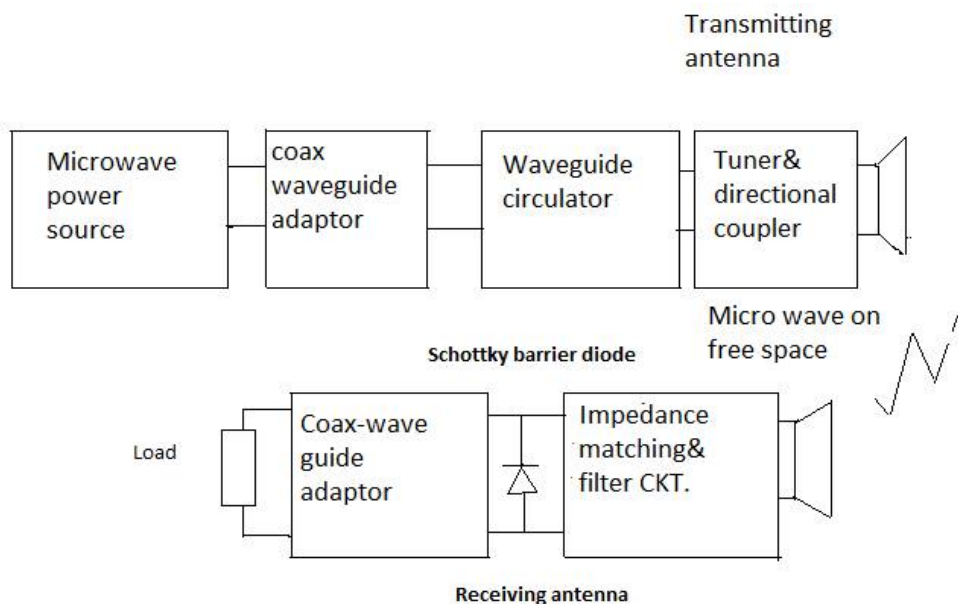


Fig.5 Functional Block Diagram of Wireless Power Transmission System

In the transmission side, the microwave power source generates microwave power and the output power is controlled by electronic control circuits. The waveguide 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 transmitting antenna radiates the power uniformly through free space to the rectenna. Impedance matching is the practice of designing the input impedance electrical load output impedance to maximize the power transfer or minimize reflections from the load.

VI. PROPOSED SYSTEM

In this system we propose the concept of transmission of generated power wirelessly in the form of microwaves to the consumer site. The microwaves transmitted by the SPS are received by the Antennas present in the grid stations present in the earth. From the main grid station the power is transmitted wirelessly in the form of microwaves to the substations/power hubs and finally the power is transmitted to the consumer (Homes) wirelessly. The grid stations contains the information of power required for each home. The transmitted power is received by the energy receiver box present in each home which contains a simple rectenna / rectifying circuit which converts the microwaves into electricity for the domestic utility. Thus through this system the power is transmitted to the consumers wirelessly which eliminates the dreadful harms caused by the conventional wired power transmission. WPT also eliminates power theft , transmission loss etc.

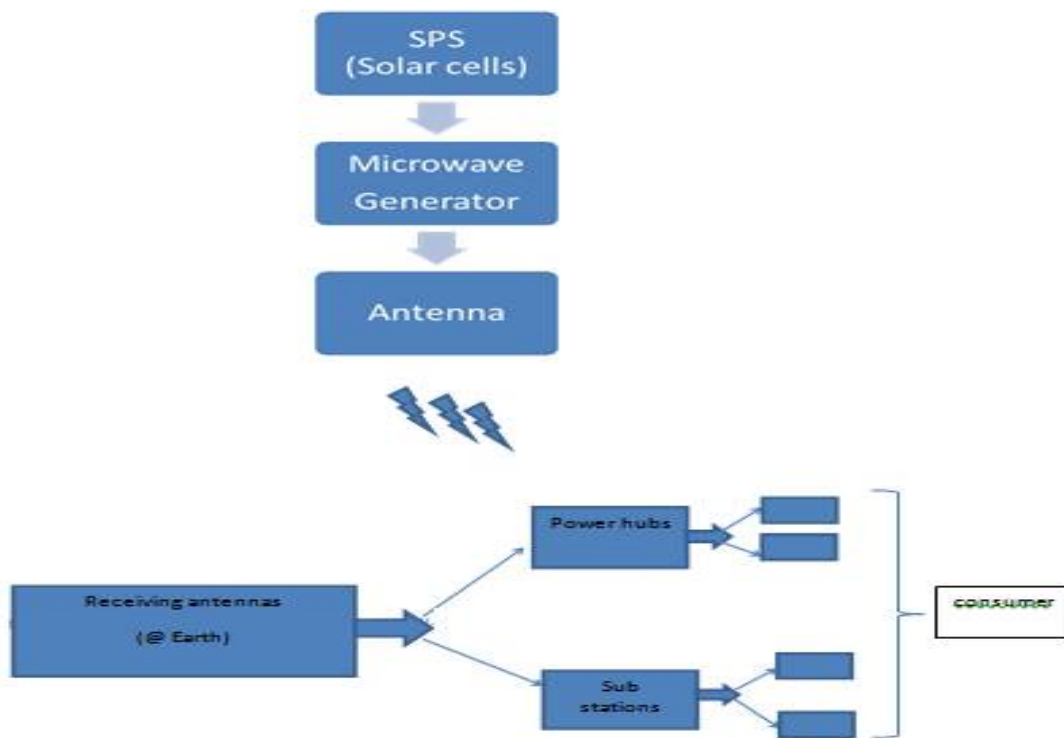


Fig.6 Block Diagram of Wireless Power Transmission System for domestic utility.

VII.ADVANTAGES

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.

VIII. APPLICATIONS

The SPS is expected to be implemented around 2030. Before the implementation of the SPS, we can consider the other application of the WPT. In recent 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.

IX. CONCLUSION & FUTURE ENHANCEMENTS

In this paper the idea of Wireless Electricity Transmission (WET) is presented. The technological developments in Wireless Power Transmission (WPT), the advantages, applications and future enhancements of WPT are also this discussed. This idea offers higher possibilities power transmission with negligible losses and in this concept the renewable energy resources are used. 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 become economically viable. The process of wireless power transmission can also be adopted for Hydal, Tidal, Wind etc. The power produced by all the above process can be transmitted wirelessly in the form of microwaves.

REFERENCES

- [1] Nikola Tesla, "The Transmission of Electrical Energy Without Wires as a Means for Furthering Peace," *Electrical World and Engineer*, Jan. 7, p. 21, 1905.
- [2] Brown, W. C., "Beamed microwave power transmission and its application to space", *IEEE Trans. Microwave Theory Tech.*, vol. 40, no. 6, 1992, pp.1239-1250.
- [3] Supporting Document for the URSI White Paper on Solar Power Satellite Systems, 2006.
- [4] McSpadden, J. O. and J. C. Mankins, "Space Solar Power Programs and Microwave Wireless".
- [5] Glaser, P. E., "Power from the Sun, *Science*", No.162, 1968, pp.857-886. *Power Transmission Technology*, IEEE Microwave Magazine, December 2002, pp.46-57.
- [6] Matsumoto, H., "Research on Solar Power Station and Microwave Power Transmission in Japan : Review and Perspectives", *IEEE Microwave Magazine*, December 2002, pp.36-45.
- [7] Sivan, L., "Microwave Tube Transmitters *Microwave Technology Series 9-*", Chapman & Hall, 1994.
- [8] Hatsuda, T., K. Ueno, M. Inoue, "Solar power satellite interference assessment", *IEEE Microwave Magazine*, Vol. 3, No. 4, Dec. 2002, pp.65-70.
- [9] Little, F. E., S. J. Kokel, C. T. Rodenbeck, K. Chang, G. D., Arndt, and P. H. Ngo, "Development of Retrodirective Control Transmitter for Wireless Power Transmission", *The Radio Science Bulletin*, No.311, 2004, pp. 38-46.
- [10] Gutmann, R. J. and R. B. Gworek, "Yagi-Uda Receiving Elements in Microwave Power Transmission System Rectennas", *Journal of Microwave Power*, Vol.14, No.4, 1979, pp.313-320.