Review Of Existing Microwave Beamed Wireless Energy Transfer Schemes

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I. ABSTRACT

Wireless energy transfer being an early idea of efficient power transmission avoiding complexity with hazardous wires. It is known that electromagnetic energy also associated with the propagation of the electromagnetic waves. This paper presents the concept of wireless energy transfer based on Tesla's inventions i.e., transmitting power as microwaves from one place to another in order to reduce the transmission and distribution losses. This concept is known as Microwave Power transmission (MPT).This paper also presents the different methods of WET, mainly focussing on microwave beamed energy transfer and its advantages, disadvantages, biological impacts and applications of MPT.

Key words: microwave energy transmission, power beaming, Tesla inventions, SBSP, SERT, proposed projects of MPT.

II. INTRODUCTION

One of the major issue in power system is the losses occurs during the transmission and distribution of electrical power. 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. Microwave Power Transmission is one of the promising technologies and may be the righteous alternative for efficient power transmission.

III.HISTORY OF WIRELESS ENERGY TRANSFER

Nikola Tesla, who invented radio and shown us he is indeed the "Father of Wireless". Nikola Tesla is the one who first conceived the idea of 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

Fig:1

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 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.

IV.METHODS OF WIRELESS ENERGY TRANSFER

Wireless energy transfer or wireless power is the transmission of electrical energy from a power source to an electrical load without artificial interconnecting conductors. The most common form of wireless power transmission is carried out using direct induction followed by resonant magnetic induction[1]. Other methods under consideration include electromagnetic radiation in the form of microwaves or lasers.

A. ELECTROMAGNETIC INDUCTION

Energy transfer by electromagnetic induction is typically magnetic but capacitive coupling can also be achieved. It is categorised in to A) electro dynamic induction B) electro static induction.

B.ELECTRODYNAMIC INDUCTION METHOD

The electrodynamics induction wireless transmission technique is near field over distances up to about one-sixth of the wavelength used. Common uses of electrodynamics induction are charging the batteries of portable devices such as laptop computers and cell phones, medical implants and electric vehicles.

C.ELECTROSTATIC INDUCTION METHOD

Electrostatic or capacitive coupling is the passage of electrical energy through a dielectric. In practice it is an electric field gradient or differential capacitance between two or more insulated terminals, plates, electrodes, or nodes that are elevated over a conducting ground plane. The principle of electrostatic induction is applicable to the electrical conduction wireless transmission method.

D.ELECTRO MAGNETIC RADIATION

Far field methods achieve longer ranges, often multiple kilometre ranges, where the distance is much greater than the diameter of the device(s). The main reason for longer ranges with radio wave and optical devices is the fact that electromagnetic radiation in the far-field can be made to match the shape of the receiving area. Mainly classified as A) Microwave beam method B) Laser beam method.

V. Microwave transmission

The atmospheric attenuation of microwaves in dry air with a perceptible water vapour level of 0.001 mm. The downward spikes in the graph correspond to frequencies at which microwaves are absorbed more strongly, such as by oxygen molecules. Microwave transmission refers to the technology of transmitting information or energy by the use of radio waves whose wavelengths are conveniently measured in small numbers of centimetres; these are called *microwaves* [2]. This part of the radio spectrum ranges across frequencies of roughly 1.0 gigahertz (GHz) to 30 GHz. These correspond to wavelengths from 30 centimetres down to 1.0 cm. Microwaves are widely used for point-to-point communications because their small wavelength allows conveniently-sized antennas to direct them in narrow beams, which can be pointed directly at the receiving antenna. This allows nearby microwave equipment to use the same frequencies without interfering with each other, as lower frequency radio waves do. Another advantage is that the high frequency of microwaves gives the microwave band a very large information-carrying capacity; the microwave band has a bandwidth 30 times that of all the rest of the radio spectrum below it.

A. Components of MPT System

The Primary components of Microwave Power Transmission are Microwave Generator, Transmitting antenna and Receiving antenna (Rectenna). The components are described in this chapter.

A.1.Microwave Generator

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, GaNpHEMT, SiC MESFET, AlGaN/GaN HFET, and In GaAS). Magnetron is widely used for experimentation of WPT. The microwave transmission often uses 2.45GHz or 5.8GHz of ISM band. The highest efficiency over 90% is achieved at 2.45 GHz among all the frequencies.

A.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 ideal for power transmission because of its high aperture efficiency (> 95%) and high power handling capability.

A.3.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 antennas and rectifying diode. The antenna used in rectenna may be dipole, Yagi – Uda, microstrip or parabolic dish antenna.

VI.Comparision of various MPT schemes

Microwave

Power beaming by microwaves has the difficulty that for most space applications the required aperture sizes are very large due to diffraction limiting antenna directionality.

A rectenna may be used to convert the microwave energy back into electricity.

It does not allows narrow beam cross-section area for energy transmission over large ranges due to "thinned array curse".

Conversion to light, such as with a Microwave is efficient.

Conversion back into electricity is efficient, Rectenna conversion efficiencies exceeding 95% have been realized.

continuous power transmission is available .

It allows more distance-to-power capabilities.

Micro wavebeam propagation is much more affected by diffraction limits.

There is no Atmospheric absorption losses.

The large size of the transmitting and receiving antennas means that hight practical power level s.

They have increased atmospheric absorption and even potential beam blockage by rain or water droplets .

Power beaming from geostationary orbit by microwaves carries the difficulty that the required 'optical aperture' sizes are very large.

Laser method

power can be transmitted by converting electricity into a laser beam that is then pointed at a solar cell receiver. This mechanism is generally known as "powerbeaming"

In this method power is beamed at a receiver that can convert it to usable electrical energy

It allows narrow beam cross-section area for energy transmission over large ranges due to collimated monochromatic wavefront propagation

compact size of solid state lasers-photovoltaics semiconductor diodes fit into small products.

No radio-frequency interference to existing radio communication such as Wi-fi and cell phones.

Conversion to light, such as with a laser, is inefficient

Conversion back into electricity is inefficient, with photovoltaic cells achieving 40%–50% efficiency.

Possibility of continuous power transmission is immediately available as soon as the first space power station is placed in orbit;

coherence characteristics of Lasers allows better distance-to-power capabilities

Laser beam propagation is much less affected by diffraction limits.

Atmospheric absorption causes losses.

Less practical power levels because of small sizes.

There is no potential beam blockage by rain or water droplets .

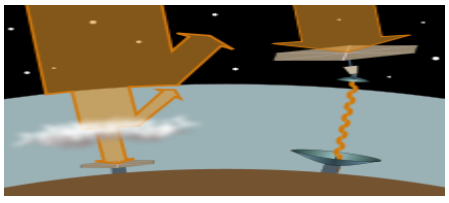
Power beaming from geostationary orbit by laserbeam have no difficulty occurs because of small sized components.

In laserbeam th reception efficiency is poor, but its cost and complexity is less.

VII.APPLICATIONS OF MPT

This microwave beam method of energy transmission has found its advent in many fields. Some of them are:

A) SPACE-BASED SOLAR POWER (SBSP)



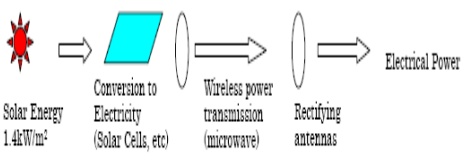


Fig.2 Transmission of the solar energy to the ground

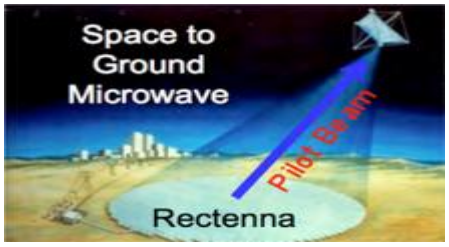
Space-based solar power (SBSP) is the concept of collecting solar power in space for use on Earth. It has been in research since the early 1970s [3].

Some projected benefits of SBSP a system are:

- Higher collection rate: In space, transmission of solar energy is unaffected by the filtering effects of atmospheric gasses. Longer collection period: Orbiting satellites can be exposed to a high degree of solar radiation, generally for 24 hours per day, whereas surface panels can collect for 12 hours per day at most.[1]
- Elimination of weather concerns, and it will reside in atmospheric gasses, cloud cover, wind, and other weather events.
- Elimination of plant and wildlife interference.

Rectenna

The collecting satellite would convert solar energy into electrical energy on-board, powering a microwave transmitter or laser emitter, and focus its beam toward a collector (rectenna) on the Earth's surface. Radiation and micrometeoroid damage could also become concerns for SBSP.



A laser pilot beam guides the microwave power transmission to a rectenna.

NASA Sun tower concept.

Advantages of space-based solar power over conventional solar designs

- Efficiency and reliability. Solar power collection in space is seven to ten times more efficient than collection on Earth.

- Collectors in geosynchronous Earth orbit (GEO), about 36,000 kilometres above Earth, is that it uses the constant and unobstructed output of the Sun, unaffected by the Earth's day/night cycle.

- SBSP can overcome the limitations of conventional methods i.e limitations like

Weather ,Variable seasons , Atmospheric blocking of sunlight ,Poor direct sunlight at higher and lower latitudes

- Expensive and limited storage capacity
- SBSP cell can provide an estimated 6-8 times more power than a comparable solar cell on the Earth's surface.

- Future space-based solar power projects could lead to jobs for five million people, who would build and launch the satellites

FUTURE GOALS OF SBSP(Space-based solar power)

The goal is set to realize the 1 GW class operational solar power satellite in the Geo-stationary Earth Orbit in 20 to 30 years. 1GW is an output of a popular atomic power plant. Solar lights are collected by mirrors at the generator / transmitter.

The first step is the demonstration of the wireless power transmission (WPT) and evaluation of environmental effects that may be caused by the wireless power transmission [4].

The second step is building a 250MW class prototype solar power satellite will be built in the Geo-stationary Earth Orbit. Economical and Efficient space transportation system must be developed to realize this system. 1GW of power will just be sufficient to serve the purposes of the partial basic activities of the world in 2020!!!

Differences between SBSP and Existing Schemes

SBSP there have been a number of technical advances: (1) a factor-of-three increase in PV efficiencies; (2) a factor-of-four increase in the efficiency of solid-state high-power microwave transmitters (3) improved beam steering technologies; (4) vastly improved robotics and (5) significantly

reduced PV cell thickness. 6) SBSP energy is still over 40 times the cost of wind energy – assuming similar system lifetimes.

B) SERT(Space Solar Power Exploratory Research and Technology program)

In 1999, NASA's Space Solar Power Exploratory Research and Technology program (SERT) was initiated for the following purposes:

Perform design studies of selected flight demonstration concepts.

Evaluate studies of the general feasibility, design, and requirements.

Create conceptual designs of subsystems that make use of advanced Space Solar Power (SSP) technologies to benefit future space or terrestrial applications.

Construct technology development and demonstration roadmaps for critical Space Solar Power (SSP) elements.

SERT went about developing a solar power satellite (SPS) concept for a future Giga watt space power system, to provide electrical power by converting the Sun's energy and beaming it to Earth's surface, and provided a conceptual development path that would utilize current technologies [5].

V111. Merits of Wireless Electricity Transmission

- cost associated with deploying towers and cables can be saved.
- During the rains and after natural disasters it is often hard to manage the cables and towers.
- It is possible to deliver electricity connection to the under developed areas of the world there is no infrastructure support.
- The transmission and distribution loss associated with traditional electricity grids can be overcome.
- The electricity generation using microwaves is more environments friendly.
- Moreover it does not involve any emission of carbon gases.
- The monthly electricity bills using conventional electricity supply can be cut to very low.

1X.Demerits of Wireless Transmission

- Biological effects associated with the wireless transmission of electricity due to the high frequency microwave signals is the first demerit of this technology.
- This project is a onetime expense but it involves a lot of initial expenditure.
- This technology is limited to the use of few technologies like solar satellites and Tesla grid.

X. Conclusion

Wireless technology has completely revolutionized the way we communicate with one another. Cell phones have become an absolute necessity. Wireless Internet has allowed us to access information from the web in a matter of seconds. People can now check their stocks or the news while sipping coffee.The better technology, namely Wi-Fi, has made wireless technology fast and easy. Wireless technology is ever-changing and improving, By adopting these new Wireless technologies in the fields of agriculture and power transmission, the economy of the country should be increased which leads to increase GDP(Gross Domestic Product),then the country will be developed and becomes more powerful.

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