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SPACE-BASED SOLAR POWER PLANT IN A HELIOCENTRIC ORBIT

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ABSTRACT
This proposal builds upon a sequentially developing area of solar energy harvesting by means of space based solar power plant on a heliocentric satellite. Solar power harvesting is the conversion of sunlight into electricity using photo-voltaics. The international energy agency projected in 2014 that by 2050 solar energy would contribute about 16 % of worldwide electricity consumption and it would be the world's largest source of electricity, furthermore most solar installation would be in INDIA and CHINA.

The main problem of having an earth based solar power plant is that the night time that last for 12 hours which prevents a continues production of energy and the presence of a diffusing atmosphere which results in the loss of 55-60% of solar energy. A space based power plant differ from the current solar collection methods in that the means used to collect energy would on an orbiting satellite instead of on earth's surface, which provides a higher collection rate and a longer collection period.

Keywords
Lagrangian point, power plant, heliocentric orbit, Microwave, Base station, magnetron, klystron, space, solar panel.

OBJECTIVES
To develop a satellite which converts solar energy to microwave radiation and a base to convert it back to electricity and hydrogen for practical use.

1. INTRODUCTION
Right from the beginning of 1970s, it has been a research topic of having a satellite based solar power plant which would satisfy the electricity needs of an entire nation. The-

United States (NASA) and Japan (JAXA) are almost been successful in creating such power plant using geocentric satellites which orbits around the earth. Under the circumstances geocentric satellites can only satisfy us moderately. Reason been, it orbits around the earth not the sun. Hence we need to look scope of having a heliocentric satellite which rotates around the sun alongside earth's orbit.

As INDIA being able to launch successful, low cost interplanetary mission and ready for its maiden mission for sun, ADITYA. We could make use of INDIA'S advanced launching technologies to solve the countries rising energy needs and electricity crises by sending the satellite along with ADITYA in 2020.

2. TECHNOLOGY

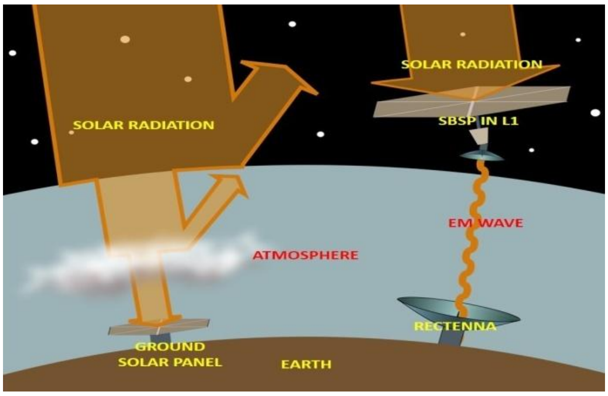

Fig 1

There are several phenomenon that acts on solar radiation when it comes in interaction with the atmosphere. The main type of loss comes due to the reflecting back of solar radiation as it starts penetrating earth's atmosphere as well as scattering which occurs when small particles and gas molecules diffuse a part of incoming radiation in random direction. Another main reason of energy loss is, if intercepted, some gases and particles in the atmosphere have ability to absorb incoming insolation. But, a huge amount of energy loss is due to the reflection of radiation due to the clouds. Hence approximately 55 to 60 per cent of solar energy is becoming unavailable just because of the presence of a diffusing atmosphere.

3. WHAT IS ITS IMPORTANCE AND APPLICATION
There is many thing, which elaborate the importance of this.

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3.1 Clean energy directly from sun
It is the most important source of renewable energy available today which comes as electromagnetic waves directly from the sun.

3.2 No pollution
It provides us with environment friendly energy that we can use instead of nuclear or thermal energy which produces tremendous amount of pollution.

3.3 Wide distribution possibilities
Due to the high amount of energy harvested daily by the satellite which comes uninterruptedly increases the possibilities of distribution, and the climatic conditions of earth does not influence the quality or quantity of the energy to be distributed.

3.4 Conservation of resources.
Increased commercial usage of solar energy reduces the use of resources such as coal, petroleum, thorium, polonium, uranium etc.

3.5 Balance of initial cost by efficient electricity production.
The amount of energy which would be produced daily by the system is more than enough to balance the initial cost or investment and that of maintenance.

3.6 Complete solution for India energy needs.
Currently India is capable of producing 298 GW electricity, as soon as the system is being installed this would rise to an amount of 657 GW.

3.7 Economic growth by providing electricity to near neighbors.
Low cost energy can be widely distributed throughout the country and the amount which is in excess can be provided to neighboring countries like Nepal, Bangladesh, and Afghanistan etc.

4. BASIC TERMINOLOGY
4.1 Lagrangian point

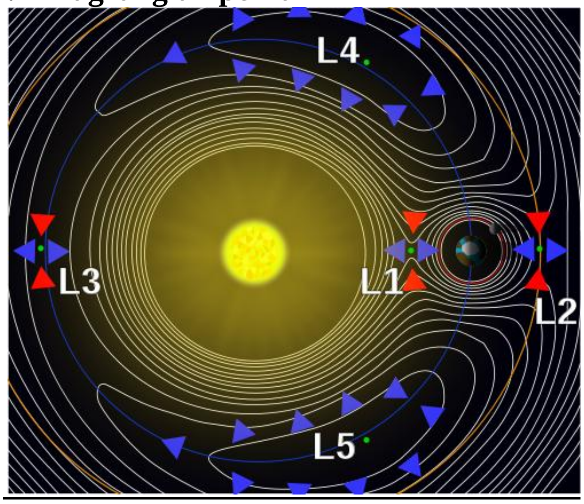

Fig 2

In celestial mechanics, the Lagrangian points are positions in an orbital configuration of two large bodies where a small object affected only by gravity can maintain a stable position relative to the two large bodies. The Lagrange points mark positions where the combined gravitational pull of the two large masses provides precisely the centripetal force required to orbit with them. There are five such points, labeled L1 to L5, all in the orbital plane of the two large bodies. The first three are on the line connecting the two large bodies and the last two, L4 and L5, each form an equilateral triangle with the two large bodies. The two latter points are stable, which implies that objects can orbit around them in a rotating coordinate system tied to the two large bodies.

Fig 3

4.2 Klystron
A klystron is a specialized linear-beam vacuum tube, which is used as an amplifier for high radio frequencies, from UHF up into the microwave range. Low-power klystrons are used as oscillators in terrestrial microwave relay communications links, while high-power klystrons are used as output tubes in UHF television transmitters, satellite communication, and radar transmitters, and to generate the drive power for modern particle accelerators

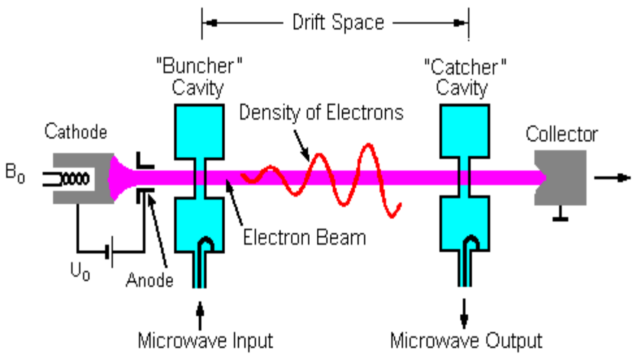

Fig 4

In a klystron, an electron beam interacts with radio waves as it passes through resonant cavities, metal boxes along the length of a tube.[1] The electron beam first passes through a cavity to which the input signal is applied. The energy of the electron beam amplifies the signal, and the amplified signal is taken from a cavity at the other end of the tube. The output signal can be coupled back into the input cavity to make an electronic oscillator to generate radio waves. The gain of klystrons can be high, 60 dB (one million) or more, with output power up to tens of megawatts, but the bandwidth is narrow, usually a few percent although it can be up to 10% in some devices.

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4.3 Magnetron

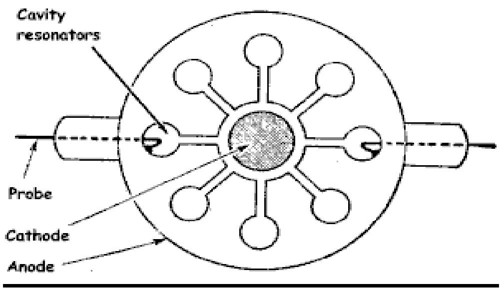

Fig 5

Magnetron is a high-powered vacuum tube that generates microwaves using the interaction of a stream of electrons with a magnetic field while moving past a series of open metal cavities (cavity resonators). Bunches of electrons passing by the openings to the cavities excite radio wave oscillations in the cavity, much as a guitar's strings excite sound in its sound box. The frequency of the microwaves produced, the resonant frequency, is determined by the cavities physical dimensions. Unlike other microwave tubes, such as the klystron and traveling-wave tube (TWT), the magnetron cannot function as an amplifier, increasing the power of an applied microwave signal; it serves solely as an oscillator, generating a microwave signal from direct current power supplied to the tube.

5. DESIGN AND SPECIFICATION

Every roadmap needs a destination, and space based solar power, we are proposing a commercially viable 2 Giga Watt space based solar power harvesting system.

The system would consist of a heliocentric satellite, The Cad Design of satellite is shown below. Aluminum and composite materials are used for satellite structures. High reliability materials such as aluminum, Kevlar, and different types of carbon fiber reinforced polymers are used because of its unique behaviors which helps them to endure highly harsh environments as well as thermal cycling.

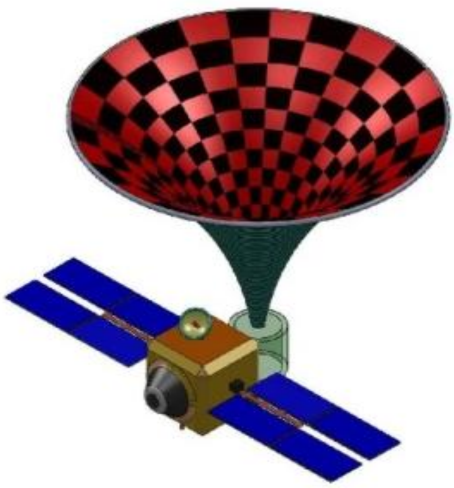

Fig 6: CAD design of satellite

Satellite Specification

- Photovoltaic cells: - silicon based solar cells.
- Net weight of satellite: - 380kg.

6. COMPONENTS OF SATELLITE

6.1 Plasma analyzer package

Uses to study the composition of solar winds and its energy and velocity distribution. Solar wind is a magnetized plasma consisting of charged particles (protons, alpha particles, electrons, and heavier ionized atoms with magnetic field embedded in it) flowing out of the sun in all directions at a very high speed – an average of about 400 km/hr.

6.2 Infrared radiometer

Radiometer or roentgen meter is a device for measuring the radiant flux (power) of electromagnetic radiation. For Example, infrared rays which are coming from sun.

6.3 Long wavelength spectrophotometer

Device for the quantitative measurement of reflection, transmission and absorption properties of the photovoltaic material to calculate the efficiency and life of the harvester on a regular basis

6.4 Tri-axle fluxgate magnetometer

Device used for measurement of magnetization of the satellite body and structures and to measure the strength and direction of magnetic fields around the satellite in space.

6.5 Neutral particle detectors

Used to detect space debris and space objects around the satellite and to give commands to the electrostatic ion thrusters to control the attitude of the satellite

6.6 Visible emission line – microwave generator

It is the most important device use in this satellite, the electromagnetic radiation from sun including visible spectrum, infrared, and ultraviolet rays are being harvested and converted to electrons in ballistic velocity using the photoelectric effect of silicon and thus formed electrons are passed through a vacuum tube in its ballistic velocity under an oscillating magnetic field to produce microwaves of required quality

7. CONNECTION AND WORK

7.1 Satellite placement

A Lagrange point is a location in space where the combined gravitational forces of two large bodies, such as Earth and the sun or Earth and the moon, equal the centrifugal force felt by a much smaller third body.

The nearest Lagrangian points being L1 and L2, we can place our satellite at any of these positions, but considering the position of L2, it is behind earth relative to sun hence it would always remain in the shadow of earth harvesting no energy at all. Hence we could understand the most suitable position is

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L1 which is in between earths and Venus orbits. So the satellite would always be facing its harvester towards sun and the microwave radiation emitter would always face earth. There are many more benefits when we place our satellite at a Lagrangian point close to earth. The satellite wouldn't be requiring any coolant to stay cool. The location itself allows us to have enormous band width and it will ease the communication and power transfer.

Firstly the satellite will be placed in lowest orbit of approximately 800 km perigee by using multistage launch vehicle. As soon as the satellite is placed at its primary orbit its solar panels for the purpose of reaching till L1 will get activated and the 3-month long journey of the satellite will start, using electrostatic ion thrusters' satellite will change its attitude and will progress to its next 3 stages of orbits which are around earth. At the tertiary orbit around earth which is having a perigee of 1.5 million kilometers, the solar panels of satellite will be switched off and it will automatically fall into the proposed orbit under the combined influence of earth and sun. As the next step the solar power harvesters which are in its compressed form will be opened upwards (Figure) to form a flower like structure which will trap the solar energy and pass on to the microwave generator.

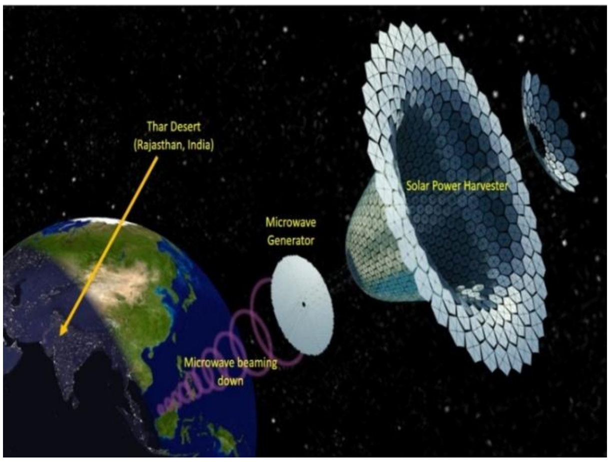

Fig 7

7.2 Base station

Fig 8

The base station can be build up in Thar Desert, Rajasthan in INDIA considering the climatic conditions and position. On the surface of a three-kilometer-long base station outfitted with ten billion miniature rectifying antennas receives the microwave beamed down from a satellite at L1, which is at almost 1.5 million kilometers from earth, converting them back to DC current.

7.3 Wireless power transfer using microwaves

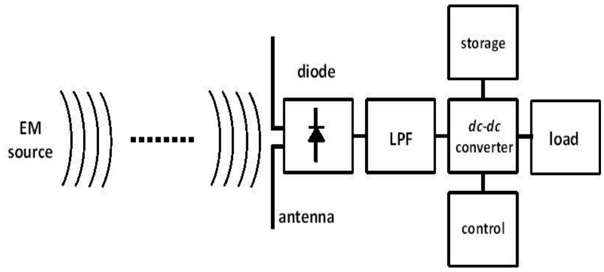

Fig 9

Since we cannot transfer power using laser beam for the same reason we would want to place solar collectors above the atmosphere in the first place, it has to be by microwaves (wavelength = 1 m and frequency = 2.45 to 5.8 GHz).

To generate microwaves, DC current supplied from photovoltaic cells can be directed to magnetrons, klystrons or other vacuum tubes. Vacuum tubes use the ballistic motion of electrons under the influence of oscillating magnetic fields to generate microwaves.

The efficiency of conversion of DC electricity to microwaves and vice versa both being about 85-95%, we can have access to 90% of the energy harvested by the satellite.

8. LIMITATIONS

- Lower frequency microwaves require very large antennas whereas high frequency microwaves have less atmospheric penetration.
- Exposure to high energy microwave beam is fatal.
- Due to the presence of space objects such as asteroids and space debris there are chances of failure and degradation of photovoltaic panel as well as the satellite equipment.

9. DELIMITIONS

- There exists a trade of between using lower frequency microwaves for easier penetration of the atmosphere and higher frequency microwaves for decreasing the antenna size. Therefore the transmission frequency is between 2.45 and 5.8 GHz.
- On the ground physical access is controllable via fencing and by observing air flight control spaces over base station, aerial access can be restricted.
- Maintenance of satellite can be done tele- robotically.

10. CONCLUSION

"*Solar energy, it is the future"*. From the primitive earth based solar power plants our brains have reached till the space based solar power harvester. As a much efficient power generation method, SBSP is been accepted by the leading space research organization such as JAXA, ROSCOSMOS, NASA, and CNSA. But why not us? We are capable of cheap interplanetary mission, we have the most advanced launching vehicles and we are leading the world in energy requirements. Thus comes a heliocentric solar energy harvesting system which can be placed alongside mission ADITYA at the most appropriate regime, L1 in our solar system. Thus we put forward the concept of a heliocentric solar power plants which satisfies the needs of our entire nation and to make the hasten to be a super power nation much easier.

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