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A REVIEW ON WIRELESS POWER TRANSMISSION

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ABSTRACT:

In today's environment, wireless power transmission technology is becoming more popular. The disadvantages of traditional wired technology are eliminated with this technique. The transfer of electric power from a power source to an electrical load without the use of distinct manufactured conductors is known as wireless power transmission. The move to a wireless power transmission system was motivated by the desire to provide reliable power transmission at a low cost and to make life easier. Inductive coupling by magnetic fields is the main technology employed in wireless power transmission. The working mechanism of wireless power transmission is similar to that of a transformer, in which an oscillating magnetic field is created by passing alternating current through a transmission coil. When this magnetic field interacts with the receiver coil, an alternating EMF is produced (voltage). New technologies are being deployed as the relevance of wireless power transfer grows. In this review, we will look at various wireless power transmissions and determine which is the most efficient.

INTRODUCTION:

Wireless Power Transfer (WPT) makes it possible to supply power through an air gap, without the need for current-carrying wires. WPT can provide power from an AC source to compatible batteries or devices without physical connectors or wires. WPT can recharge mobile phones and tablets, drones, cars, even transportation equipment. It may even be possible to wirelessly transmit power gathered by solar-panel arrays in space.The concept of transferring power without wires, however, has been around since the late 1890s. Nikola Tesla was able to light electrical bulbs wirelessly at his Colorado Spring Lab using electrodynamic induction.

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WPT uses fields created by charged particles to carry energy between transmitters and receivers over an air gap. The air gap is bridged by converting the energy into a form that can travel through the air. The energy is converted to an oscillating field, transmitted over the air, and then converted into usable electrical current by a receiver. Depending on the power and distance, energy can be effectively transferred via an electric field, a magnetic field, or electromagnetic (EM) waves such as radio waves, microwaves, or even light.

LITERATURE SURVEY:

In this paperH. Y. Lee and G. S. Park stated, the equation of output power was formulated with transmission distance as variables and verified through experiments. By using this formulated equation, it is possible to predict the trend of output power according to various variables such as coil size or inductance. In addition, the resonance characteristics according to the transmission distance were analysed through the circle diagram and FEA. From these results, it is possible to know the influence of the transmission distance and the magnetic cause of the frequency splitting phenomenon in the MRWPT.**[1]**

Hu, Biao; Li, Hao; Lidemonstrates a long-distance high-power MWPT system based on asymmetrical resonant magnetron and cyclotron-wave rectifier, and the design and exploration of the asymmetrical resonant magnetron, the cyclotron-wave rectifier, and the transceiver Cassegrain antenna are analysed in detail, respectively. Finally, the simulation of the long-distance high power MWPT system can achieve 8.5 kW DC power with about 1% DC-DC transmission efficiency at the operating 2.45 GHz frequency and the 10 km distance away. **[2]**

Thetransmission antenna for near-field MPT has been introduced. An experiment was conducted over a 10 m transmission distance to validate the theoretical analysis and the simulation. The nearfield focused Tx antenna was shown to be applicable in MPT to improve the efficiency. Compared with the UFA, the NFFA focuses more power upon the receiving aperture, and the transmission efficiency is improved from 32.98% to 41.85% when the receiving aperture size is 1 m × 1 m. **[3]**

X. Yi, X. Chen, L. Zhou, S. Hao, B. Zhang and X. Duanhave been demonstrated following points in this paper. 1) Magnetic resonant coupling can be used to deliver power from a large source coil to one or many small load coils, with lumped capacitors at the coil terminals providing a simple means to match resonant frequencies for the coils. This mechanism is a potentially robust means for delivering wireless power to multiple receivers from a single large-source coil. 2) A relatively simple circuit model describes the essential features of the resonant coupling interaction, with parameters that can be either derived from first principal's descriptions, from direct measurement or from curve fitting techniques.**[4]**

X. Duan, L. Zhou, Y. Zhou, Y. Tang and X. Chenexperimentally demonstrate efficient short-distance WPT based on microwave radiation for the first time, expanding the MPT application beyond only suitable for long-distance WPT to date. The experimental results show that the transmission efficiency at 2.45 GHz reaches 52.3%, 52.5%, 47.9% and 41.7% over a distance of 5 cm, 10 cm, 15 cm and 20 cm, respectively. For a wide incident angle range from –52.5° to +52.5° on E and H-plane, the transmission efficiency over distance 15 cm merely declines 12% and 22.2% at most, respectively.**[5]**

CLASSIFICATION OF WIRELESS POWER TRANSMISSION:

Wireless power transmission is classified as far field and near field. Near field power transmission based on the electromagnetic induction. Far field power transmission is based on the electromagnetic radiation. There are two types in electromagnetic induction, type-1 is inductive coupling and type-2 is magnetic resonant inductive coupling. And electromagnetic radiation is two types, type-3 microwave power transfer and type-4 is laser power transfer. This chapter gives the brief about all the types of power transmission.

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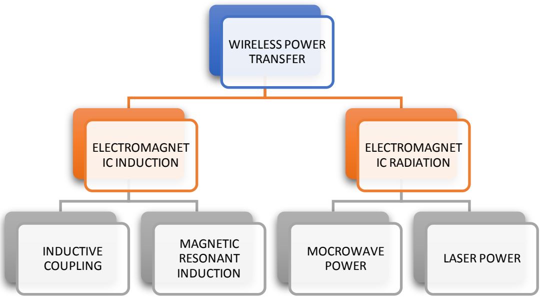

Fig 2.1 Classification of Wireless Power Transmission.

NEAR FIELD AND FAR FIELD:

The near field and far field are the regions of the electromagnet field (EM) around and object, such as a transmitting antenna, or the result of radiation scattering off an object. Non-radiative near-field behaviours dominate close to the antenna or scattering objects, while electromagnetic radiation far-field behaviours dominate at greater distances.

INDUCTIVE POWER TRANSMISSION:

WORKING OF INDUCTIVE POWER TRANSMISSION:

Inductive power transfer (IPT) power is transferred between coils of wire by a magnetic field. The transmitter and receiver coils together form a transformer. An alternating current (AC) through the transmitter coil creates an oscillating magnetic field by Ampere's law. The magnetic field passes through the receiving coil, where it induces an alternating EMF (voltage) by Faraday's law of induction, which creates an alternating current in the receive. The induced alternating current may either drive the load directly, or be rectified to direct current (DC) by a rectifier in the receiver, which drives the load.

CIRCUIT ANALYSIS OF IPT:

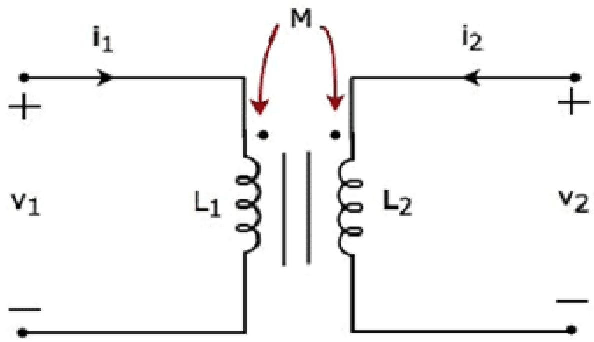

Fig 2.2 Circuit Diagram of Inductive Power Transfer

The loop equations are:

$V_1 = J\omega L_1 + J\omega M I_2$ ------(2.1)

$V_2 = J\omega M I_1 + J\omega L_2 I_2$ ------(2.2)

$M = K\sqrt{(L_1 L_2)}$ ------(2.3)

$L = \frac{\text{⍰} N^2 \pi r^2}{l}$ ------(2.4)

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Where:

- M is the mutual inductance.
- N is the no. of turns of the coil.
- V is voltage, I is current.
- K is the coupling coefficient.

INDUCTIVE POWER TRANSMISSION EFFICIENCY:

The efficiency of any inductive power transmission system is dependent upon a number of factors including the coupling, k between the inductors and their quality factor. In turn these are dependent upon a variety of other factors including

- **Inductor sizes:** The ratio of diameters of the coils, D2/D1 has a direct impact on the coupling. It has an effect because for maximum coupling all the lines of magnetic flux should pass through the primary and couple into the secondary coil.
- **Inductor shape:** Again, the shape of the coils will change the level of coupling of magnetic flux.
- **Distance between coils:** The distance between the two coils has a major effect on the efficiency of the inductive power transmission. As the coils move apart, the inductive coupling reduces rapidly as it is what is termed a near field effect. In practice efficiency levels of 90% and more can only be achieved if the distance to coil diameter ratio is less than about 0.1. Any greater than this and the efficiency of the inductive power transmission falls very rapidly.
- **Coil resistance:** The resistance in the primary and secondary coils will cause power to be dissipated as heat. This will be seen as a reduction in the Q or quality factor of the coils in the system

APPLICATIONS OF INDUCTIVE POWER TRANSMISSION:

- Electric tooth brush
- razor battery charging
- induction stovetops
- industrial heaters.

MAGNETIC RESONANT POWER TRANSMISSION:

WORKING OF MAGNETIC RESONANT POWER TRANSMISSION:

Magnetic Resonant coupling uses the same principles as inductive coupling, but it uses resonance to increase the range at which the energy transfer can efficiently take place. Resonance can be two types: (a) series

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resonance and (b) parallel resonance. The principle of these both types of resonance is to get maximum energy transfer same but the methods are quite different.

CIRCUIT ANALYSIS OF MRPT:

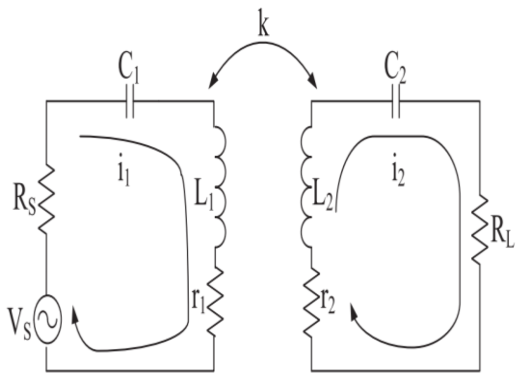

Fig 2.3: Circuit Diagram If Magnetic Resonance Power Transfer

By applying Kirchhoff's voltage law, the loop equations are:

$V_s = Z_1 \; i_1 + j\boldsymbol{\omega}k \; \sqrt{(L_1L_2)}\, i_2$ -------------(2.5)

$0 = j\boldsymbol{\omega}k\sqrt{(L_1\,L_2)} \; i_1 + Z_2 \; i_2.$ -------------(2.6)

Angular resonant frequency, $\omega_0 = 2\pi f_0$.

Equivalent input impedances in the Tx and Rx can be expressed as

$Z_1 = R_s + r_1 + j\omega L_1 + 1/j\omega C_1$ -------------(2.7)

$Z_2 = R_L + r_2 + j\omega L_2 + 1/j\omega C_2$-------------(2.8)

The currents generated in the Tx and Rx can be obtained as:

$I_1 = \frac{V?}{Z_2+\omega^2 k^2 L^1 L^2/Z_2}$-------------(2.13)

$I_2 = \frac{j\,\omega K\,\sqrt{(L_1L_2)}}{Z_2}.I_1$ -------------(2.14)

The two loops are magnetically linked with coupling coefficient

$K=M\sqrt{(L_1\,L_2)}$ -------------(2.9)

$M = \frac{r^3}{\sqrt{(r^2+d^2)^3}}$-------------(2.10)

Resonance frequency $= \frac{1}{2\pi\sqrt{LC}}$-------------(2.11)

Quality factor $= \frac{f}{\Delta f} = \frac{\omega L}{R} = \frac{2\pi fL}{R}$-------------(2.12)

The output power can be calculated as follows:

$P_{out}=|I_2|^2 R_L$ -------------(2.15)

MAGNETIC RESONANCE POWER TRANSFER EFFICIENCY:

- If the geometry and material parameters of the coils are fixed, the transfer efficiency is related with resonant frequency f and mutual inductance M, which varies with the distance, orientation angle, and centre deviation of the transmitter and the receiver.
- If the resonant frequency is fixed, the transfer efficiency varies the distance, orientation, and centre deviation of transmitter and receiver change.
- When frequency tuning is applied, the efficiency obtained is higher than fixed-frequency operation

APPLICATIONS OF MAGNETIC RESONANCE POWER TRANSFER:

- Charging portable devices,
- biomedical implants,
- electric vehicles,
- powering buses, trains, MAGLEV,
- RFID (Radio-frequency identification)

MICROWAVE WIRELESS POWER TRANSMISSION (MWPT):

COMPONENTS OF MWPT:

The microwave wireless power transmission consists of:

- Modulated power supply
- Magnetron
- Transmitting Cassegrain antenna
- cyclotron wave rectifier

DESCRIPTION OF THE COMPONENTS USED IN MWPT:

- **Modulated power supply-1,2:**

  The modulated power supply is used for the bench test and measurement. It can output DC or AC voltage or both. This modulated power supplies working for the cathode with pulse to continuous wave operation.

- **400KW asymmetrical magnetron:**

  The 400KW asymmetric magnetron is theoretically and experimentally confirmed to be high efficiency and high-power microwave generator. This magnetron will convert the input power into microwave power in the presence of magnetic field.

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- **Transmitting Cassegrain antenna/Receiving Cassegrain antenna:**

  The power is pumped into the transmitting and receiving antennas, which are used to connect the microwave generator(magnetron) ant the rectifier (cyclotron wave rectifier). In order to simplify the system and make it feasible, the transmitting and receiving antennas are designed to be the same Cassegrain antenna. Which is simple in structure, high conversion efficiency and high-power handling capacity.

- **Cyclotron wave rectifier:**

  Cyclotron wave rectifier will convert the received microwave power to DC power with the conversion efficiency of 85%, after suitable signal processing this power can be feed to the power grid afterwards.

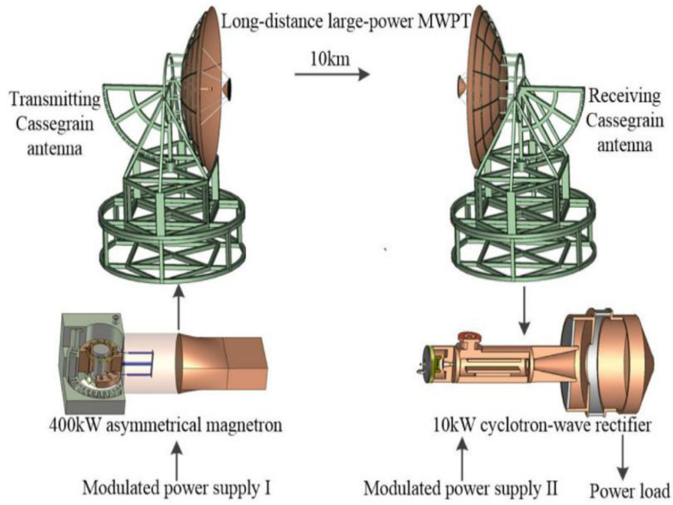

Fig 2.4: Long Distance Microwave Power Transmission.

WORKING OF MWPT:

Working of the microwave power transmission is, the input power is feed in to the 400kw asymmetric magnetron (which convert the input electrical power into microwave power in presence of magnetic field). This converted microwave power is feed into the transmitting Cassegrain antenna (this antenna transmits the microwave power to the desired distance). the transmitted microwave beam is received through the receiving Cassegrain antenna. This received microwave beam is feed into the cyclotron wave rectifier. Then the rectified power is given to the load.

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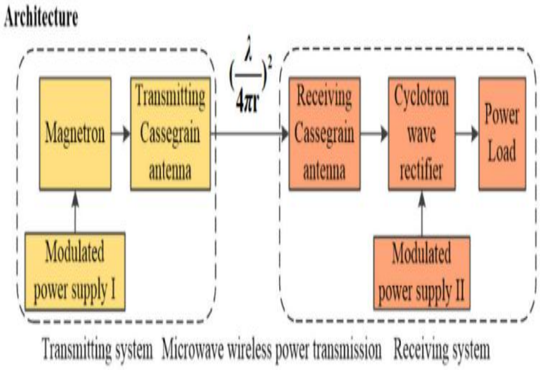

Fig 2.5: Architecture of Long-Distance Microwave Power Transmission

APPLICATIONS OF MICROWAVE WIRELESS POWER TRANSMISSION:

- Powering drone aircraft,
- Charging wireless devices,
- Sending power to the remote areas where transmitting lines are difficult of built,
- Fuel- free airplanes,
- Generating power by placing satellites with giant solar arrays in Geosynchronous
  Earth Orbit and transmitting the power as microwaves on the earth called Solar Power Satellites (SPS) will be the largest application of MWPT.

WIRELESS LASER POWER TRANSMISSION:

Power can be delivered by turning energy into a laser beam that is received and focussed onto photovoltaic cells when electromagnetic radiation is closer to the visible portion of the spectrum (0.2 to 2 micrometres).This mechanism is generally known as 'power beaming' because the power is beamed at a receiver that can convert it to electrical energy. At the receiver, special photovoltaic laser power converters which are optimized for monochromatic light conversion are applied.

COMPONENTS OF WIRELESS LASER POWER TRANSMISSION:

- grid or generator
- laser power supply
- laser diode
- beam director
- photovoltaic array
- power controller
- load

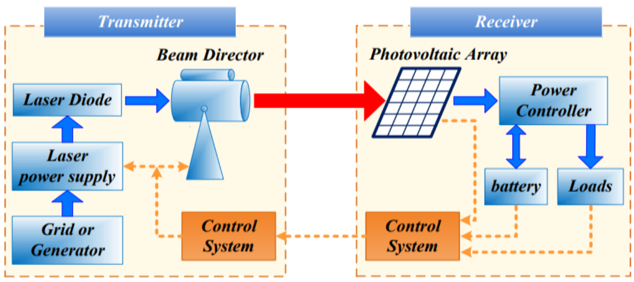

Fig 2.6: Architecture of laser Power Transmission

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BASIC PRINCIPLES OF LASER POWER TRANSMISSION:

The above figure shows a block diagram of the HILPB [high intensity laser power beam] system. As seen, the transmitter of the system converts power from a common source (battery, generator, or grid) into a monochromatic beam of light via a laser. This laser beam is then shaped with a set of optics, and directed via a beam director to the remote PV receiver. While in the receiver, specialized PV cells matched to the laser wavelength and beam intensity convert the laser light back into electricity to be used to charge a battery, run a motor, or do other work. In many ways, the HILPB system can be viewed as a kind of extension cord, with electrical power going in at one end, and electrical power coming out at the other end.

BLOCK DIAGRAM OF IDEAL EFFICIENCY OF HILPB SYSTEM:

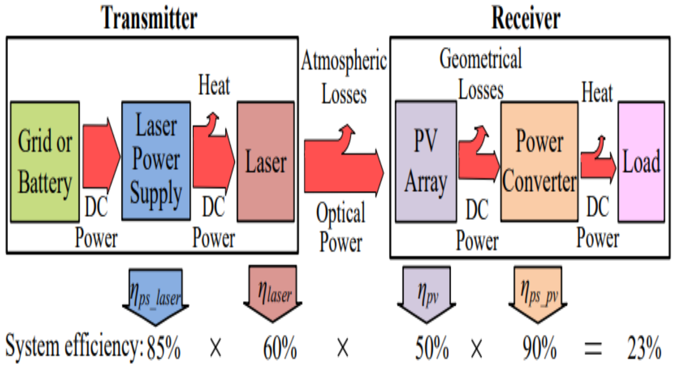

Fig 2.7: Block diagram of ideal efficiency of HILPB system

APPLICATIONS OF WIRELESS LASER POWER TRANSMISSION:

- Charging portable devices,
- powering drone aircraft
- powering space elevator climbers.

ADVANTAGES COMPARED TO OTHER WIRELESS METHODS ARE:

- Collimated monochromatic wavefr ont propagation allows narrow beam cross-section area for transmission over large distances. As a result, there is little or no reduction in power when increasing the distance from the transmitter to the receiver.
- Compact size: solid state lasers fit into small products.

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- No radio-frequency interference to existing radio communication such as Wi-Fi and cell phones.
- Access control: only receivers hit by the laser receive power
-

DISCUSSION AND CONCLUSION:

Tabular representation of various parameters of wireless power transmission:

Method / parameters	Inductive Coupling	Magnetic Resonance	Microwaves	Laser
Distance between transmitter and receiver circuits	A few millimetres	A few meters	Up to 100 kilometres	A few meters but could be used for longer distances by using high intensity beam
Transmitted power	Up to a few watts	Up to a few kilo watts	Up to hundreds of Megawatts	Up to hundreds of Megawatts.
Efficiency	Low	High	High (Up to 54%)	High (Up to 30%)
Cost	Economical because the used equipment is cheap and available	Economical because the used equipment is cheap and available	Relatively expensive compared to other methods	Same economic conditions of inductive coupling
Safely	It is safe from biological point of view	It is safe from biological point of view	Dangerous on health due to high frequency rays (1 ghz to 1000 ghz)	Injurious to human health

Table 3.1: Various Parameters Of Wireless Power Transmission

Resonance wireless power transmission		
Normal RWPT system	**RWPT system with class -E inverter**	**RWPT system with spiral-type superconducting resonance coil**
Coil diameter=288mm		Width of coil=500mm
Coil height=40mm		Coil height=500mm
Inductance2.552mH	Mutual inductance=11.11(µH)	Inductance=30.75(uH)
Capacitance=24.814nF	Capacitance=200nF	Capacitance=114nF
Resonant frequency=20K	Resonant frequency=85KHz	Resonant frequency=85KHz
Distance=300mm	Distance =11cm	Distance =400mm

Efficiency=96.7%	Efficiency=96.1%	Efficiency=87.06%

Table 3.2: Analysis Of Resonance Wireless Power Transmission

Conversion efficiency of each stage in laser power transmission							
Wave length (nm)	**Electro optical efficiency (%)**	**Launch and receiving efficiency (%)**	**Transmission and receiving efficiency (%)**	**Photoelectric efficiency (%)**	**Circuit efficiency (%)**	**Total efficiency (%)**	**Laser-electrical total efficiency (%)**
532	0.85%	93.50%	86.96%	2.04%	82.5%	0.01%	1.37%
1030	5.30%	91.00%	85.71%	2.22%	90.8%	0.08%	1.60%
8080	15.47%	86.00%	53.49%	0.93%	90.9%	0.11%	0.73%
The ideal efficiency of a HILPB system							
Laser power supply efficiency(%)		**Transmission and receiving efficiency (%)**	**Photoelectric efficiency (%)**	**Power converter efficiency(%)**	**Total efficiency(%)**		
85%		60%	50%	90%	23%		

Table 3.3: Analysis Of Laser Power Transmission

CONCLUSION:

Based on this study, we can say that the magnetic resonance WPT is the most promising technique for powering devices wirelessly with high efficiency over up to few meters. We can improve the efficiency by tuning the parameters of the magnetic resonance wireless power transmission. the problem of distance is solved by using different length and diameter of the coils used in the system. The transmitting distance depends on the parameters of the coils used in the system, by varying the parameters we can achieve different distances at maximum efficiency. Being safe for humans and environment, magnetic resonance WPT can spread to be the standard charging method for most portable devices in the next few years. So, we recommend researchers to focus on this technology. Even though, microwave power transfer is trying to find its way to replace high power transmission lines. The cost of installation is very high. And the system is very bulky which requires large area. Not only that due to health concerns, many researches should be done to find a safe solution that could enable using microwaves for long-distance high-power transmission.

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