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Wireless Power Transfer Applications And Its Comparison With Wired Short Distance Transmission

Vishal Thakur[1],Shivani Abrol[2]
[1]*Student, Master Of Technology, Electrical Engineering Department, GNE College (PTU),India*
[2] *Assistant Professor, Electrical Engineering Department, GNE College (PTU),India*

Abstract: Wireless Power Transmission or WPT is transmission of electric power from one place to other without the use of conventional wired system as well as charging of batteries without used of wired connection. The transmission as well as distribution losses in wireless system would be negligible. This paper focuses on the different advantages that wireless system possess over conventional wireless system in terms of efficiency parameters as well as different components of wireless system that effect the efficiency of the system. It also presents some practical applications that wireless system have as well as related to technological advancements**.**
Index-Terms: coupling, efficiency, electromagnetic, inductive, resonance, wireless power, Witricity.

I. INTRODUCTION

Today the world we live has wireless energy in it to the extent that the air that we breathe probably contains more information than oxygen. This is also an age where electronic devices like mobile phones, MP3 players, laptop computers and domestic robots exist alongside old-fashioned power wires and bulky batteries and are as much a basic necessity of daily life as anything.

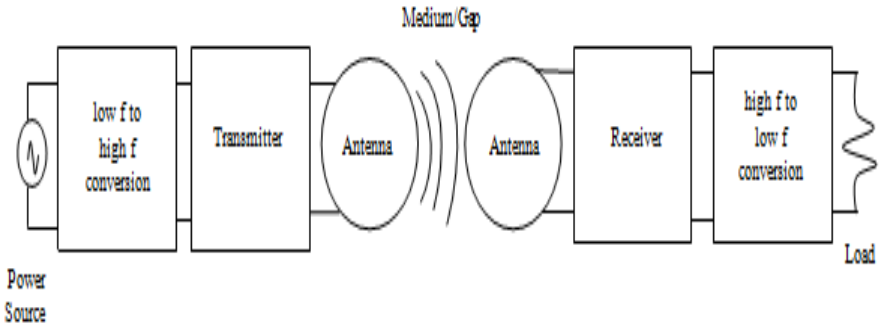
Back in the 1890s Nikola Tesla, one of great pioneers of electromagnetism, was the first to envision that electricity, then a newly found form of energy, should be delivered to everybody as cheapest as possible. His dream was to transfer electrical energy wirelessly over long distances using big coupled electromagnetic resonators able to generate very large electric fields, which were meant to propagate most likely either via conduction through the ionosphere (presumably including gigantic sparks) or through the Earth itself (possibly via so-called Schumann resonances). That was the first step towards global wireless power transmission.
Though that idea failed to be replicated in the practical form due to technological as well as capital limitations of the time, various advances in technology over the century has improved the wireless transfer of energy more feasible. With the current boom in medical research as well as trying to replace the dependence of conventional non-renewable energy with vast amount of renewable energy sun and earth has to offer, the advances in WPT has seen an enormous growth so as to transfer energy from one place to another with least amount of losses became more and more convenience and will continue to do so in near future.

II. BRIEF HISTORY AND DESCRIPTION

- 1819 : Hans Christian Oersted discovered electromagnetism
- 1831 : Michael Faraday demonstrated electromagnetic induction
- 1873 : James Clerk Maxwell stated set of equations now known as Maxwell's equations
- 1887 : Heinrich Hertz created radio waves using a self designed oscillator
- 1894 : Tesla wirelessly lights up single-terminal incandescent lamps at his lab
- 1895 : Guglielmo Marconi sent first wireless telegraph
- 1964 : William Brown controlled a model helicopter powered by microwave beam
- 1968: Peter Glaser proposes wirelessly transferring solar energy captured in space.
- 2007: Using Electrodynamic Induction, a research group led by Prof. Marin Soljačić, at MIT, wirelessly power a 60W light bulb with 40% efficiency at a 2 metres (6.6 ft) distance,opening new scope in the technology

Wireless Power Transmission essentially describe the transmission of electrical energy from a power source to an electrical load, without connectors, across an air gap or any medium. The basis of a wireless power system involves essentially two coils – a transmitter coil and a receiver coil. The transmitter coil is energized by alternating current to generate a time varying magnetic field, which in turn induces a current in the receiver coil. Usually the system is operated in high frequency

To minimize losses as well as to provide more system control.



Wireless transmission is advantageous in instances where interconnecting wires are inconvenient, hazardous, or impossible. 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. Table 1 generalizes the various wireless power transfer technologies currently in use :

III. TYPES AND TECHNOLOGIES OF WPT

Wireless Power essentially describe the transmission of energy from a power In general, Wireless Power Transmission can be classified as :

Table 1

Technology	Energy Transfer	Enabling Power Transfer
Inductive coupling	Magnetic fields	Coils of wire
Resonant coupling	Magnetic fields	Resonant circuits
Capacitive coupling	Electric fields	Conductive coupling plates
Magneto-dynamic coupling	Magnetic fields	Rotating permanent magnets
Microwave radiation	Microwaves	Phased arrays/dishes
Optical radiation	Light/infrared/ultraviolet	LASERS/photocells

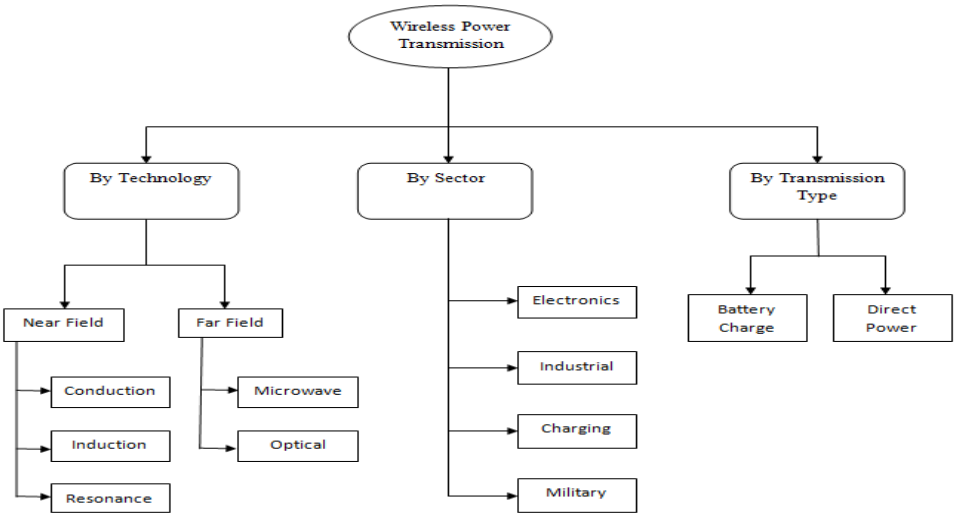


Fig. 2 Classification of WPT

A. By Technology

- Near field

Its range is from centimetres to few metres. The power is lost inversely proportional to distance with increase in distance

1. **Conduction:** It exploits the process of conduction i.e. energy is transmitted through collisions between neighbouring molecules.
2. **Induction:** This technique works on the method of electromagnetic induction. Some example of its general usage is in transformers.
3. **Resonance:** Developed recently by Witricity, this technique works on principle of magnetic resonance i.e. at a particular frequency, inductive and capacitive reactance of a circuit are equal.

- **Far Field**

  Its range is from few metres to hundreds of kilometre. The power lost is minimal as long as transmitter and receiver are in line of site with each other.

1. **Microwave/Radio waves:** In this technique, the power to be transmitted is converted in microwaves and then transmitted. A Rectenna or solar array could be used as a receiver.
2. **Optical:** The power transmitted is converted in LASER beams which has much low diffraction in atmosphere, thus minimal power loss.

B. By Sector

- **Consumer Electronics**

  Automatic wireless charging of mobile electronics as well as direct wireless powering of stationary devices eliminating expensive custom wiring & unsightly cables.

- Industrial Appliances

  Wireless power and communication interconnections across rotating and moving joints (robots, packaging machinery etc.), thus, eliminating costly and failure-prone wiring.
- Wireless Charging

  Charging for existing electric vehicle classes: golf carts, industrial vehicles and for future hybrid and all-electric passenger and commercial vehicles, at home, in parking garages etc.
- Military Applications
- For high tech military systems (battery powered mobile devices, covert sensors, unmanned mobile robots and aircraft, etc.).

C. By Transmission Types

- Direct Wireless Power

  All the power a device needs is provided wirelessly, and no batteries are required. This mode is for a device that is always used within range of its wireless power source.
- Automatic Wireless Charging

  When a device with rechargeable batteries charges itself while still in use or at rest, without requiring a power cord or battery replacement.

IV. BASIC PARAMETERS AFFECTING WPT

A. Coil Shape

The shape of coil used as antenna will determine the area to which the power will be transmitted.

B. Coil Impedance

Maximum power will be transmitted if transmitting coil's impedance is equal to receiving coil impedance which could be achieved by resonating both sending and receiving coil's at a similar resonating frequency.

C. Distance between coils

The total distance between two coils i.e. sending and receiving coils also affects the power transmitted too. Usually the transmitted power reduces inversely proportional to the increase in distance.

D. Number of coils

The number of coils used as transmitter and receiver affects the transmitted power directly. With increase in coils used, the complexity of the circuit also increases.

E. Intermediate Coils, if any

Intermediate coils, if used must be perfectly matched with the impedance of the transmitting and receiving coil impedance, thus providing potential to increase the distance vastly.

F. Area of coil's turn

The area of the coil's turn will affect the power transmitted directly as with increase in coil's area, its range will also improve.

G. Coil Alignment

The alignment of transmitter/receiver coil would affect the power transmitted from one end to other. There are two different forms of misalignment that could occur :-

- Lateral misalignment : Coils are in parallel, but their centers do not meet horizontally or vertically.
- Angular misalignment : Centers of both transmitter and receiver coil are well aligned but the coils are turned by and angle.

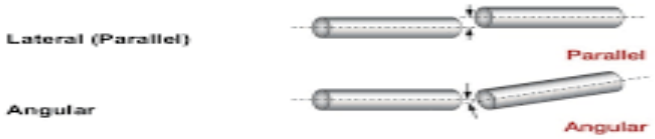


Fig.3 Misalignments in coils

V. GENERAL EQUATIONS OR FORMULAE USED

The coil parameters parameter effect the WPT as from the Biot-Savart law,

$$dB = \frac{\mu}{4\pi}\int I\frac{dl \times \hat{r}}{r^2}$$

where B = Total Magnetic Field
I = current in coil
l = length of coil
r = point in space

and also from Faraday's law, voltage induced at receiver end,

$$V = \frac{\partial}{\partial t}\int B.dS$$

where V = voltage at receiver
B = Magnetic Field
S = Surface area of the coil

The general technology analyzed in our research, which mostly involves Witricity is Magnetic Resonance.
The LC circuit does not resonate by itself without a power source. The LC circuit must be driven, for example by an AC power supply, for resonance to occur.
In order to achieve a resonance frequency in the circuit the inductive reactance and the capacitive reactance of the resonator coil will equal such that:

$X_L = X_C$

or $\omega L = \frac{1}{\omega C}$

now $\omega = 2\pi f$

Capacitive Reactance: $X_c = \frac{1}{2\pi fC}$

Inductive Reactance: $X_L = 2\pi fL$

Thus Resonant Circuit formula: $4\pi^2 f_r^2 LC = 1$

Thus resonant frequency: $f_r = \frac{1}{2\pi\sqrt{LC}}$

where Xc = Capacitive Reactance in ohms
X_L = Inductive Reactance in ohms
f_r = Frequency in Hertz
L = Inductance in Henry
C = Capacitance in Farads

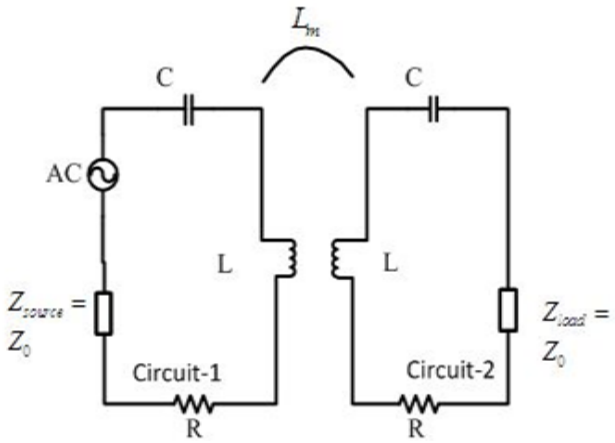


Fig. 4 General representation of magnetic resonance

VI. PARAMETERS ON WHICH EFFICIENCY OF A SYSTEM DEPENDS

The efficiency of an electrical system depends on various parameters. Some of those parameters this research analyses are :

A. System Performance

One of the most important parameter to calculate efficiency of a system, the performance of the WPT system in terms of power obtained at load as well as speed of the system as whole.

B. Time

It defines the time taken to switch on the system or the time taken to get power at receiving terminal from the moment it is transmitted.

C. Cost

It includes the overall cost of the transmission system. For wired system it usually includes all the cables or conductors used as well as cost of distribution system whereas for wireless systems it includes cost of frequency converters, coil and transmitter/receiver circuit.

D. Losses

This considers all the ongoing losses in the systems. For wired system it includes both transmission and distribution losses.

E. Sensitivity and Reliability

It is one of the most, if not the most important parameter to calculate the efficiency of any system. A system should be moderately sensitive as well as very reliable in long run for easing and benefiting the seller and consumer.

VII. PREDICTIVE ANALYSIS

Table 2 depicts the generally predicted results from the research:

Table 2

Efficiency Parameter	Wired System	Wireless System
Performance	High	High
Time	Less	Less
Cost	High	Low
Losses	Moderate	Average
Sensitivity and Reliability	Moderate to less	High

The above parameters can be tested using manual data collection or using simulation techniques. The expected results can be verified from the calculations as it is assumed for a general wired system and WPT technology as a whole i.e. both near field and far field techniques, which have different values.

It should be also noted that losses in the near field WPT system increases drastically with the increase in the distance of the transmission, as more and more power is lost to the air medium, whereas in far field techniques, the losses are very less due to high intensity of waves used and the constraints are only the technological constraints related to transmitter and receiver system.

VIII. CONCLUSION

It is predicted that wired system will have very high performance compared to wireless system which is having high performance with new advances in technology. Though the ability of wireless systems to catch even ambient power that is present in the environment could give the extra power boost to the system with few modifications..

The time taken to operate the wired system is very less as power is transmitted as soon as system is turned on, for the wireless system, it would operate as soon as transmitter and receiver circuits are ready to operate.

The cost of installing a wired system would be much higher due to installation of all the wires as well as protection system. Wireless systems would avoid all the process of installing wires, thus the occurrence of faults and theft in system would be very low. The only cost would be that in control of system as well as installation of small compact devices and their protection, which in term is much cheaper.

Currently total losses in wired system on average is nearly 20-30% (both transmission and distribution). Whereas in wireless system, for near field technologies, losses increases with increase in distance; whereas in far field techniques, the system has very low losses as long as transmitter and receiver are in line of sight.

The sensitivity and reliability of wired system is very less due to synchronous interconnection of the system, thus any fault if not properly taken care would travel the system and can damage whole system. Whereas in wireless systems, the system has the advantage of not interconnected with each other, thus as long as transmitter/receiver are in line of site with each other, the system would work perfectly.

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