Wireless Power Transfer : The future

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Abstract

The technology for wireless power transmission or wireless power transfer **(**WPT**)** is in the forefront of electronic development. Applications involving microwaves, solar cells, and resonance of electromagnetic waves have had the most recent success with WPT. The main function of wireless power transfer is to allow electrical devices to be continuously charged and then subsequently, lose the constraint of a power cord. The concept of resonance causes electromagnetic radiation at certain frequencies to cause an object in another location within the appropriate line-of-sight to vibrate. This vibration can allow energy to be transmitted between the two vibrating sources. Solar cells, ideally, would use a satellite in space to capture the suns energy and send the energy back to Earth. This paper will explore the future technological applications of microwaves, resonance, and solar cells in WPT and explain the basic technique of transmitting power wirelessly. It will also include problems encountered during experimentation and recent advances in the field. The paper will also include the futuristic applications of WPT and its ability to solve the energy crisis.

Introduction

Although the idea is only a theory and not widely implemented yet, extensive research dating back to the 1850's has led to the conclusion that WPT is very possible. Electricity by today's standards is considered essential to life. Electricity has been the fuel for technological development since its first applications dating back to the late 16th century. This phenomenon, however, comes with a price – a great price. The cost of making electricity is harmful to the environment. The Energy Information Administration's records show that nearly 50% of all electrical plants are high polluting coal plants. Major changes in the environment have occurred over the last 30 years that are detrimental to the future of this planet. If this path is left constant, scientists have predicted that certain parts of the world could be uninhabitable by 2050, probably as a result of greenhouse effect.

The solution is to reduce greenhouse gas emissions into earth's atmosphere through alternative power generation, and transmission. One sustainable technology leading this change is wireless power transfer (WPT). The concept of wireless power transmission has been around since the mid-17th century. WPT is exactly what the name states; to transfer electrical power from a source to a device without the aid of wires.

The founder of Alternating Current electricity, Nikola Tesla, was first to conduct experiments dealing with WPT. His previous experiment of lighting gas discharge lamps from over 40 kilometer away, wirelessly, was a success. His idea came from the notion that earth itself is a conductor that can carry a charge throughout the entire surface. Although his idea of a world system of WPT could never be properly funded; his initial research sparked the scientific world into a whole new theory of power generation and transmission. While Tesla's experiments were not creating electricity, but just transferring it, his ideas can be applied to solve our energy crisis. His experiments sparked new ideas such as applications involving microwaves, lasers, resonance and solar cells. Each application has its respective drawbacks but also has the potential to aid this planet in its dying need for an alternative to create power.

Today, portable technology is a part of everyday life. Most commonly used devices no longer need to draw power from the supply continuously. But from portability emerges another challenge: energy.

Almost all portable devices are battery powered, meaning that eventually, they all must be recharged–using the wired chargers currently being used. Now instead of plugging in a cell phone, digital camera, televisions, tablet phones or laptop to recharge it, it could receive its power wirelessly.

Wireless Power Transmission

Generally, power is transmitted through wires. This paper gives an original idea to eradicate the hazardous usage of electrical wires which involve lot of confusion, particularly, in organizing them. Imagine a future in which wireless power transfer is feasible: cell phones, household robots, mp3 players, laptop computers and other portable electronics capable of charging themselves without ever being plugged in, freeing us from that final, ubiquitous power wire.

Wireless power transfer is a varied and complicated process. There is more than one system that works to complete the process. Three more scientifically sound ideas are space solar cells, lasers, and resonating electro-magnetic waves. While each process varies in the way, the energy is collected and used. The mechanisms of converting from Radio Frequency (RF) energy to Direct Current (DC) energy and vise-versa are the same for all WPT systems. The process of converting DC to RF starts with the power - that power to be transmitted is first tapped from the main power grid at about 50Hz to 60Hz Alternating Current.

A magnetron is a microwave vacuum tube consisting of a diode (with a cylindrical anode) through which the field of a powerful external permanent magnetic field passes. The magnetic field causes electrons leaving the cathode to travel in spiral paths between the electrodes. This action gives the tube a negative-resistance characteristic, resulting in oscillation when the tube is connected in an appropriate circuit. Some magnetrons have a built-in resonant cavity. This electric tube is used to generate high power output in the Ultra-High Frequency (UHF) and Super High Frequency (SHF) bands. The basis of its operation is the interaction of electrons with the electric field to generate alternating-current power output. Therefore, energy then is supplied to an oscillator-fed magnetron and electrons are emitted from the central terminal. A positively charged anode surrounds the inner cathode to attract the electrons. Due to the current flowing through the magnetron, the magnetic field produced causes the electrons to experience the cyclotron effect.

The circling electrons pass resonating cavities of the magnetron and create a pulsating magnetic field which constitutes of an electromagnetic radiation in microwave frequency range. The voltage coming out of the rectifier that connects the AC grid to the magnetron controls the magnetron anode DC voltage.

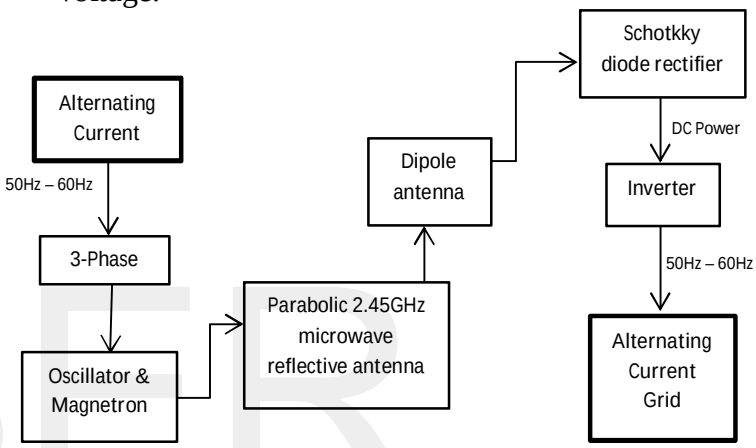

Figure 1 - Wireless Power Transfer process through microwave

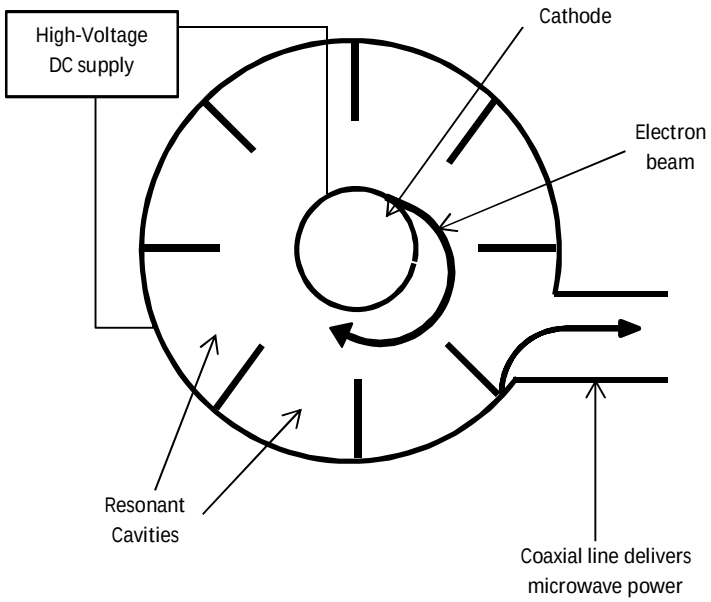

Figure 2 : Cross-section of a Magnetron

Since the anode is attracting the electrons into it (the cyclotron effect), the DC voltage that is supplied to it will determine the strength of the magnetic field. The stronger the magnetic field, the greater the force on the electrons through the resonating cavities. Although frequency of the radiation can be adjusted by varying the inductance or capacitances of the resonant cavities, the experimental transmitting frequencies with the highest success rate are 2.45GHz and 5.8GHz.

The process of 'catching' the energy for it to be used in the conversion back to DC has different obstacles than the process of transmission. A problem with transmitting RF energy long distances is that it will lose its strength due to free space propagation. In order to compensate for this loss, antennas are connected in arrays. This increases the RF energy absorbed thus increasing the efficiency of the transmission. A series-parallel-assembly of Scohttky diodes (rectenna) is then used at the receiving end to convert the microwave power back into DC. These diodes contain a low standing power rating but RF qualities enabling it to rectify the incoming microwaves into usable energy.

Using resonating electromagnetic waves is the system that will most likely be seen in the near future in applications that demand less than 10m of transmission. When two objects vibrate at the same frequency, they create larger amplitude together, rather than standing alone. If an antenna resonating with a particular frequency is brought within a few meters of a receiving antenna resonating at the same frequency, then the energy can be 'tunneled' through space and into the receiving antenna to be rectified. The quantum phenomenon of tunneling allows the energy to travel through space without being propagated. In a sense, the energy being tunneled is able to cross the potential gap between the two antennae without losing any energy. This resonating causes electromagnetic waves to vibrate through space. The energy is then used to recharge a battery inside the device. Since no energy is lost during the transfer, any surrounding circuitry is not harmed.

Solar power is a truly unlimited energy supply. Using the resonating electromagnetic waves system in coordination with outer space solar cells takes wireless power transfer to a new scale. In geosynchronous orbits, solar satellites would be illuminated by the sun's rays 99% of the time. A constant transmission of energy from the satellites down to earth would prove that there would be no need for costly storage devices to hold excess energy. The theory includes massive outer space panels attached to these satellites that would continuously absorb the sun's rays. The energy would be beamed back to Earth using the electromagnetic wave system. Wasted heat cause from the absorption and transmission can be radiated right back into space, eliminating the potential for overheating. This has been looked into extensively, especially for the reasons of the energy problems in the world today. Particular problems, however, occur when trying to implement a WPT system able to sustain such a demand as currently needed. Besides the cost and complexity to build such a large scale system, a recent study shows that the solar collectors would cover many square miles just in space. The receiving collectors on earth would cover close to 50 square miles. Despite the setbacks, this form of WPT is receiving currently the most attention in the science world due to the fact that it can transmit energy at close to 85% efficiency.

The use of lasers to transfer energy is a much different process from those above. This process involves transferring energy from a source to a receiver by beaming a laser to an object with a solar cell receiver. This idea is possible but is highly inefficient. The laser would need a direct line of sight to the object it is charging. Also, converting electricity to a laser and back to electricity causes a loss of energy. Energy from the laser is absorbed into the atmosphere also causes a loss of energy. In theory the system would work, but it is not an efficient form of wireless power transfer and would not be worth the trouble that the system would cause.

Sustainability

Sustainability is an attempt to provide the best outcomes for the human and natural environments both now and in the future. When looking at Wireless Power Transfer, the standard application of charging small electrical devices has no harmful effect on the environment. Wireless Power Transfer, on a large scale, has been projected to produce only twenty grams of carbon dioxide- the worst cause of global warming- per kilowatt hour. This is significantly lower than oil which emits eight hundred and forty-six grams of carbon dioxide per kilowatt hour. Nuclear energy emits about the same rate as Wireless Power Transfer, but Wireless Power Transfer has no radioactive waste that is harmful to the environment.

Wireless Power Transfer also has an application in the medical field. A Pacemaker, (electrical device designed to stimulate regular beating of the heart, using electrodes implanted in the body) today has an average lifespan of five to eight years. If the pacemaker is wirelessly powered, there is no need to have open heart surgery every five to eight years. This can be used for any electronic medical device placed in a human. A new idea that uses wireless power transfer is a device that automatically distributes medicine to the body. It works by placing an apparatus, filled with a medicine of some kind, under the skin. Then by sending power to the apparatus, it releases the correct amount of previously specified medicine.

The most futuristic idea that uses wireless power transfer is space travel. If scientists and engineers can find a way to send out energy waves to limitless distances, space travel would change significantly. First, a space ship would be built that could take in the energy waves and use the waves to thrust the vehicle and run the other system within it. Once in space, the vehicle would be able to travel as far as the RF waves would allow it. This will help the world learn more about our galaxy and beyond.

Application

Wireless power transfer has the ability to change the world with all the different applications it has to offer. As simple as charging a cell phone to supplying the Earth with all the energy it needs. The first applications that consumers are most likely to see would be a charging station that will range from about one to five meters. This is a small box-like object that will be able to charge compatible electronics within the range of the system. Wireless power transfer charging systems are proven to have efficiencies near that of conventional charging devices. For example, a household would need about one transmitter per room and allow the house be completely wireless. This will strictly be a convenience to consumers and not serve any other service. Electronic companies may not like this new concept due to the fact that they will not be able to make a different charger for everything they make and force consumers to pay for the different chargers. The biggest advantage, especially with personal devices incorporating wireless chargers is that one does not have to consciously 'charge' the devices, they charge themselves every time they come within the range of a power transmitter.

Once wireless power transfer becomes more advanced, the scale of applications can begin to grow. The range of the electromagnetic waves will begin to increase. Once the range reaches around twenty meters, entire homes will be able to be charged by a single transmitter located close to the home. As the range expands entire blocks and streets will be powered by a single transmitter. Once this point emerges, consumers can notice cars converting to completely electric with the capability of being wireless charged. Roads will adapt to have wireless chargers spaced so far apart so a car will be able to run endlessly.

The final step in this phase involves outer space solar panels. Using the outer space solar panels to collect the Sun's energy, solar powered satellites will beam it back to Earth. This will severely reduce our dependence on conventional fuels. This will be a never ending supply of energy. At this stage of wireless power transfer, consumers will notice

changes in the stock market including petroleum, natural gas, and coal. Homes and cars will no longer need to be heated or powered by these resources. The two major problems in the world are oil dependence and global warming. This system will help treat both problems. This will take many years to complete but the world should start to look at this as a permanent solution. Wireless power transfer will solve the energy crisis.

Concerns with Wireless Power Transfer

Wireless power transfer is possible, but when trying to sustain a constant power level, some problems can occur with the efficiency of the transmission. This occurs most noticeably in the electromagnetic wave system. The problem with radio waves is that they scatter the energy in different directions through free space propagation. This causes the efficiency to be much lower than if they could be transmitted directly to the receiving antennas. If a world-wide electromagnetic wave WPT system was used, then free space propagation would cause numerous problems. The free space energy would either go unused or would be received by antennae that the transmission was not intended for. This would pose the most direct problem to consumers within the WPT grid. Individual consumers would either not be receiving their required energy, or would be receiving too much and paying a much high electricity bill. These are some problems that are trying to be corrected through multiple antennae arrays, but high efficiencies have yet to be accomplished.

Another concern consumers have is the safety of free flowing energy and its effect on the human body. Microwave beams are the main concern of wireless power transfer. The safety issues are closely related to those that involve cell phones, radar, and wireless internet. Unlike what many consumers think, cancer is not the main concern. Typically other problems such as severe headaches, sleep disturbances, memory loss, learning disabilities, attention deficit disorder, and infertility affect a person before cancer. So far there has not been any reported major health issues related directly to microwaves but any extended period of EM exposure can cause serious health risks.

Another concern consumers may have is the fact that energy is around them all the time. The air filled with energy is not a danger to humans. The way the system works is that the transmitted energy only reacts with an object resonating at the same frequency as itself. This means that the energy would only interact with something if it is vibrating at the same rate as the energies wavelength, or, is in resonance. If an electronic device would have a system in itself that operate at the same wavelength as the energy being transmitted, it could fry the electronic device and blow the circuit. Some things that could still be affected by wireless power include RADAR, x-rays, radar guns, and radio. These are major things that will have to be dealt with if wireless power transfer becomes widely used.

Conclusion

Wireless power transfer has the potential to change this planet on so many different levels. Whether it is charging a handheld device, to changing the effect of global warming on this planet, wireless power transfer has an answer. The most commercially viable application arising to counter the effects of global warming and the increasing demand for electricity is WPT through microwave transmission from space. This application will supply limitless power to earth and also open up many new opportunities for space exploration. With WPT through resonance and inductive coupling, emerging technology companies are able to broaden the capabilities of most small electronics including cell phones, PDAs, and mp3 players.

By forecast, Wireless Power Transfer will be the most marketable and sustainable alternative to fossil fuel power plants. With advancements in the field happening all the time, a worldwide wireless power transfer system is a possibility in the near future.

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