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Technical Note

Wireless transmission of solar panel energy with the help of mutual induction

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ABSTRACT

The world is slowly shifting towards the more reusable energy sources. These include energy harvesting methods such as solar power, windmills, tidal and geothermal energy, and more. The world is also understanding the importance of proper insulation when it comes to design of buildings. One of the problems that is being automatically due to this is global warming, and other natural disasters. Solar panels play a critical role in overcoming this problem. An inverter is usually attached to solar panels to convert the DC source to an AC signal. In this work, a transmitter takes this energy, and then, through the use of Faraday's Law, induces the power into a secondary coil through electromagnetic waves. The receiver then converts these electromagnetic waves to an alternating current, which is then transmitted, rectified, filtered and used. This work covers exactly that, and works on improving the efficiency of such wireless systems, bringing to life the vision one sought by Nikola Tesla, using clean energy.

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INTRODUCTION

The concept behind Wireless Power Transmission (WPT) systems involve electromagnetic fields. The idea is that an electric field that changes over a period of time induces a magnetic field with a phase of 90, while this magnetic field induces an electric field on another phase of 90. This causes oscillations of electromagnetic fields which are transmitted by a coil. For the receiving coil, there is a similar oscillation but every time a magnetic field is induced in the primary coil, the receiving coil induces an electric field [1]. However, these fields have a limited range. There are two different types of field classifications that are near field and far field regions. Figure 1 shows the classification. Ideally, near field regions are more efficient and there is a lower diffraction which eventually leads to a high permeability.

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This is also classified into two types of coupling, which are inductive and capacitive. Normally, inductive coupling relies on magnetic flux and is safer.

The industry tends to focus mostly on near-field regions since far-field regions are inefficient with low permeability, and even lesser penetration. They are unsafe. Figure below shows how a near field system is broken down into different blocks, with a range of 10cm [2]. Usually within the transmitter circuit is a section which inverts the DC voltage into an AC signal to be sent to a coil. This frequency is usually at a high frequency, which increases efficiency of the system. This is why it is a critical part of the system. As the wavelength comparably large distance from transmitter to receiver, the system is classified as a near-field system. Eventually after receiving, the electricity is converted from AC to DC, which allows DC current to be used in applications such as mobile charging. Figure 2 Show the typical near-field power system structure.

Wireless Power Transmission Systems tend to rely on EM radiations, so it can pose a health hazard to people when considering high power energy transfers wirelessly. The idea is that if the human body absorbs too much wireless energy, it can lead to cell mutation which can lead to cancers or other diseases [2]. Contradictory to this statement, the World Health Organization states that when faced with a dilemma in this regard, there are existing standards from the ICNIRP and IEEE which allow safe product development [3].

These two standards are:

"IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" and "ICNIRP Guidelines for Limiting Exposure to Time- Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)".

It is projected that the market value of wireless power transmission, which was around $8.5 billion in 2018, would eventually be reaching approximately $10 billion in the coming three years, by 2023, shown in figure 3[4]. Another researcher, with his group, in 2012 concluded that the market would be influenced majorly by some of the bigger stakeholders such as IEEE, Google, Facebook etc. shown in Figure 4 [5]. The ideology is in the fact that the majority of revenue should be from infrastructure and industries, and mobile devices. When this happens, the consumers for wireless power usage will rise and hence the technology will be further developed. It's been forecasted that in the

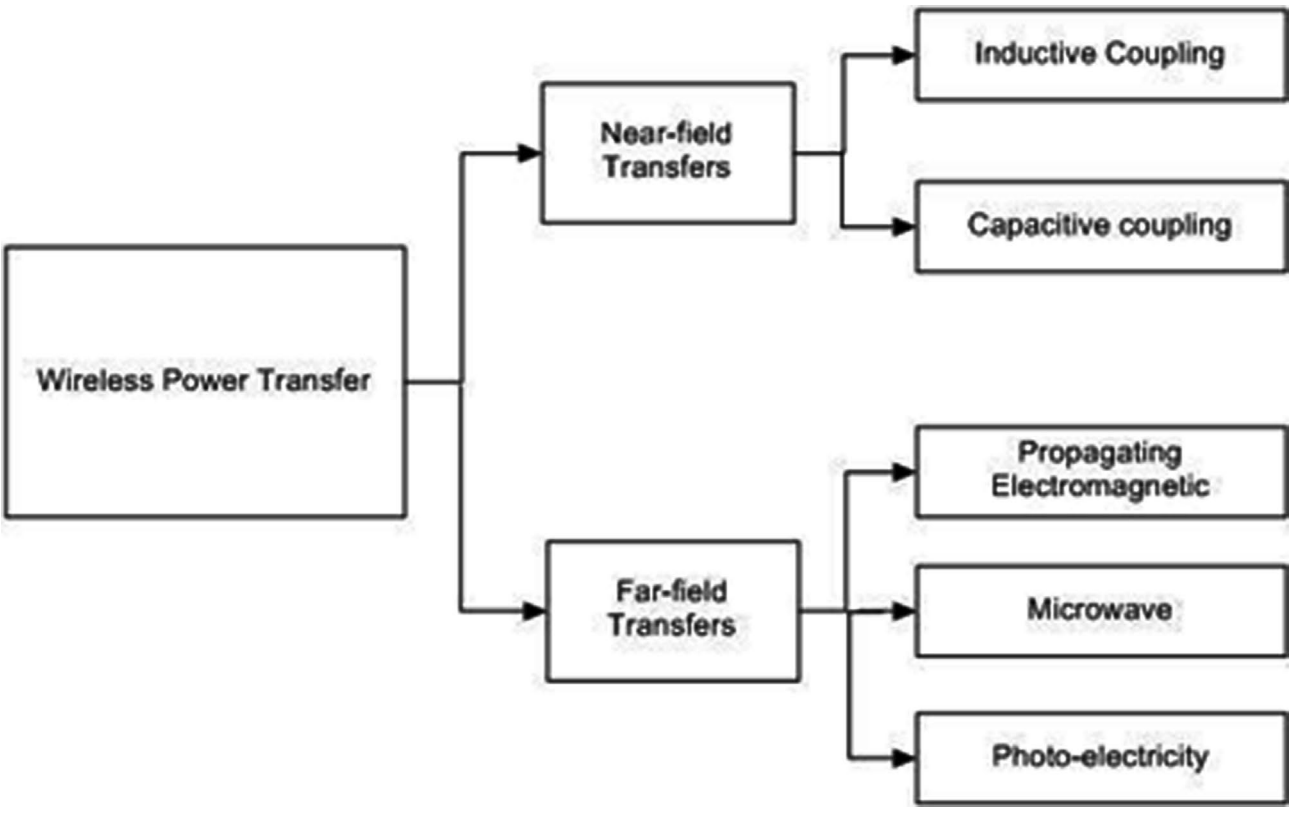


Figure 1. Wireless power transmission types.

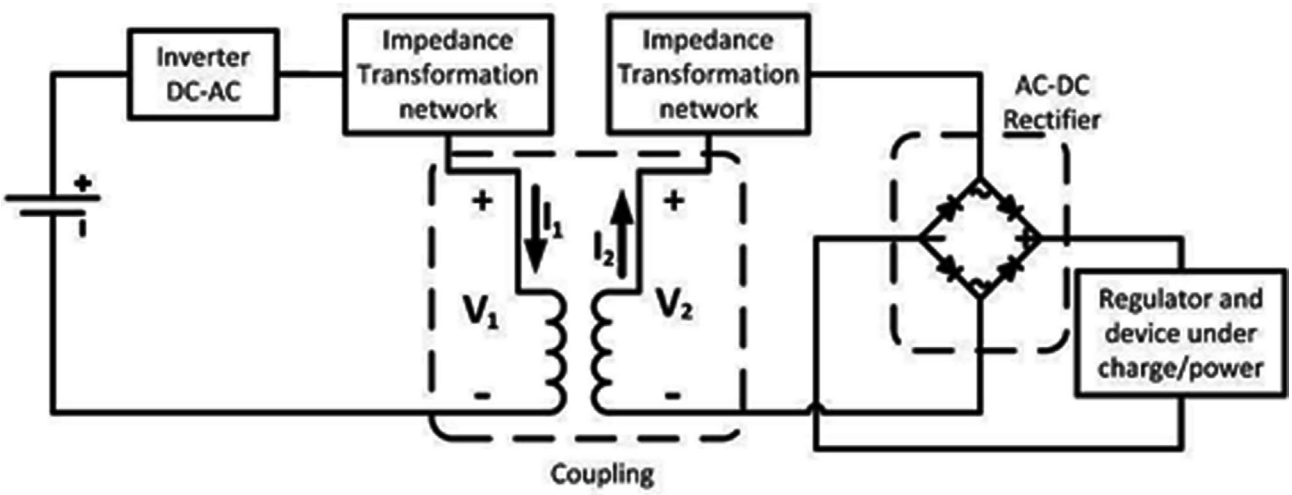


Figure 2. Typical near-field power transfer system structure.

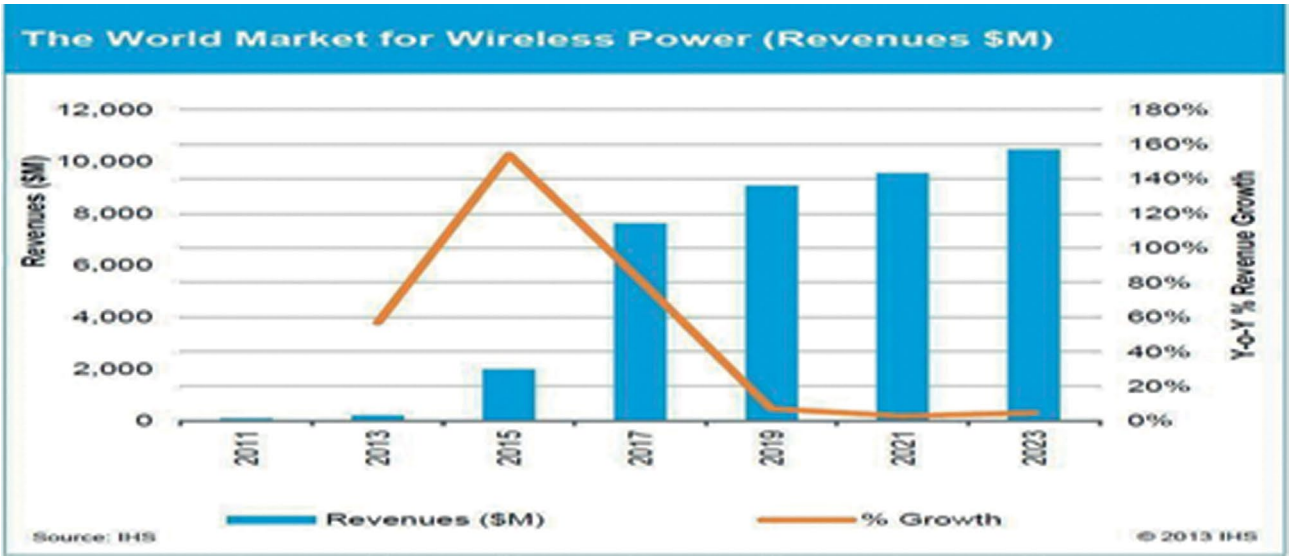


Figure 3. The world market for WPT.

Asia-Pacific, the revenues for wireless technology will rise to 40% compared to North America's 27% at the end of this year, shown in figure 5 [5].

ADVANTAGES

Of course, since wireless power transmission (WPT) takes away the requirement for heavy, bulky, expensive cables, it cuts down on costs heavily. However, it also cuts down on another cost; pylons and transmission towers are also eliminated. This leads to a better projection of the pros of the WPT systems, since most people don't realize this fact. Many different components of the conventional power transmission system would be eliminated, such as sub-stations.

Another benefit of WPT systems is that there is a freedom of choice for the receivers and transmitters. In some cases, mobile units can also be deployed to have an adjustable range of power transmission, which could change location as per requirement. As this would be cutting down on transmission costs, the unit rate for electricity would fall, thus removing a heavy load on the economy of the world

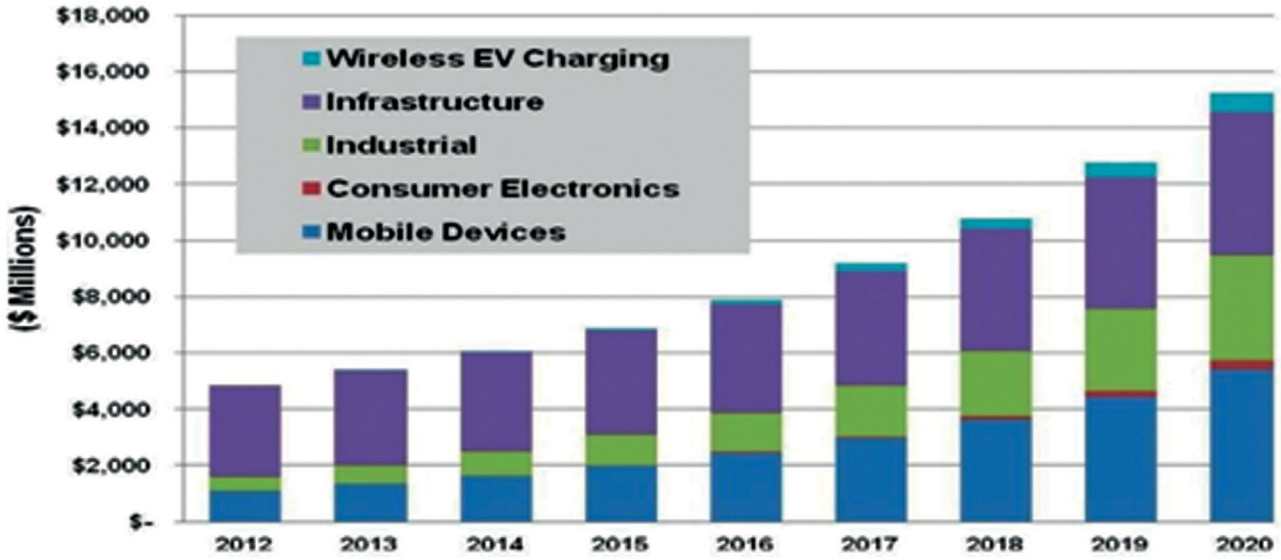


Figure 4. Wireless Power revenue by application.

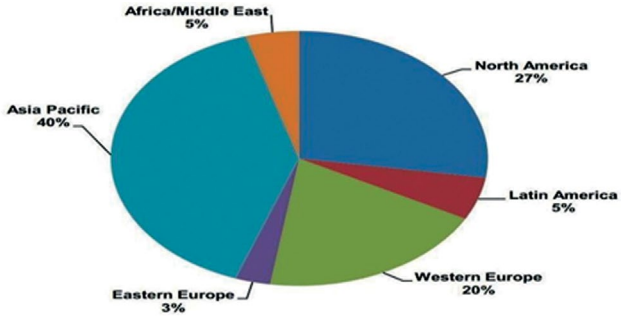


Figure 5. Wireless Power revenue share by regions in 2020.

and even in situations that involve power breakdowns, a large amount of problems would be solved.

For these WPT systems, the following advantages can be seen:

- Solar energy collection is efficient at greater heights, especially orbiting the Earth
- Energy that doesn't radiate, is safer for biological beings.
- The power losses could become very small
- Radio waves would not interfere with the power signal
- Resonant systems allow for high efficiency over long distances.

APPLICATIONS

- It's going to be possible eventually to raise the efficiency of solar power by using solar panel satellites, which will be using a microwave transmitter to transmit the captured solar energy, and transmit it to the ground, which will receive these microwaves using receivers, which could power entire homes and offices.
- We can expect in the near future that inside homes will be an inductive receiver that will be able to receive energy from wireless transmitters. These receivers will then be connected to further transmitters which will let entire houses, offices and buildings be wireless. Televisions, computers, mobiles, air conditioners all would be working without wired connections by receiving wireless energy.
- In emergencies, or in under-developed countries such as Pakistan where the national grid is unreliable in terms of uninterrupted power, wireless systems are most efficient in maintaining backup. In situations of dire emergency, if the energy system goes down, the universal power source provided by wireless transmitters would help maintain stability.
- The utopia for uninterrupted, consistent power would be a smart city with multiple receiver, transmitter and booster towers which could be totally free from wired connections. From cars to houses to trains and even airports, everything could function using wireless energy which would lower the carbon footprint of the system to major extents.
- One of the systems that is already in effect is wireless charging of electric cars. Tesla has released several of these cars, and many modern cities implement these wireless charging systems. The vehicle only has to stay above the charging station, and the wireless energy charges the electric cars at a super speed.
- The train tracks could be turned into electromagnetic induction transmitters, with powerful receivers on

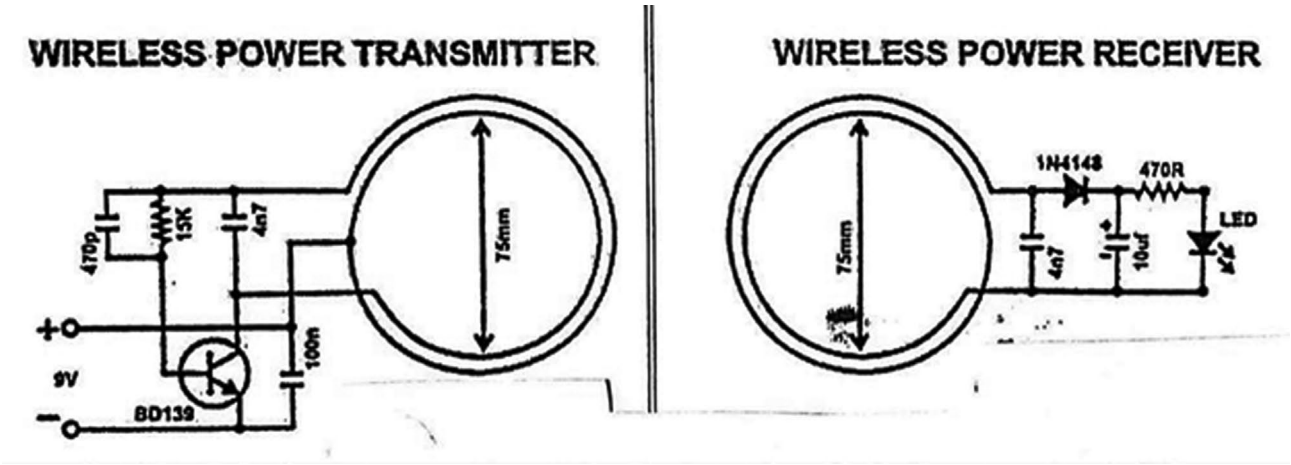


Figure 6. Circuit diagrams of Wire Power Transmitter and Receiver.

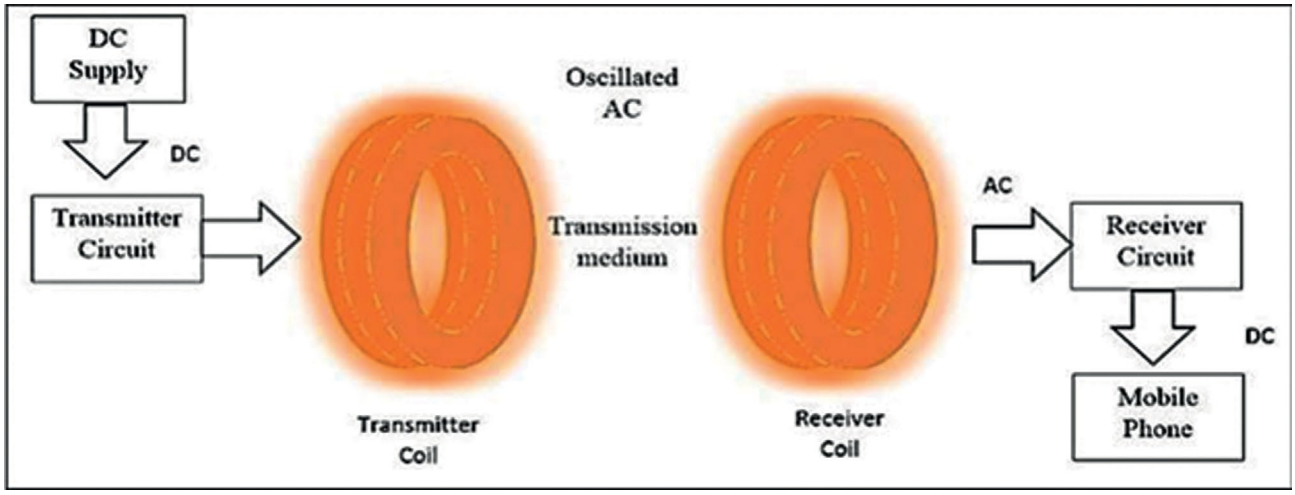


Figure 7. Complete schematic diagram of Wire Power Transmission system.

the trains which would make these systems wireless. Traditionally, the heavy wires on the electric train tracks cause the trains to become hazardous as they are transmitting 200Vac.

METHODOLOGY

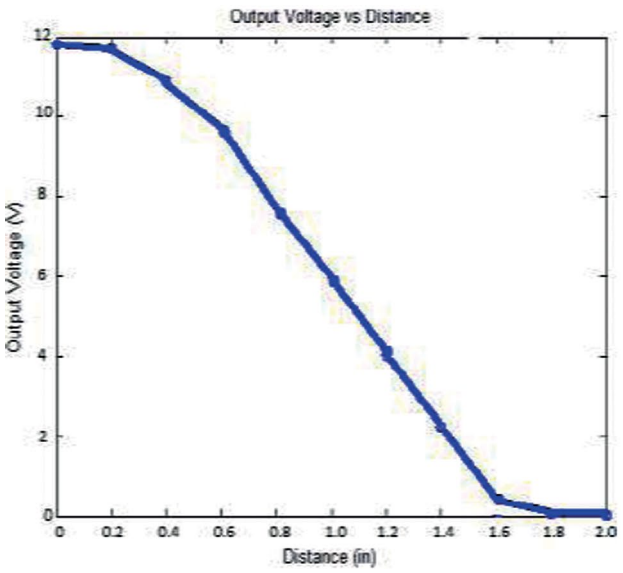
Designning and Working

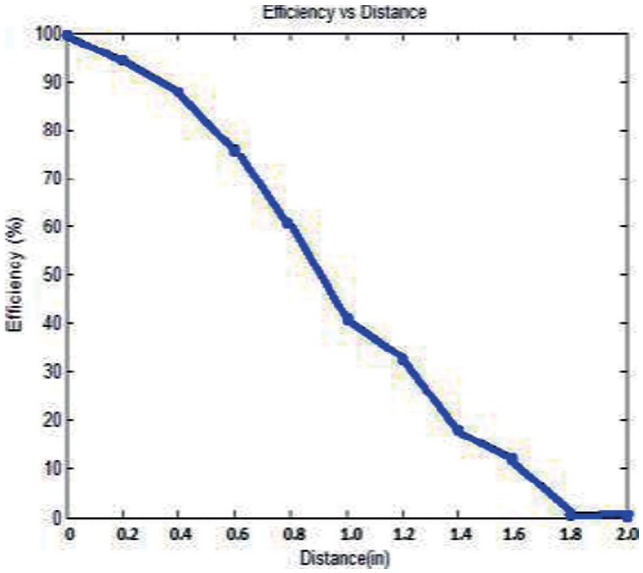
In this project, the essential principle involves converting DC power to AC power using switching and filters and then again converting it back to DC using voltage regulator. Electrical energy stored in rechargeable 18V battery supplied by solar panel. Transfer of energy by induction to the receiver via mutual induction. The transfer of energy performed by magnetic field.

When we turn on the switch the solar panel supply its energy via battery and battery starts charging. During this system, primary and secondary coils works as a transformer and generates AC voltage. The bi-polar NPN transistor "BD139" is placed which is employed to regulate on and off the load. Three capacitors are used in transmitter circuit and two capacitors are used in receiver circuit with their suitable resistances. In this system, capacitors are used for filtration which reduce the effect of noise sources. The system will work by using transmitting and receiving coils to transmit power from an AC line to resistive load. We place a voltage regulator which converts AC voltage into DC voltage which transmits the facility to the electrical load.

Physics and Mathematical Framework behind this work:

According to Orested's law, when the current is stable, a magnetic flux is generated. Expanding upon this is Bio-Savart's law, which is given by the following equation:





$$B = \frac{\mu_o}{4\pi}\int_1 \frac{Idl \times e_r}{r^2} \quad (1)$$

Where, *Idl* is the symbol for the current source in the wire, divided into nearly infinite segments *r* is a vector quantity that shows the displacement from the current source to the point in the field

e_r is the unit vector of *r* and μ_o represents the permeability of free space.

$$B = \frac{\mu_o NIa^2}{2(a^2+d^2)^{\frac{3}{2}}} \quad (2)$$

B represents the magnetic flux, N is the number of turns of the coil or loop, and I is the amount of current through this loop, a represents the radius of the transmitter and d is the distance between the transmitter and receiver.

And the estimate for the amount of flux received by the receiver is given by

$$\phi = \iint_s BdS \quad (3)$$

Where, S is the surface area of the secondary coil. Applying Faraday's law to find the amount of EMF induced, it is given by:

$$\varepsilon = -\frac{d\phi}{dt} \quad (4)$$

One of the phenomena that occurs during this process is that the variation in electric field of the receiving coil tends to induce a magnetic field in itself. This is known as self-induction and is represented by L:

$$L = \frac{N\phi}{I} \quad (5)$$

By combining the two equations shown above:

$$\varepsilon = -M\frac{dI}{dt} \quad (6)$$

And from here we achieve M which is the mutual inductance of the two coils combined, measured in Henry. As the emf induced on the coil is proportional to the mutual inductance, it can be represented by the following equation:

$$M = k\sqrt{L_1 L_2} \quad (7)$$

Here, k is known as the coupling factor where L1 and L2 are inductances of the primary and secondary coil. If the equation is alternating, then we get the following equation:

$$\emptyset = \iint_A \frac{\mu_o Nisin(\omega t)a^2}{2(a^2+d^2)^{\frac{3}{2}}} dA \quad (8)$$

The equation above shows that whatever voltage in the secondary coil is induced is a function of multiple parameters discussed above.

RESULTS AND DISCUSSION

An experiment has conducted to urge the WPT efficiency. The transmission coupling was supply from DC source. The difference within the distance between primary transmitter and secondary receiver are varied to get the distance for WPT.

The voltage transmitted to receiver drops because there is increase in the distance between the transmitter and receiver. The efficiency of the power transmitted drops because there is increase in the distance between transmitter and receiver.

The graph result shows the different distances with the voltage varied when the distance is different The DC input source was used which is a solar panel and the mobile phone is used as a load. The DC output voltage is getting decrease as the distance increases, it shows inverse relation. Mobile phone stops charging if the distance increases which means less voltage transferred to the load. The above measurements suggest that the system is suitable when the distance from transmitter coil to the receiver coil ranges from 0 to about 1.4inches. From the graph, we conclude the WPT is higher when the distance is low.

Based on experimental result, the study on WPT has aspect in terms of distance and range of frequency and the result show the closer the distance, the transfer of voltage is higher, distance of the nearest is the most efficient WPT. The system further enhanced by integrating the charging adapter with the mobile so that users will need to place mobile phones on charging pad to charge it.

CONCLUSION

Solar power generation and Wireless Power Transfer both the technologies are focused in our work. The idea of WPT through renewable power generation provides clean, green, non-conventional and efficient power transmission through wireless medium. This would offer great development in the field of solar and wireless technology. The physics and laws behind wireless power technology are the main steps of the project which were discussed. Review the current industry situation and available solutions are evaluated. The system consist of transmitter and receiver boards developed and uses a coupling phenomenon to transfer of electricity. By utilizing the wireless technology, we can get rid of fossil fuel electric power plants that generates harmful greenhouse gases for global warming. Wireless electricity transmission overcome these problems well. However, technology will change concept of electricity in near future and to acquire the most efficient, effective, pollution free and healthy way of getting electricity.

Now it a reality that power transmission can be possible without wires to any terrestrial distance. Many Electrical and Electronic Engineers and Researchers' have published numerous experiments, observations, and measurements, qualitative and quantitative. Dr. Nicole Tesla is the father of this invention. It has an amazing economic and social impact on our society. Many countries around the globe will benefits from this service. Finally, we can say "GOODBYE WIRES"

FUTURE WORK

Wireless Power Transmission Technologies with the help of solar power considered as a great scope in future of generation of power and transfer. Solar Satellites will be the future for supplying non-conventional energy. Commercial Space-Solar Power System operational within 25 years. Only time will tell if this is achievable goal or not. The technological and financial challenges facing by space- solar power are far from trivial. We know that history shows humans can achieve tremendous success when sufficient motivation is given. We can also implement this technology in wide range of applications such as shopping malls, airports, office environment, home appliances and any other public spaces by overcoming the constraints.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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