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An Overview of Wireless Power Transmission System and Analysis of Different Methods

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Abstract: The overall concept of wireless power transmission and its strategy for finding an efficient means to distribute power without stringing wires that could wirelessly transport electricity are demonstrated in this paper. This study examines the latest trends and technological advancements in the field of wireless power transfer. Wireless power transfer has become commonplace in future societies with advanced technology.
Keywords: latest trends, technological advancements, wireless power transmission, stringing wires, ubiquitous

I. INTRODUCTION

Because electricity has become a commodity rather than an intangible energy, demand has risen dramatically, and it is now used in every corner of the globe. The development of EV charging network infrastructure is a critical component of their development [1],[2]. As long as the contemporary smart grid, by deploying distributed energy generating and storage systems, supports sustainable mobility. Wireless power transmission, as defined in [3], is the transfer of energy over a long distance without the use of separate artificial conductors. [4] It is currently also employed in biomedical applications, where it is advantageous to reduce the size of a device so that wireless sensors can be incorporated [5]. The simultaneous wireless information and power transfer has gotten a lot of consideration in the research community. Using radio frequency signals efficiently for both wireless information transmission and wireless power transfer at the same time [6]. In the coming years, the wireless power transfer business will continue to grow [7]. The transmission of electric power from a power source to an electrical load without the use of interconnecting cables is known as wireless energy transfer or wireless power transmission [8]. In situations where linking cables are difficult, harmful, or impossible, wireless transmission is advantageous. In the case of wireless power transfer in electric vehicles, efficiency is the most important factor [9]. Direct induction and then resonant magnetic induction are used in the general form of wireless power transmission [10]. Other technologies under investigation are radio waves, such as microwaves, or laser beam technology, depending on the distance over which the energy must be carried [11]. Despite the fact that those issues continue, additional demands arising from greater use of wearable devices like mobile phones and operations in unclean or damp conditions [12] necessitate new approaches to powering equipment [13]. The wireless power transmission has been an unused technology since Tesla's time. Tesla had long attempted to establish a global wireless power distribution system [14]. He was unable to accomplish the assignment due to a lack of finance and technology at the time. From then on, this technology has not progressed to the point where it is fully usable for practical purposes [15]. There has always been research in this topic, and there have been recent developments. Despite advancements, commercial wireless power transmission has yet to be embraced.

II. OVERVIEW ON THE FIRST EXPERIMENT ON WIRELESS POWER.

Nikola Tesla, a Serbian-American inventor established a foundation in the field of wireless transmission of electrical power, led the first experiment in late nineteenth century.

It was the first system that could wirelessly transmit power. From 1891 through 1898, he experimented with wireless transmission in his "experimental station" in Colorado. He experimented with the transmission of electrical energy using a tesla coil radio frequency resonant transformer, which created a high voltage of high frequency alternating currents, allowing him to transfer power over short distances without the use of wires. He used a resonant circuit which is earthed on one end to successfully light a small incandescent lamp.

Outside the premises of laboratory, a coil with the bottom end grounded and the higher end unbound. The current which induced in the three turns of wire wound around the lower end of the coil ignites the lamp. Tesla planned the Wardenclyffe tower for trans-Atlantic radio telecommunications as well as to demonstrate wireless electrical power transmission.

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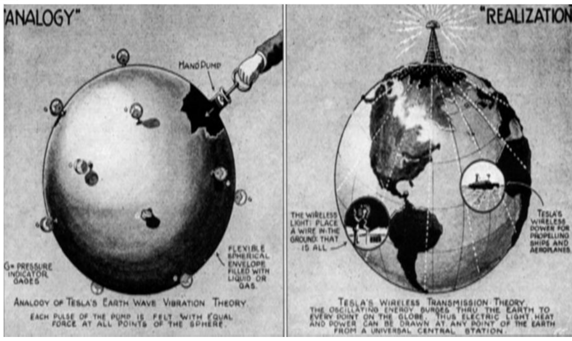

Fig. 1 Nikola tesla wireless power transfer plan. Fig 2**:** Wardenclyffe tower at Shoreham, New York

Brown devised the rectenna in the early 1960s, which converts microwaves directly to DC electricity. In 1964, he demonstrated its capability by powering a helicopter entirely with microwaves. Short-range, medium-range, and long-range wireless power transmission technologies are divided into three categories based on transmission distance: short-range, medium-range, and long-range transmission. It is shown in table 1.

TABLE I
Tabular Representation Of Research Developments In Field Of Wireless Power Transmission

Year	Achievement
1899	Transmitted power wirelessly over a distance of 26 miles at which he had lit up a bank of 200 light bulbs and ran one electric motor. With tesla coil and claimed that only 5% of the transmitted energy was lost in the process.
1901	Wardenclyffe tower also called as tesla tower is the first and early experimental wireless transmission station designed by Nikola Tesla on long island in 1901-1902, located in the village of Shoreham, New York.
1960	Design of rectenna for microwave mode of wireless power transfer was made.

III.METHODS OF WIRELESS POWER TRANSMISSION

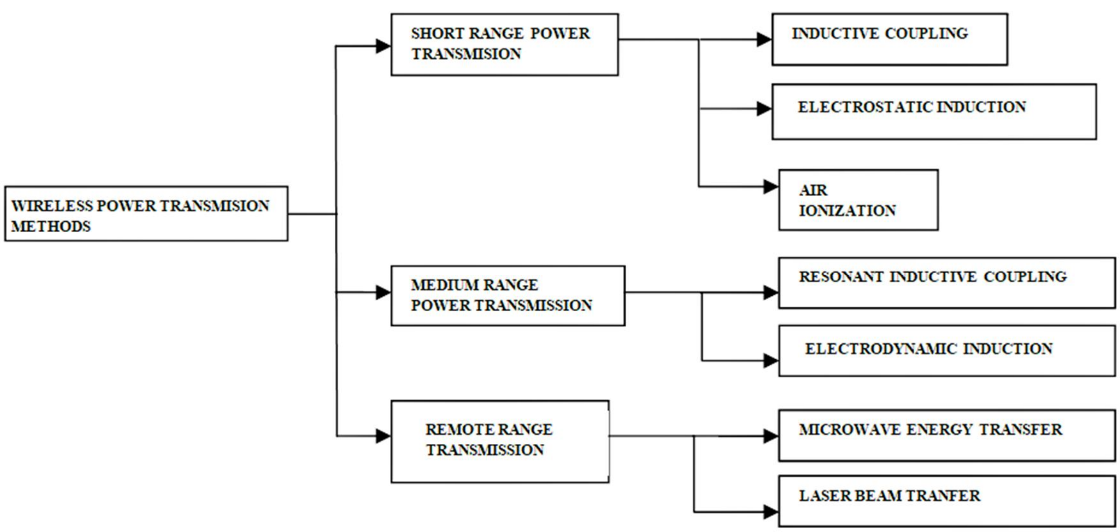

Fig. 3 Block diagram of wireless power transmission methods

A. Short Range Power Transmission

Power can be wirelessly delivered from the transmitter to the receiver over small distances of a few centimeters to a few meters using this technology. It's also referred to as "Near-field" method. Inductive coupling, resonant inductive coupling, and air ionization are all used in this process.

1) *Inductive coupling:* The energy is exchanged between two coils using magnetic fields in this way. However, the spacing between two coils should not be too near with this procedure. Without utilizing wires, the principle of mutual induction between two coils can be used to transfer electrical energy. The transformer, which doesn't consist any physical touch between the primary and secondary windings, is the best example of how mutual induction works. Due to electromagnetic interaction between the two coils, energy is transferred. Without any physical contact between the coils, the principle of mutual induction can be employed to transfer electrical power. The primary goal of an inductively coupled wireless power transfer (ICWPT) system is to supply electricity to a moving object via a gapped magnetic structure.

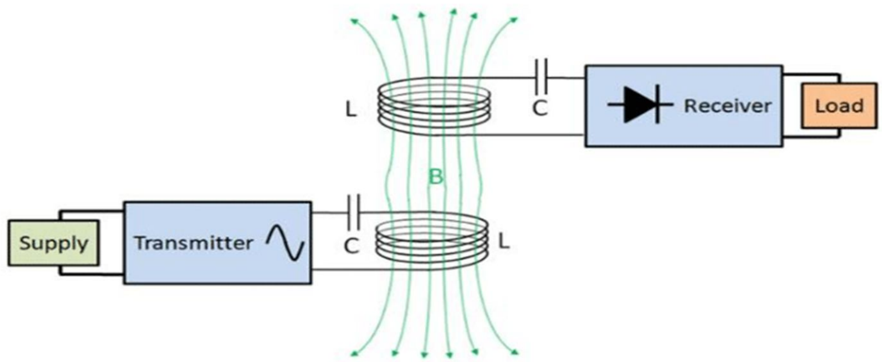

Fig. 4 wireless power transfer through inductive coupling

2) *Electrostatic Induction:* Capacitive coupling is another name for it. For wireless energy transfer involving high frequency ac potential differences sent between two plates or nodes, it can be an electric field gradient or differential capacitance between two raised electrodes above the conducting ground plane. The wireless power transfer in this technology is accomplished using the theory of " Electrostatic induction," in which charges are transferred due to differences in the charge densities of two things.

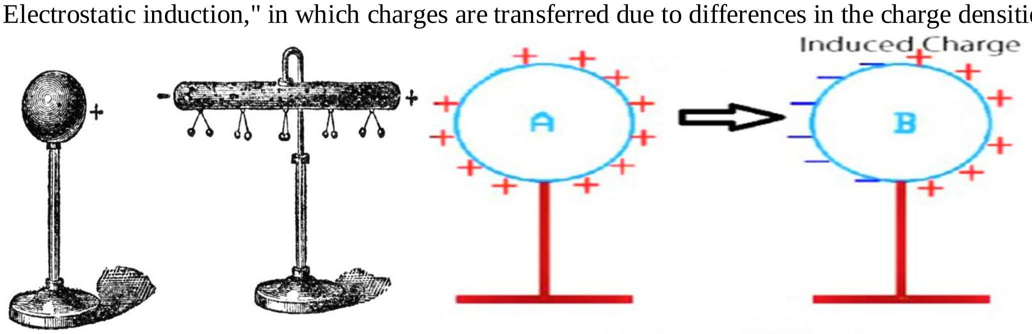

Fig. 5 Separation of charges between two bodies due to electrostatic induction

3) *Air Ionization:* The most difficult method of energy transfer is ionization of air. When the electric field around 2.11MV/m becomes very strong, conditions are met for the air to start breaking down. The ensuing electric field ionizes the surrounding air by splitting it into positive ions and electrons. Ionization does not imply that there are more negative (electrons) or positive (positive atomic nuclei / positive ions) charges than there were previously. It indicates that the electrons and ions are separated from one another more than they were in the molecular or atomic structure before. The electrons are excited to the higher energy atomic shell, the valence shell, by the high breakdown strength of air. Electrons excited to the valence or penultimate shells are now far freer to move than they were before the separation. As a result, this ionized air is far more conductive than the non-ionized air before it. In fact, any material's ability or flexibility to transfer electrons is what makes it a good conductor of electricity. There is no e-waste with this technology, it is harmless if the field strength is within limitations, and it requires minimal maintenance. This system, however, has its own drawbacks. The biggest disadvantage is the distance constraint, as ionization cannot light up a receiver over great distances. The initial investment is substantial, and the system's viability is uncertain.

Fig. 6 Power transmission through ionization of air

B. Medium Range Wireless Power Transmission

The transmission of electrical energy is done in this category across a medium distance. It was then divided into two categories: resonant inductive coupling and electro-dynamic technique.

1) *Resonant inductive coupling:* This technology uses non-radiative electromagnetic energy resonant tunnelling to transfer power wirelessly. Because electromagnetic waves would tunnel, they will not be absorbed or squandered in the air, and there will be no disturbance in electronics or injuries, as with microwave or radio transmission. The range is expected to be roughly 5 meters, according to the researchers. According to them, evanescent waves in a very high angular waveguide transport no energy; but, if a correct resonant waveguide is delivered near the transmitter, a tunnel is established towards a power drawing waveguide, which can be converted to DC using rectifier circuits. Using this procedure, a prototype model with 5-meter ranges is created, Electro-magnetic radiations which involve shorter wavelength often in the microwave range, radio waves can be made more directed, allowing greater distance power beaming. For the conversion of this microwave energy into electricity, a rectenna can be utilized. Rectenna conversion efficiencies of over 95% have been achieved. Microwave power beaming has been proposed for the transmission of energy from orbiting solar power satellites to Earth, as well as power beaming to spacecraft exiting orbit. The fundamental benefit of this technique of power transfer is that it can transfer power across a distance of up to 10 times that of inductive coupling. When compared to inductive coupling, it is unaffected by the precision between the coils. Because the power loss is negligible, there is less heat generated, which extends the coils' and device's life. The disadvantages include shorter charging cycles compared to non-resonant inductive coupling and the inability to permeate solid objects when put between them.

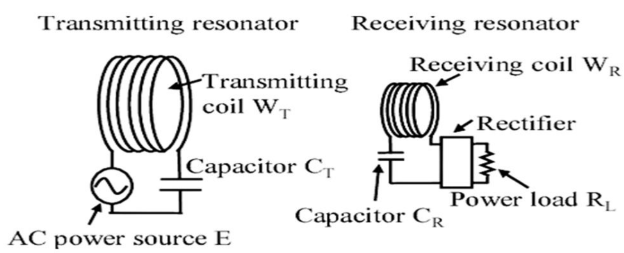

Fig. 7 wireless power transfer through resonant inductive coupling.

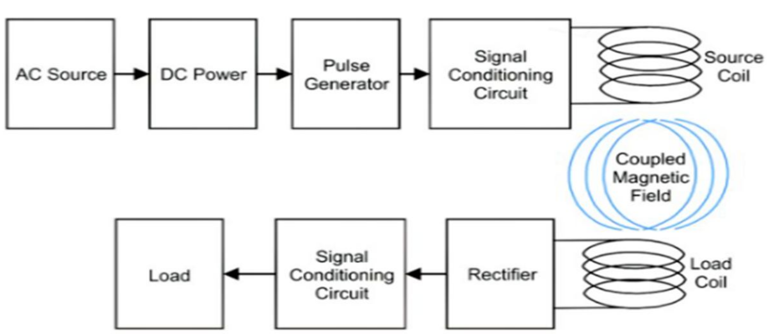

Fig. 8 schematic block diagram of resonant inductive coupling

2) *Electrodynamic Induction:* This method of wireless mode power transmission includes two or more bodies in which one is stationary and the other is in motion with respect to one another. There is always a relative motion between transmitter and receiver which induces electromotive force according to the Faraday's law of electromagnetic induction. The main problem related with non-resonant inductive coupling for wireless energy transfer particularly the requirement of efficiency on transmission distance. When resonant coupling is used the transmitter and the receiver inductors are changed to a common frequency. The current is modified from a sinusoidal to a non-sinusoidal waveform. The power transfer in the form of pulses takes place over multiple cycles. In this way, the significant power may be transmitted over a distance of up to a few times the size of the transmitter.

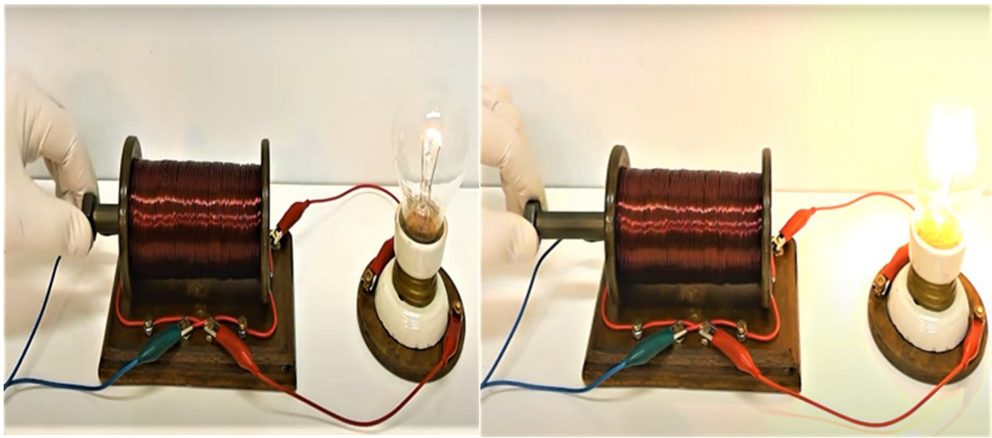

Fig. 9 Demonstration of electro-dynamic induction through fixed contact (coils) and the moving contact (electromagnet)

C. Remote Range Wireless Power Transmission

Wireless power transfer is used in this technology. The distance between the transmitter and receiver can be extended up to several meters depending on the mechanism employed. Microwave energy transfer and laser beam transfer are two types of microwave energy transfer. These strategies will be explored further down.

1) *Microwave energy Transfer analysis:* This technology allows for a large range to be achieved. For efficient wireless power transmission, it uses microwave rays. The travelling wave tube (TWT), klystron, and magnetron are the most popular microwave transmitters. The TWT is too costly and power-restraining, rendering it unsuitable for transmitting power. The klystron has long been the preferred for the conversion of DC to microwave energy, but it is also quite pricey. Magnetrons are being considered by many researchers as a viable alternative because they are both efficient and inexpensive. The frequency output of a magnetron is not as exact as that of a klystron or TWT, but power transmission is more forgiving of frequency irregularities. Microwaves are the frequency range of choice for transmission in the most recent research and projects. Using current microwave power transmission technologies, an efficiency of 76 percent is feasible. Focused microwaves are crucial for efficient transmission so that the entire energy transferred from the source is incident on the wave gathering device. Because of the high expenditure on transmitters and receivers, higher frequencies are likewise impracticable.

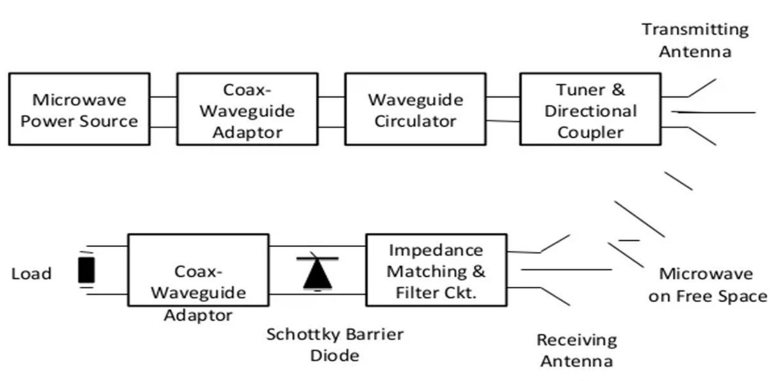

Fig. 10 Schematic block diagram of microwave energy transfer method.

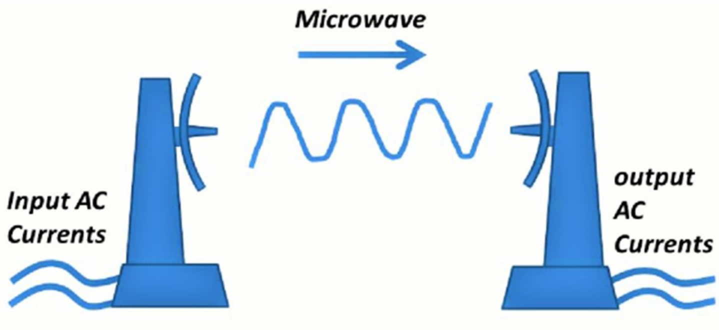

Fig. 11 transmission of power from transmitter to receiver through microwaves

2) *Laser beam transfer analysis:* The laser is used as an efficient technique of wireless transmission in this technology. It is one of the most difficult and difficult to install and administer. A laser is a device that uses optical amplification to create light and relies on the stimulated emission of radiation to do so. Light is coherently emitted by a laser. This spatial coherence allows a laser to be focused on a very small area. In order to excite to the transition energy level and de-excite to lower(stable) energy levels, laser radiation is dependent on the amount of energy received by an atom/molecule. It also determines what kind of electromagnetic rays are produced as a result of the transition. Electrical power is transported by converting electricity into a laser beam that is incident on a solar photovoltaic cell, which absorbs the laser beam's radiation energy and converts it to dc electricity. The power is beamed to the solar photovoltaic cell in the form of radiation in this approach, which is known as " power beaming." The laser beam transfer method offers several advantages, including the ability to transmit longer distances with a small beam cross-section, low power losses owing to the laser beam, compact size, and no electromagnetic interference. The main disadvantage is that solar cell efficiency is low, ranging between 40% and 50%. The conversion of laser light to electricity is inefficient, resulting in increased power losses as heat. It is used in military and aerospace applications and requires a direct line of sight. Good galvanic isolation, high power transmission rate of up to several kilowatts suitable for a wide range of applications, from low-power smartphones to high-power electric vehicles. The desire to remotely power unmanned aerial vehicles (UAVs), satellites, and other transportable electrical facilities has fueled research. The fundamental issue limiting the high intensity laser power beam (HILPB) technology is its low overall efficiency. From a power conversion standpoint, the efficiency of the lasers and PV array are the key limiting considerations for the HILPB system.

Fig. 12 Demonstration of Laser beam transfer method

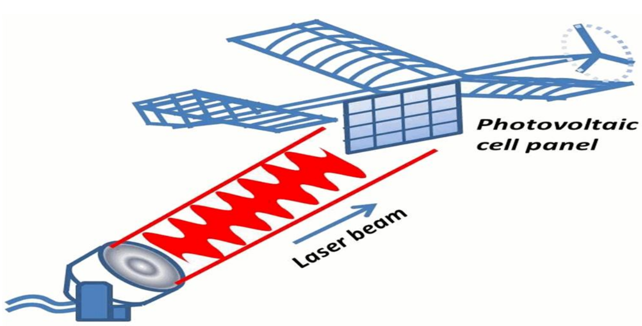

Fig. 13 wireless power transmission from the transmitter to the solar photovoltaic cell of the solar satellite through laser beam

IV. INVENTION AND EXPERIMENTS ANALYSIS

A. *Wireless Power Transmission using Rectenna*

The wireless power can be sent to sensors that are powered by electricity. A rectenna receives and rectifies a radio wave to direct current using an antenna and a rectifying circuit with diodes. The theoretical efficiency of radio frequency (RF) and DC conversion is 100%. The ZigBee sensor is a battery-free wireless sensor. A coordinator, router, and end device are all configured on the ZigBee network. The application distance is less than 5 meters. The efficiency of RF-DC conversion is roughly 60%. The company envisions uses for the wireless sensor in high-temperature conditions (850-1200 C), sensing on rotating or moving objects, and sensing in harsh environments, such as outdoors or in the sea.

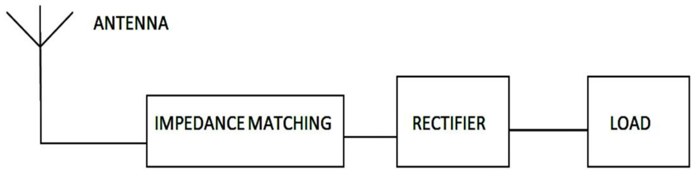

Fig. 14 Block diagram of rectenna circuit.

B. *Wireless Ubiquitous Power Source*

The omnipresence of power source has an added advantage of electrical power transmission to any region bounded within the space. During year 2009 in Japan, an experiment was performed on “Emergency UPS ‘’, There are many research projects involving emergency base stations for mobile phones through balloon or by airship. However, even if a base station for mobile phones is established for emergencies, but without electricity mobile phone cannot be used. So, an emergency UPS system is introduced for rapid and periodic recovery of electricity by wireless power. In the experiment, a mobile phone was charged using only wireless power from an airship. But later, metalized rooms are used instead for effective power transmission. The Metalized room with sustaining electromagnetic waves that reverberates all around the room provides wireless power to any device which is placed inside room. It is a 3-D technology of transferring power wirelessly. Whenever a person enters the room, the electronic gadgets which he is carrying will get charged until and unless he goes out of predefined space. In the figure shown below , when a mobile phone which is an electronic gadget is kept inside a metalized arrangement. It will be charged only when it is placed within the predefined space. Proposed idea: interrelating Ubiquitous power supply with Internet of Thing (IoT) can result in smooth and controlled operation of electronic gadgets wirelessly) .

Fig. 15 Charging of mobile phone inside a closed metallic setup using ubiquitous power supply

V. RECENT RESEARCH

A. *WiTricity*

The intelligent charging pad from WiTricity recognizes foreign or living items, such as a Coke can or the family cat, and shuts down immediately to safeguard you and your vehicle. The new method relies on the use of connected reverberating objects [10]. Two resonant items with the same resonant frequency tend to switch their energy effectively, whilst off-resonant objects interact weakly.

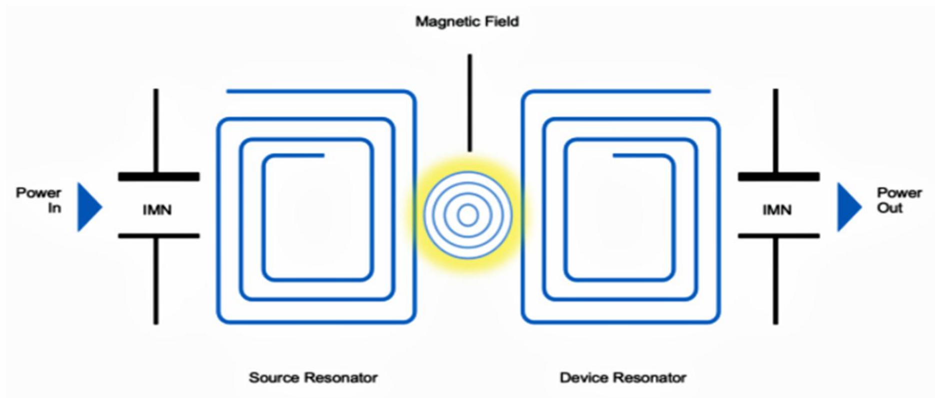

Fig. 16 schematic diagram of wireless mode of power transition using inductive coupling

It's a proprietary EV charging system that can charge an electric vehicle's battery remotely and more effectively. The total solution is magnetic resonance technology. The precisely designed low-loss resonators provide great efficiency as well as reliable operation in a variety of circumstances. When metal, hands, or feet enter the charging area, the easy driver experience is enhanced by advanced foreign object and live object detection, which safely protects and disables charging. Within the same system design, the adaptable system can convert vehicles from low ground clearance sports cars to high ground clearance UV or trucks.

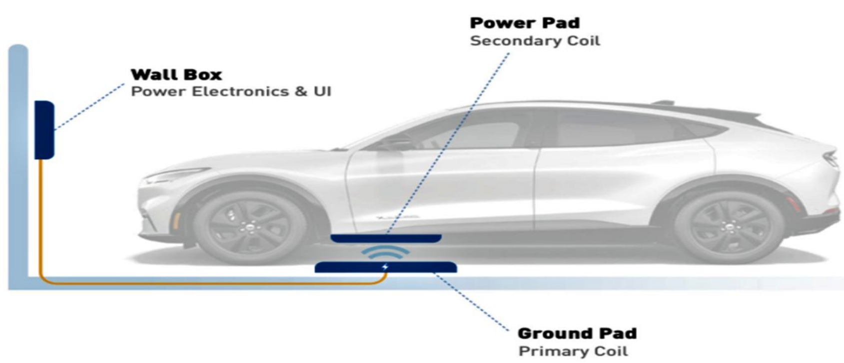

Fig. 17 Charging of EV's using wireless charging pads

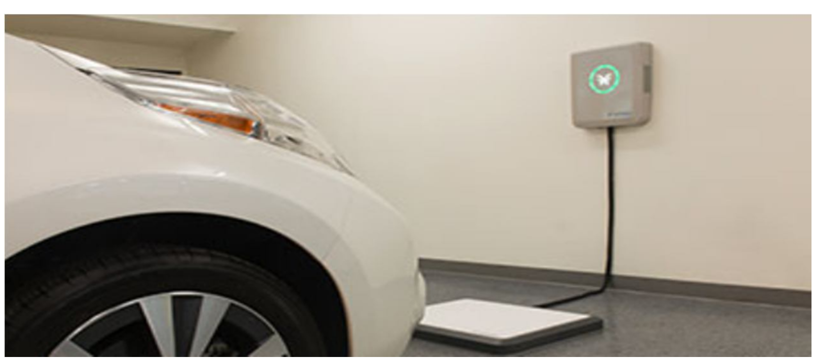

Fig. 18 Design of the wireless charging pads for EV's

B. Dynamic Charging

Because it allows power exchange between the vehicle and the grid while the vehicle is driving, dynamic wireless charging of electric cars (EVs) is becoming a popular approach. In one essential manner, dynamic charging differs from another type of wireless charging, static charge: dynamic charging means that the vehicle is moving. The vehicle parks on top of a charging pad, either in a public venue or at home, with static charging, which is already happening with modified vehicles. The charging lane is put out in a path that is connected as long as the electric vehicle's battery is charging. The car can be disconnected from the charging lane once it has been fully charged. Current electric vehicles with onboard batteries have a maximum range of 300 kilometres, however dynamic wireless charging eliminates range anxiety and allows the battery size to be reduced for the same range. Frequent charging on the road will also allow car manufacturers to reduce the size of batteries, lowering the car's cost while simultaneously extending the battery's lifespan. When batteries are not fully depleted, their condition improves. People do not resonance with the coils, therefore walking on the surface of the charging lane is safe. When a car passes, magnetic debris may be a problem. Short portions of road must be constructed (or renovated) in order to bury the wires beneath the asphalt (or a different material). Some research groups all over the world are looking for better road surface materials that can transmit wireless power. To support dynamic charging, all electric vehicles can be adapted with coils under the car.

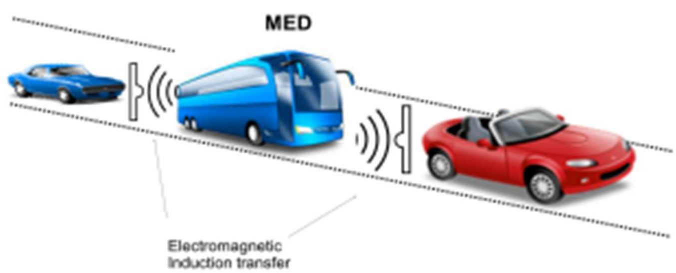

Fig. 19 Dynamic charging of EV’s in charging lane

VI. MERITS AND DEMERITS

A. Merits

The method would lower the cost of electrical energy for consumers while also removing wires, cables, and transmission towers from the landscape. When compared to a standard power system, the system's power loss is small. It has a higher level of stability and is not affected by electromagnetic propagation interference. Low-cost operation and maintenance. There will only be a few private, dispersed receiving stations required. Inexpensive transmission of electrical energy over any terrestrial distance without the use of wires, so the transmission and distribution losses will be nullified effectively, as well as no cable cost, saving energy in the form of coal used to manufacture these cables and protecting the environment from harmful gas emissions emitted during insulation failures and wire faults. The transmission efficiency can be as high as 96 or 97 percent [], and there are almost no losses.

B. Demerits

The frequency of the circulating reactive power was calculated and determined to be quite minimal, which is very biologically friendly. Transmission over extremely vast distances is still a work in progress.

VII. APPLICATIONS

1) Wireless charging of wearable electronic such as watches, air pods, and mobile phones.
2) Wireless sensors which receive electric current from the rectenna (rectifier + antenna) attached to it.
3) Low power applications (µW – several watts) like RFID, satellite communication.
4) Telemetry which is an automatic recording and transmission of data from remote or inaccessible sources to an IT system in a different location for monitoring and analysis.
5) Healthcare and Automotive industries.
6) Stationary charging (Plug-in) EV’s and Dynamic charging EV’s.
7) Power generation using satellites fitted with large solar panels and transmitting that power in the form of microwaves also called a “solar satellite “.is the most demanding application which is under development.

VIII. ECONOMIC ASPECTS

Many countries will profit economically from this wireless power transfer service, according to economic theory. especially in the case of India, this system will be more beneficial. Transmission and distribution losses are at 33% , resulting in significant revenue losses for distribution utilities. This is a revolution in the energy sector, providing increased dependability and efficiency. Fossil fuels are being preserved in large quantities, which helps to minimize greenhouse gas emissions, which in turn helps to lessen global warming. It is also the pattern of rising electricity rates and blackouts, both of which contribute to the country's development in the manufacturing and service sectors. A single resonant energy receiver is required, which may be incorporated into appliances in the future, eliminating the need for a power cord. The use of old-fashioned, fossil-fueled, loss-prone electrified wire-grid delivery systems will be optional.

IX. CONCLUSION

Compared to traditional power transmission, wireless power transmission is a more efficient and dependable means of power transmission. It is a potential future technology that will fundamentally transform the global energy system. Regardless, the entire history of wireless power transmission technology, which dates back to the time of Tesla, is examined, as well as wireless power transmission concepts. The available ways in this system are briefly outlined.

X. ACKNOWLEDGMENTS

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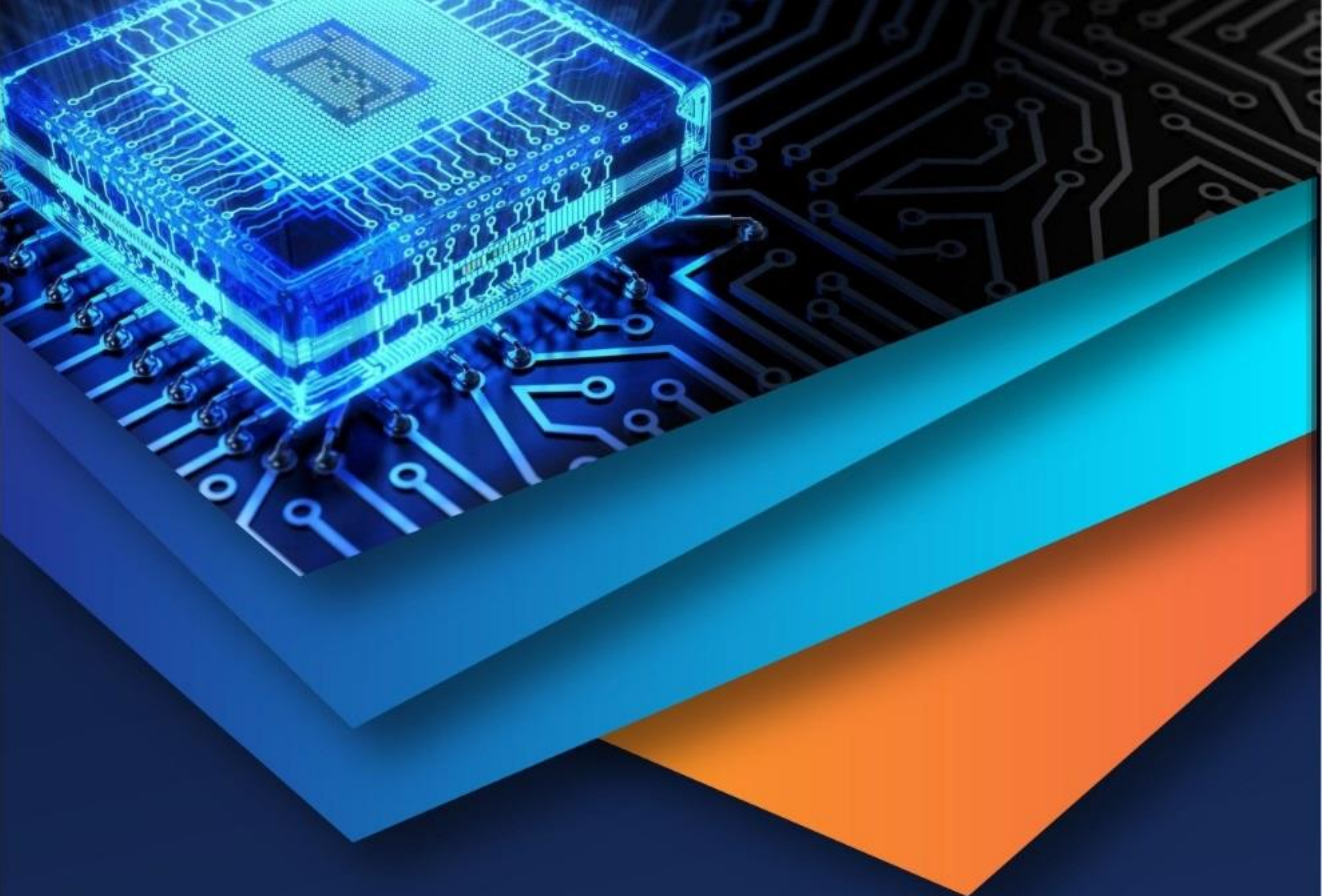

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