A New Mechanism of Dynamic Wireless charging for hybrid Electric Vehicles- Requirement of Electronic Era

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Abstract-

In this paper, the work has been done to analyze the idea of transmitting power wirelessly to Hybrid Electric Vehicles (HEVs) while they are in motion. This research depicts Wireless Power Transfer (WPT) as a mechanism which has the ability of Dynamic Wireless Charging. This reduces the dependence on foreign oil and rare materials used in the batteries. This relieves range anxiety and adds on convenience and freedom of positioning the device with respect to the source. This adaptive technique provides flexibility in device charging era. The research conducted here depicts a vast revolutionary change in the field of Electronics and Communications. Latest tools and analytical perspectives available are used to simulate the results.

Keywords-

Hybrid electric vehicles; Wireless power transfer; Dynamic resonant charging; Impedance matching network

I. Introduction

This research explores the advances in Wireless Power Technology emerged by the use of highly resonant wireless power transfer. The idea of transferring power through wireless medium has been around for over a century but the vision of wirelessly disturbing power to hybrid electronic vehicles in motion has now become of great importance. Referring to the awareness about the exhausting rate of our natural resources, it has become mandatory to use electricity as a replacement for the same. Now days a lot of electric vehicles have been introduced in India as well as in foreign countries and the charging of these vehicles is supported through physical media. But the idea of this research is to conduct a wireless media for Dynamic Power Transfer in case the vehicle is in motion, for parked vehicles, and eventually to highway charging while driving.

II. Concept behind Inductive Charging

It is possible to transfer energy using non-radiative fields. For instance, consider the example of a transformer, the operation of which can be viewed as form of wireless power transfer since it uses the principle of Magnetic Induction to transfer power from primary to secondary coil without any direct electrical connection. However, in those systems, for the operation to take place efficiently, the primary and secondary coils must be must located close to each other and carefully positioned with respect to one another [1]. But now for having freedom in positioning the primary coil (source) and secondary coil (device) relative to each other.

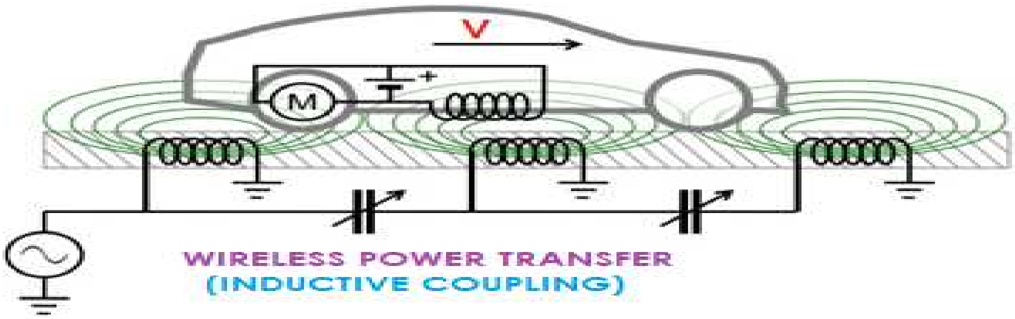


Figure: 1 Wireless Power Transfer Concept

The technique which came forward, allowing wireless transmission of power at mid-range or large range is a non-radiative approach. This approach uses resonance to transfer energy more efficiently. The resonators of high quality factor enhance the efficiency of power transfer at lower rates of coupling, i.e. at larger distances and hence this approach is also referred to as "Highly Resonant Wireless Power Transfer" as depicted in figure 1. So by the introduction of magnetic resonance or induction, wireless energy transmission is possible in a wide range of applications which were not possible before.

System Demonstration

In this section, the external architecture shall be discussed.

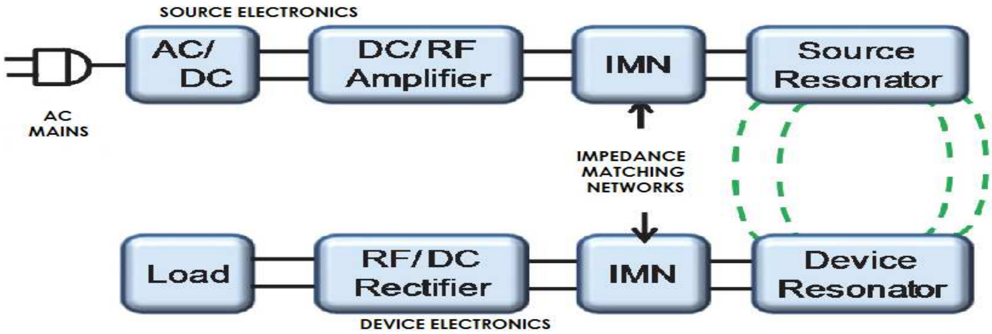


Figure: 2 External Architecture of WPT

As shown in the figure 2, the supply power for this system is either the wall power i.e. AC mains which is then converted to DC by AC/DC Rectifier block or it can be a DC voltage direct from battery or some other DC supply. However, a power factor correction stage may also be required in High Power Applications. Progressing to drive the source resonator, a high efficiency switching amplifier to convert DC voltage to a RF voltage waveform is used.An Impedance Matching Network (IMN) is used to couple the output of amplifier with the source resonator [2]. It serves to transform the source resonator impedance loaded by the inductive coupling to the device resonator and the output load. The magnetic field produced by the source resonator excites the device resonator and causes the energy to build in it and this energy, by coupling out of the device resonator can now be used to perform the work such as charging a battery or directly transferring power to the load.

III. Analytical Approach

The whole system can be viewed as a coupling coil system, see figure 3, where loosely coupled resonant mode transformers have the capability to accomplish this. The idea is to transfer large power levels to Hybrid Electric Vehicles (HEVs) in the near future. The magnetic field generated by the inductive coupling is the “Wireless Power” required to be transmitted [3].

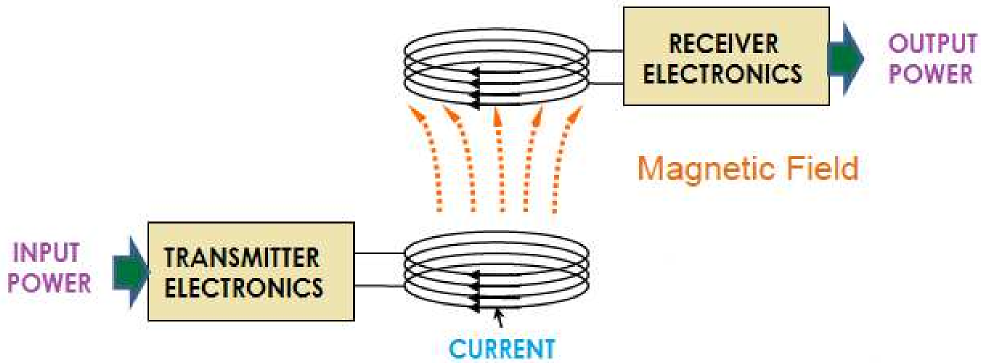


Figure: 3 Coupling Coil Systems

Formulations:-

When two resonator systems are placed in proximity with respect to each other, such that there establishes coupling between them, then it becomes possible for these systems to exchange energy. One such circuit is a series resonant circuit as shown in figure 4. The voltage source demonstrated above generates sinusoidal waveform of amplitude Vg and frequency, ω [4]. The source and device coils are represented with Ls and Ld respectivelyand the mutual inductance by M.

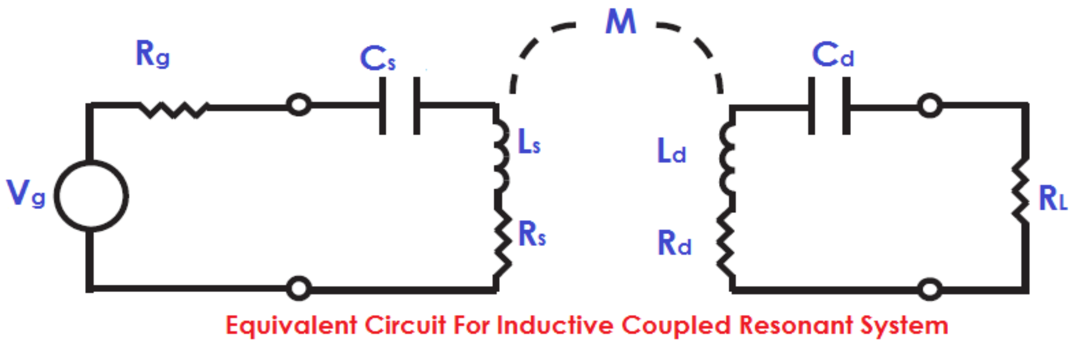


Figure: 4 Series Resonant Circuit

$M = k\sqrt{L_s L_d}$ Where k is the energy rate.

Where,

$$\frac{P_L}{P_{g,\max}} = \frac{4 \cdot U^2 \frac{R_g}{R_s} \frac{R_L}{R_d}}{\left[(1 + \frac{R_g}{R_s})(1 + \frac{R_L}{R_d}) + U\right.}$$

$$U = \frac{\omega M}{\sqrt{R_s R_d}} = \frac{\kappa}{\sqrt{\Gamma_s \Gamma_d}} = k\sqrt{Q_s Q_d}$$

Is the **Figure of Merit** for this system.

IV. Main System Characteristics

The schematic representation of WPT as shown in figure 5 requires few considerations as discussed below:

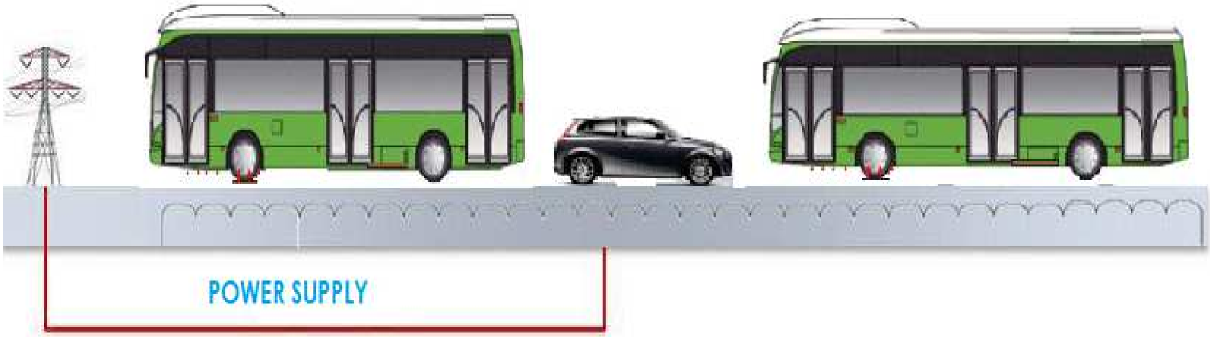
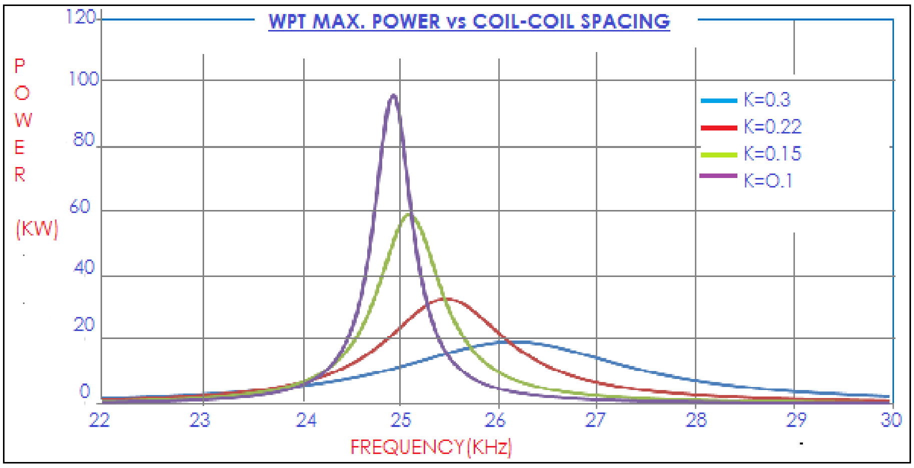


Figure: 5 Schematic Representation of WPT

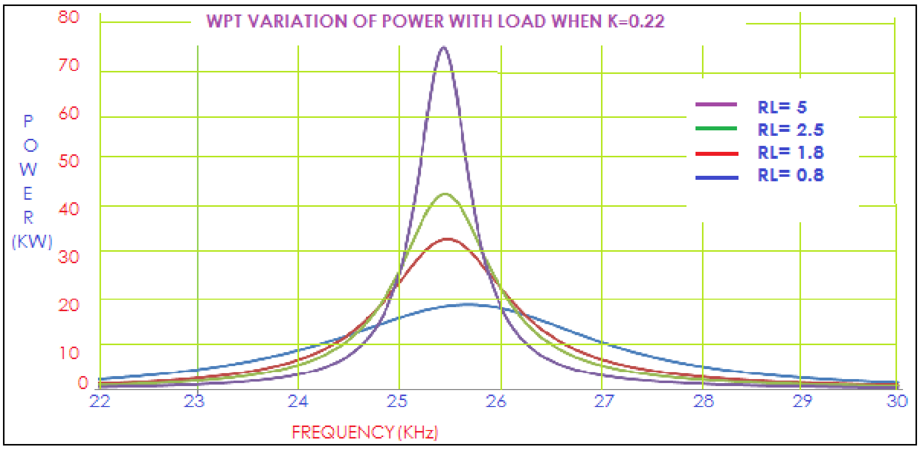
1. A full stretch of road is equipped with the primary coil.
2. Power transfer occurs with an inductive secondary, equipped within the vehicle :
   - Accomplished by a Vehicle Detection System
   - Enabled through a "dynamic" metering and billing solution

3. Maximum power limited to 80KW.

On-road dynamic charging requires dynamic load tracking and an inverter control. The design depends on validated Coefficient of Coupling, Alignment Sensitivity, and coil spacing of WPT System [6][7]. The variations of power with the frequency at different coil spacing and at varying load resistances are shown in graph 6 and graph 7 respectively.



Graph: 1



Graph: 2

Graphs 1 & 2 show Variations of Power with Frequency at Different Coil Spacing and at Varying Load Resistances

V. Future Work

Interconnected communication layer, as depicted in figure 7 above, will enable the private sectors and public interests to co-exist and flourish. Adaptive designs of grid converters and communications would greatly accelerate progress in WPT [8][9]. Additionally, further study in secondary rectification and filtering stages shall be performed by developing deeper understanding of transmitter and receiver coils electromagnetic behavior [10].

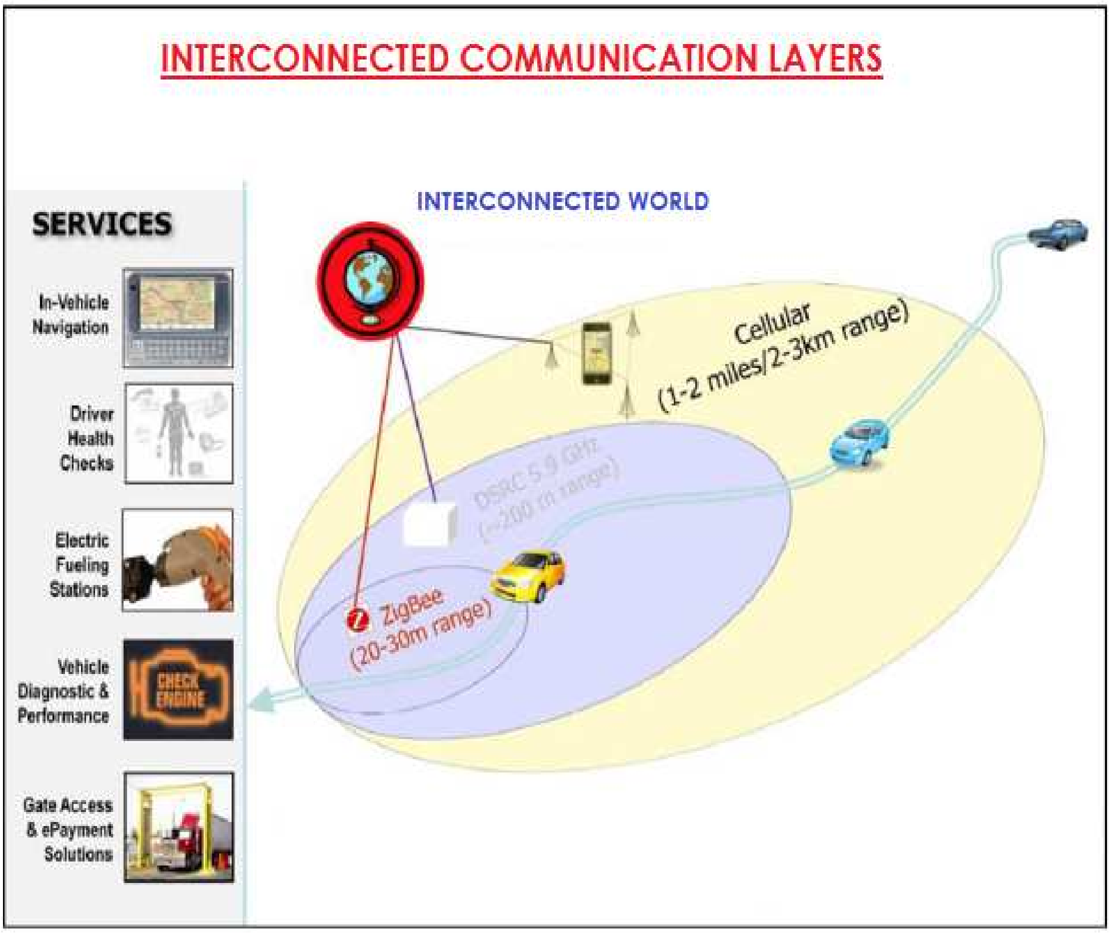


Figure: 7 Interconnected Communication Layers

VI. Conclusions

This technique simplifies the need of efficient transmission of power to hybrid electric vehicles. This wireless transmission of power provides freedom of positioning the source and device with respect to one another. This flexibility enhances the application space of WPT. A single source can be used to transmit large power levels to more than one device as shown in figure 8. Eventually, the distance between the source and the devices can be extended more conveniently by introducing resonant repeaters in between which will enable the energy to hop between them.

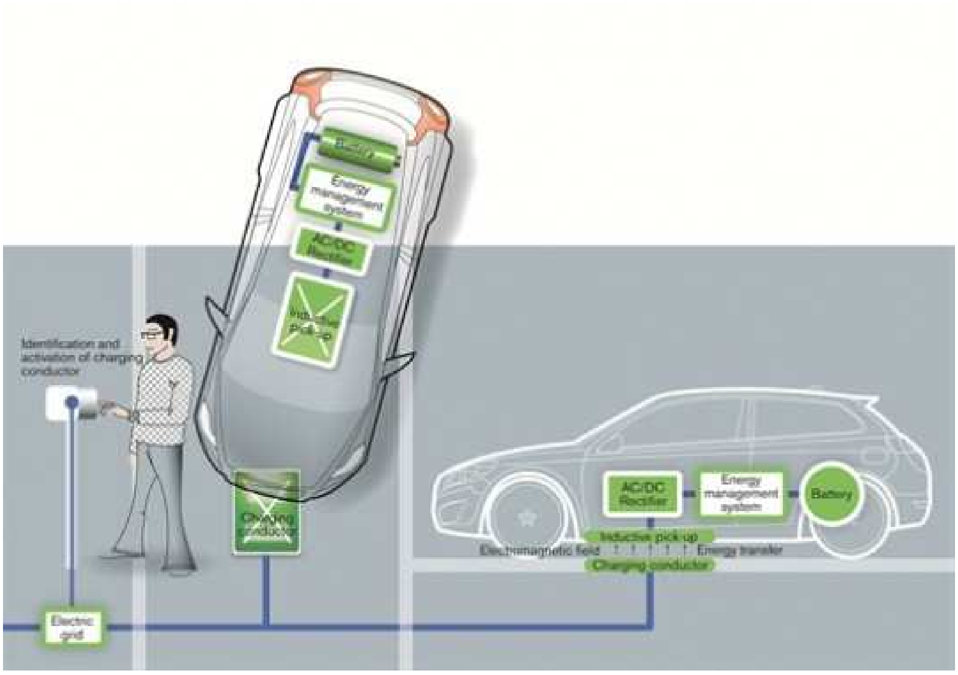


Figure: 8 Power Transmissions to More Than One Vehicle

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