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Recharging Lane for Electric Vehicles

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Abstract:

With the increase of strain on petroleum as a fuel and its adverse contributions for the increasing pollution, it has become mandatory to find out alternatives to traditional IC engine vehicles. Electric vehicles have proven revolutionary in this regard and a perfect substitute for conventional vehicles. However low range, bulky batteries and high recharging time have major drawback for its feasibility and frequent use. This paper introduces the concept of "Recharging lane for Electric vehicles". This concept is based on the use of wireless magnetic resonant coupling for inductive wireless power transfer based on Faradays law of Electromagnetic induction. This paper aims to increase the range of electric vehicle.

***Keywords* — wireless power transfer, magnetic resonant coupling, electric vehicles, mutual inductance.**

I. INTRODUCTION

Electric vehicles have induction motor as a prime mover instead of internal combustion engine. Power required for running the electric motor is obtained from series of batteries stored onboard. Speed control of electric vehicles is much easier as direct connection is given to accelerator to control the frequency of electric charge supplied to motors which governs the rotational speed of motor. As electric vehicles run on electricity, it doesn't produce any exhaust from tailpipe. Limited range and high recharging time are main drawbacks of electric vehicle

Recharging lane aims to increase range of electric vehicles by employing wireless charger integrated in the road. Road will consist of transmitting coil which will be source of primary voltage and current. The cars will be equipped with receiver coil as a source of secondary voltage and current used to recharge the battery, the power transfer between the coils will take place due to mutual inductance by magnetic resonant coupling. This mechanism is same as used in a transformer where the magnetic field is typically confined to high permeability core which also performs the functions when medium between two coils is simply air. Wireless power transfer typically used in wireless mobile phone charger, Electric generators, induction cooking.

QUALCOMM halo, American multinational semiconductor and Telecommunications Equipment Company is testing the real world prototype of recharging lane for dynamic wireless power transfer .

II. PRINCIPLE

Faraday's law of electromagnetic induction

It states that "When a conductor is placed in varying magnetic field, electromotive force is induced also known as induced emf. If the conductor circuit is closed current is also induced current.

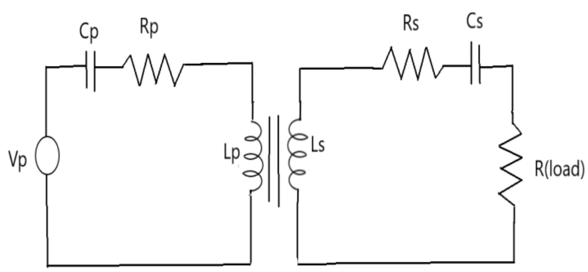
Induced emf is given,

$$E=N\frac{d\emptyset}{dt}$$

This shows that the induced emf is proportional to number of turns and change in magnetic flux. The magnetic flux cut by coil of N turns will be N times as big as that cut by one single wire.

III. MAGNETIC RESONANT COUPLING FOR ELECTRIC VEHICLES

Magnetic inductive charging is a wireless form of charging which uses electromagnetic field for a transfer of energy between two coils through electromagnetic induction. There is essentially a charging station connected to transmitting end. Energy can be transmitted through this transmitting coil and induced in receiving coil through inductive coupling of an electrical device. This energy can be used to charge batteries which are power source of electric vehicle. Induction chargers create an alternating magnetic field from the transmitting coil which is transferred to secondary coil according to Faraday's law of electromagnetic induction. As the secondary coil receives the power from varying magnetic field, it converts it back into electric current which is then stored in the batteries. This arrangement is similar to working of an electrical transformer. The receiving coil can be fitted on portable devices.



In the above circuit diagram
Vp=Input voltage at primary coil
Ip=Current at primary coil.
Cp=Capacitance at primary circuit
Rp=Resistance of primary circuit
Lp=Inductance of primary circuit
Np=Number of turns of primary coil
Vs=Voltage at secondary coil
Is=Current at secondary coil
Cs=Capacitance in secondary circuit
Rs=Resistance of secondary circuit
Lp=Inductance of secondary circuit
Np=Number of turns of secondary coil

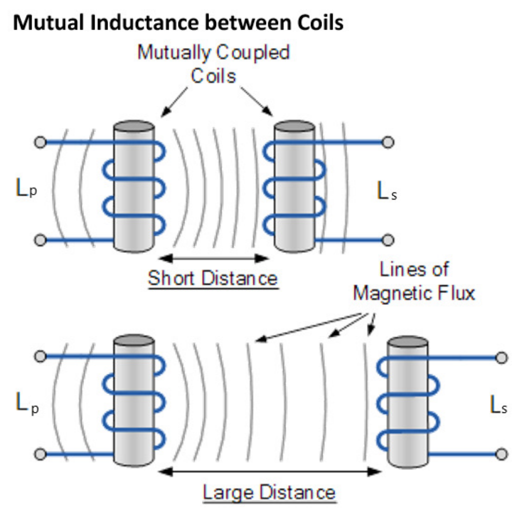
Greater distances of the transmission between sender and receiver coils can be obtained by using resonant inductive coupling. Resonant inductive coupling is a type of inductive coupling where electromagnetic induction or coupling of two coils becomes stronger when the coils resonate. Resonance is a phenomenon that takes place when the frequency at which the force is applied equals to natural frequency of system. In this case, resonance will take place when both the coils will resonate at same frequency that is frequency of receiver coil should be same as transmitter coil.

For resonance, Fp=Fs

Where $F=\frac{1}{2\prod\sqrt{(LC)}}$

Where Fp= Frequency of primary coil
Fs= Frequency of secondary coil

Induced voltage is directly proportional to mutual inductance between two coils



Mathematically, $V=M\frac{dI}{dt}$

As voltage is directly proportional to mutual inductance M, greater the mutual inductance greater will be the voltage induced. Resonant coupling is used for same purpose to increase mutual inductance by strongly coupling the systems at resonant frequency.

$$Lp=\frac{\mu_o \mu_r Np^2 A}{l}$$

$$Ls=\frac{\mu_o \mu_r Ns^2 A}{l}$$

$$M=\sqrt{(Lp * Ls)}$$

Where,

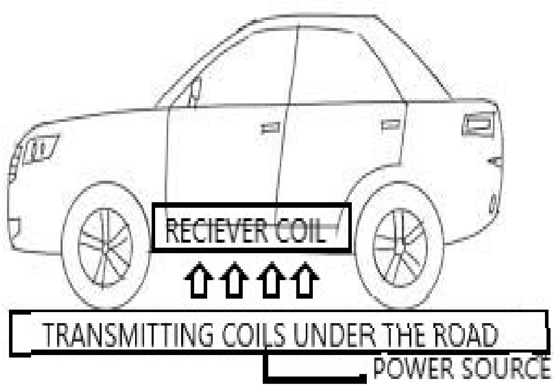
$\mu_o \mu_r$= permeability of material

M= mutual inductance between both the coils

A= area of coil

L= length of coil.

IV. EXPERIMENTAL SETUP



In a following figure it is observed that electric car is fitted with a secondary coil. A set of primary coils are installed inside the road to transmit voltage of 350V at 30kW-hr power. This transmitted power in secondary coil is converted into voltage which is used to store inside a set of Lithium ion batteries .Coils are made up of Copper wire having specified number of turns.

Specification of electric vehicle (Nissan Leaf)

Charging time	7.5 hours
Range	270 km
Voltage	350V
Capacity	40kW-hr
Battery type	Laminated Li-ion

Coil specifications:

Parameters	Primary side	Secondary side
Resistance	1.14 Ω	1.13Ω
Inductance	635µH	634 µH
Capacitance	39991 pF	399970 pF
Resonant frequency	100kHz	100kHz
Outer diameter of coil	450 mm	450 mm
Number of turns	57	57

V. SPEED LIMIT ON RECHARGING LANE

First considering speed of 50kmph

Electric car specifications are:

Total range for 100%= 270km for 100% charge

Therefore, for 1% charge= 2.7km

Total charging time for 100% charge= 7.5hrs

Total charging time for 1% charge= 4.5mins

Now consider the length of recharging lane to be 100km

At speed of 50 kmph total time taken to cover 100km= 2hrs=120mins

Total charging lost after 100 kms = $\frac{100}{2.7}$= 37.03%

Total charging due to recharging lane in 120 mins= $\frac{120}{4.5}$= 26.66%

Final charging after 100 kms(considering initial charging to be 100%= 100-37.03+26.66= 90%

Battery saved due to recharging lane = 26.66%

Increase in range= 26.66* 2.7= 72kms

Now consider speed= 40kmph

Electric car specifications are:

Total range for 100kms= 270km for 100% charge

Therefore for 1% charge= 2.7km

Total charging time for 100% charge= 7.5hrs

Total charging time for 1% charge= 4.5mins

Now consider the length of recharging lane to be 100km

At speed of 40 kmph total time taken to cover 100km= 2.5hrs=150mins

Total charging lost after 100 kms = 37.03%

Total charging due to recharging lane in 150 mins = 33.33%

Final charging after 100 kms (considering initial charging to be 100%= 100-37.03+33.33= 97%

Battery saved due to recharging lane = 33.33%

Increase in range= 33.33* 2.7= 90kms

Hence it is observed that as speed decreases the range increases, the speed limit should be up to 50kmph.

VI. LOSSES IN WPT SYSTEMS

Though the power can be transmitted to an electric car in dynamic condition, but wireless transfer is less efficient than wired charging due to transformer losses that occur during power transfer which are as follows

1. Core losses: They are the hysteresis loss and eddy
   - Hysteresis losses: it occurs due to reversal of magnetization of transformer core. IT depends upon frequency of reversal and flux density.
   - Eddy current losses: When AC current is supplied in primary winding, it generates alternating magnetic flux which produces induced emf. However this induced emf may get transferred to some other steel parts. This induced emf causes circulatory currents which may cause energy loss due to heat.
2. Copper losses: It is loss of energy due to resistance offered by transmitting coils and receiving coils.

VII. SAFETY PRECAUTIONS

The voltages at which an electric vehicle runs can be highly dangerous. Therefore some safety measures should be taken in order to ensure the safeguard of the passengers. The high voltage circuitry should be isolated from the chassis or any other conductor directly in touch. The ground coils should be given a protective layer of net or any conducting material to avoid its breakage. Proper earthing should be provided to all the circuits.

VIII. CONCLUSIONS

Using the said technology we have studied how the application of Faraday's Law of electromagnetic induction can be used and applied to charge electric vehicles. Wireless Power transfer for electric vehicles not only decreases the problem of recharging the electric vehicles for long hours but also helps to increase the range of vehicle when they are on the go. Electric vehicles are one of the best substitutes for the conventional vehicle running on petroleum as a fuel. WPT systems not only help to increase the range of electric vehicles but also can help to reduce the weight of batteries used. This project implied on a large scale can be very useful for the mankind. The ever increasing pollution in which exhaust from cars being the major contributor can be checked to a certain extent. Electric vehicles not only help to reduce the air pollution but their silent working mechanism helps to reduce noise pollution. After the implementation of this project, we can hope to see the use of electric vehicle to be more predominant.

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