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WIRELESS TRANSMISSION OF ELECTRICITY USING MAGNETIC COUPLING IN HYBRID VEHICLE

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Abstract – *This Paper throws light on the modification of the existing wired charging system of the hybrid electric vehicle. The Hybrid Electric Vehicle is the key technology towards the pollution free environment as the existing gasoline system vehicles are the main cause of greenhouse gases. The existing wired charging system has the limitations such as expensive, inconvenient, hazardous and efficiency furthermore consumer do not prefer the plugin charging system for vehicle because of charging related issues. The basic principle of magnetic resonant coupling is implemented to transmit power from the transmitter coil to the receiver coil, controlled by the driving circuit which is switched ON and OFF by detecting the presence of the vehicle. The limitations of the wired charging system are overcome and a maximum efficiency can be obtained.*

Key Words: hybrid electric vehicle, magnetic resonant coupling, wired charging system, driving circuit

1. INTRODUCTION

If you are using an electronic device perhaps a mobile phone and you need to recharge the battery then you will probably have to get a charger and connect the phone to the wire. But what if you could charge it without having to connect it to wire? Meaning power will be transferred wirelessly. This is possible through a concept called Wireless Power Transmission. Research and studies have been done ever since the 19th century but it is only recently that this concept has begun to be implemented. Currently engineers are trying to discover how to increase the efficiency of power transmitted wirelessly and also methods that that are safe to human beings and the environment and notwithstanding, methods that are cheaper and hence can be commercially viable. Though still in the early stages, several electronic companies are beginning to roll out devices that can wirelessly transmit power.

Wireless power transmission (WPT) is based on the principles of electromagnetic induction, Magnetic resonant coupling and Microwave Power Transmission. Electromagnetic induction works on the concept of a primary coil generating a predominantly magnetic field and a secondary coil being within that field so a current is induced within its coils. This causes the relatively short range due to the amount of power required to produce an electromagnetic field.

Microwave power transmission is more efficient method works on the transmission of electromagnetic waves at frequency ranging from 1 GHz to 40 GHz and wavelength from 1mm to 1m. The electrical energy is converted into microwaves using microwave generator and transmitted to longer distances. As electromagnetic waves are hazardous for humans this method is not preferred.

The idea behind the Magnetic resonant coupled wireless power transfer system is to exchange energy efficiently by creating a strong magnetic coupling between to object that are tuned to resonate at the same frequency. This phenomenon occurs between the current carrying coils through their varying or oscillating magnetic fields.

The project seeks to eliminate the use of wires in the transmission of power from the source to the device to be powered. Although WPT is based on electromagnetic induction, there are various methods that are used. Some are less efficient than others and costly while others don't allow for a longer range of transmission. In this project, it is required to design and construct an electronic device that shall transmit power within a Medium range so Magnetic resonant coupling is implemented. This device can then be used to charge batteries for Hybrid electric vehicle. Hence this suitable method will be used to ensure that enough power is transmitted wirelessly so that it can then charge batteries.

2. THEORY

Inductive or magnetic coupling works on the principle of Electromagnetism. When a wire is proximity to a magnetic field, it induces a magnetic field in that wire. Transferring energy between wires through magnetic fields is inductive coupling.

Magnetic resonant coupling uses the same principles as Inductive coupling, but it uses resonance to increase the range at which the energy transfer can efficiently take place. Resonance can be two types: (a) series resonance & (b) Parallel resonance. In these both types of resonance, the principle of obtaining maximum energy is same but the methods are quite different.

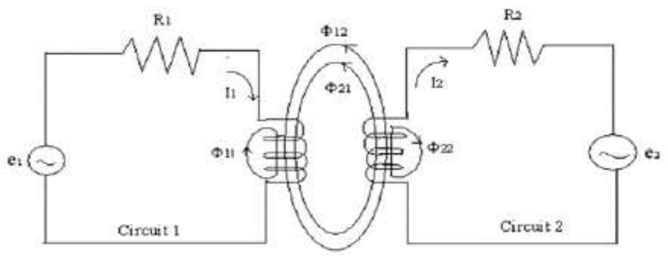

Fig -1: Magnetic coupling with four component fluxes

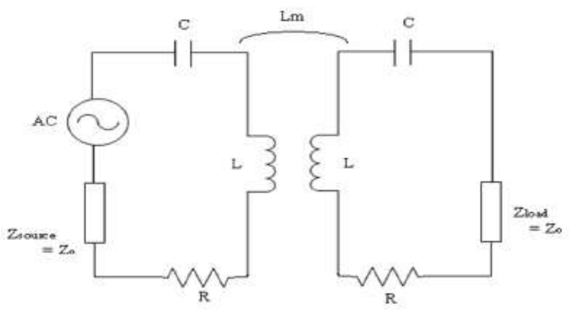

Fig -2: Equivalent circuit of Magnetic Resonant Coupling

Quality factor (Q-factor) is a dimensionless parameter That describes the characteristic of an oscillator or resonator, or equivalently, characterizes a resonator's bandwidth relative to its center frequency. Higher Q indicates a lower rate of energy loss relative to the stored energy of the oscillator; the oscillations die out more slowly. Q factor determines the qualitative behavior of simple damped oscillators. A system with low quality factor ($Q<0.5$) is said to be over damped. Such a system does not oscillate at all, but when displaced from its equilibrium steady state output, it returns to it by exponential decay, approaching the steady state value asymptotically. System with high quality factor ($Q>0.5$) is said to be underdamped. Underdamped systems combine oscillation at a specific frequency with decay of the amplitude of the signal. A system with an intermediate quality factor ($Q=0.5$) is said to be critically damped. Like an over damped system, the output does not oscillate, an does not overshoot its steady-state output. Like an underdamped response, the output of such a system responds quickly to a unit step input. The efficiency of the coupled system depends on how much energy is transferred from the transmitted to the receiver circuit.

$$\eta_{energy} = \frac{\text{Max.Reciever Energy}}{\text{Max.Transmitter Energy}}$$

The maximum energy found on the transmitted Max. Transmitter Energy ($E_{Transmitter.max}$) is the amount of energy initially put on the input capacitor Ct by the voltage source V_0.

$$E_{Transmitter.max} \approx E_{init} = \frac{1}{2} C_t (V_{in})^2$$

Where V_{in} is the voltage of C_t at time t=0, during positive pulse duration Ct acts like a voltage source and completes a series loop with the transmitter elements, R_t ,L_t ,C_t.

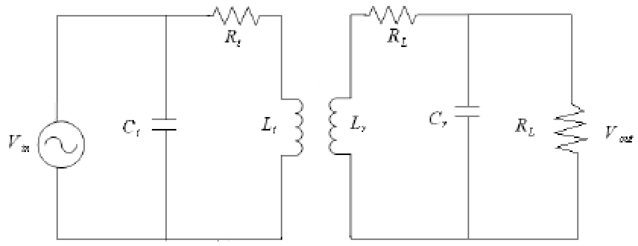

Fig -3: Resonant Wireless Power transfer Circuit diagram

The maximum energy transferred to the receiver is only a fraction of input energy. The energy found is receiver circuit is:

$$E_{Reciever} = \frac{1}{2} Lr\,(I_r)^2 + \frac{1}{2} C_r\,(V_{cr})^2$$

At maximum voltage level on receiver circuit, current becomes zero and no current flows the circuit. At this point energy stored in receiver inductor is zero because current is zero. Thus, maximized receiver energy is:

$$E_{Transmitter.max} = \frac{1}{2} C_r (V_{out.Max})^2$$

3. METHODOLOGY

The general principle of operation was designed using Magnetic coupling and ensuring that the power transfer was as efficient as possible and the transfer within the near field. The design also ensured for purposes of versatility and optimization the battery charging circuit was energy efficient and prevented losses.

The circuit was divided into two sections:

a.) Transmitter Circuit
b.) Receiver Circuit

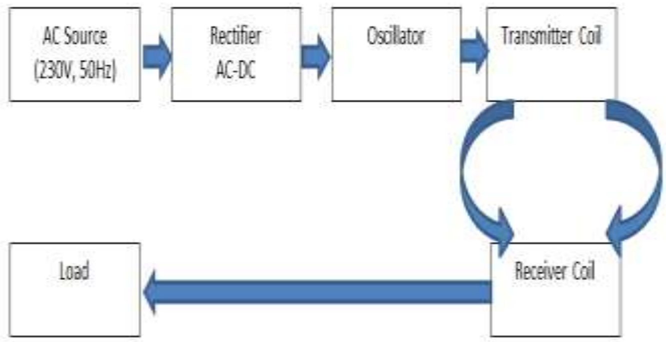

Fig -4: Block Diagram

The input power to the system is AC (230V, 50Hz) which is converted into a DC Power with the help of Rectifier. The oscillator is connected with a rectifier as an input and at the output side the Transmitter coil is in turn coupled resonant magnetically to a Receiver coil. The coils are made up of the high conducting materials such as copper. With the help of the oscillator an oscillating signal of resonant frequency is generated and passed through the transmitter coil, it generates an oscillating magnetic field. The receiver coil tuned at the same resonant frequency receives the power through the Magnetic field generated by the transmitter coil.

4. BATTERY CHARGING SYSTEM OF VEHICLE

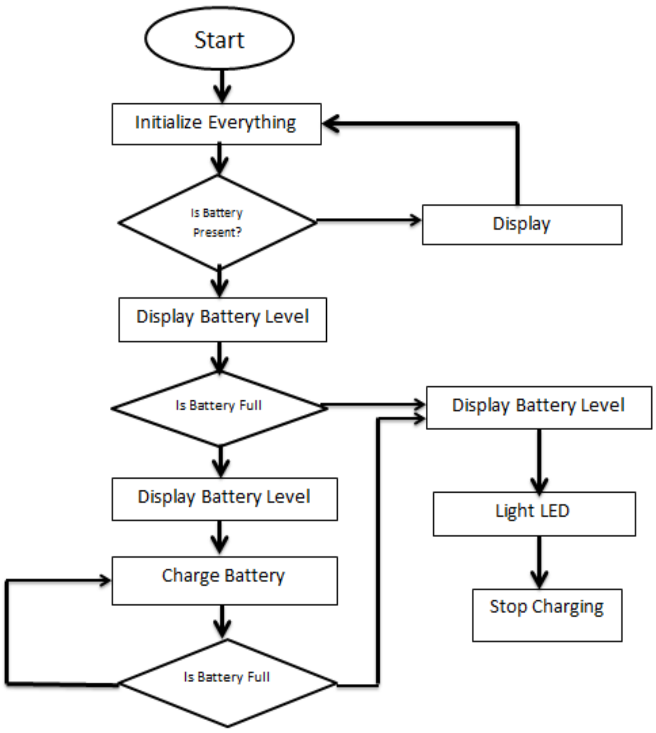

Chart -1: Flow chart

The battery charging circuit consisted of the rectifier which converted the ac power to dc, a microcontroller, a 16X2 LCD and a CD4066 switch. This part was largely controlled by the microcontroller. Initially a relay was used as the switch once the battery is full. However it was drawing more current and thus acted as load. The CD4066 became a better alternative as it consumed less current and also was less bulky as compared to the single channel relay. One of the challenges with modern chargers is that once charging is complete; there is no notification to the user to stop the charging. To solve this; a tripping command is given by the microcontroller and the battery charge is full, is displayed on the LCD. An RGB LED was instead used. Its operation was coded and loaded to the microcontroller. It was observed that, once the battery started charging it heavily loaded the rectifier voltage and caused it to drop significantly. The battery internal resistance is suspected to be the major cause of this.

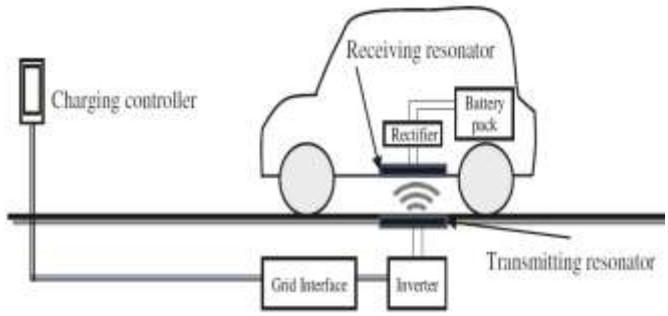

Fig -5: Battery charging system of vehicle

5. CONCLUSIONS

An electronic device that wirelessly transmits power and then charges batteries was developed. We were able to design discrete components such as the oscillator, coils and a full bridge voltage rectifier for the system design process.

Conclusions that were drawn from the project study are as follows:

1. Based on the theory of wireless charging via Magnetic Resonance coupling, which was the method used in the project, it was seen that various aspects i.e. distance, resonant frequency, quality factor; coil turns ratio determine the efficiency of WPT.

2. With This method the State of Health (SOH) and State of Charge (SOC) is also Monitored and Maintained

3. It can also be concluded that WPT can be used in other applications. In the project we were able to charge a 9V battery from power that was transmitted wirelessly.

4. Lastly, we can conclude Magnetic Resonance Coupling method of WPT is more convenient and efficient for the charging system of Hybrid Electric Vehicles.

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