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Wireless Power Transfer System for Moving Vehicles Using Magnetic Resonance

Amal Mathew[1], Athul P[2], Shijimol T S[3], Yeldo Pailo[4], Prof. Haritha Viji[5],

Prof. Emmanuel Babu P[6]

[1,2,3,4]*Student, Dept. of Electrical and Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India*
[5,6]*Assistant Professor, Dept. of Electrical and Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India*

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Abstract - *Modern Electric Vehicles have a drawback of long charging time, bulk battery packs, short lifetime etc. This can be rectified by using dynamic wireless charging. The paper discusses about the dynamic wireless charging and its prototype. Dynamic wireless charging uses magnetic resonance for transmitting power. AC power from grid is converted to DC using a rectifier, this DC is then converted to high frequency AC using a power inverter. This high frequency AC is supplied to transmitting coils laid under the road. This high frequency AC produces resonating magnetic field on the transmitting coil. The receiving-end coil under the electric vehicle picks up the magnetic field and the induced emf is supplied to a rectifier. The rectified output is given to motor and battery on the vehicle. This method is an efficient approach to provide charging plans for electric vehicles from a global point of view, without overloading of electric system and reduce the charging time.*

Key Words: **Electric Vehicle(EV), Metal Oxide Semiconductor Field Effect Transistor(MOSFET), Pulse Width Modulation(PWM), Wireless Power Transfer(WPT)**

1. INTRODUCTION

Electric vehicles differ from fossil fuel-powered vehicles in sense that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power and renewable sources such as tidal power, solar power and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, wireless energy transfer such as inductive charging, or a direct connection through an electrical cable. The electricity may then be stored onboard the vehicle using a battery, flywheel, or super-capacitors. Vehicles making use of combustion engine can only derive their energy from a single or a few sources, usually non-renewable fossil fuels. A key advantage of electric or hybrid electric vehicles is regenerative braking and suspension, their ability to recover energy normally lost during braking as electricity to be restored to the on-board battery. However, EVs are highly depended on the external energy support.

In recent years, there has been many advanced developments on Electric Vehicles (EV). Many automobile manufactures has come forward to make the eco-friendly transportation system. Governments of many countries provides subsidy and tax incentives for these transportations. But the battery capacity, battery life, range of the vehicle are the fields that requires improvement. Nowadays, wireless power supply devices which supply electric power wirelessly (in the medium of air) to apparatuses without power cables have come to be in practical use. Wireless power transfer (WPT) is a breakthrough technology that provides energy to communication devices without the power units. With the remarkable progress being made recently, this technology has been attracting a lot of attention of scientists and R&D firms around the world. Recently, the usage of mobile appliances such as cell phones, PDAs, laptops, tablets, and other handheld gadgets, equipped with rechargeable batteries has been widely spreading. It is known that electromagnetic energy is associated with the propagation of electromagnetic waves. Theoretically, all electromagnetic waves can be used for wireless power transmission (WPT). The difference between the WPT and communication systems is only efficiency. The transmitted energy in a communication system, the transmitted energy is diffused to all directions. Though the received power is enough for a transmission of information, the efficiency from the transmitter to receiver is quiet low. By using the same technology for EVs, then the vehicles can charge the battery on run and this increases the range of travel, decrease in charging time etc.

In this paper, the dynamic power transfer system for moving EVs based on the WPT is discussed.

2. PROPOSED SYSTEM

2.1 Construction

The system mainly consists of a AC-DC converter, a high frequency inverter, transmitting coil, receiving coil. The transmitting coil is placed on the road. The receiving coil is fixed under the vehicle. When the vehicle is in motion the transmitting coil fixed on the road generates alternating magnetic field and when EV passes over the transmitting coil, the receiver coil on the bottom the vehicle gets coupled with the alternating magnetic flux produced by the transmitting coil. This induces an emf on the receiving coil. This emf can be used for charging battery.

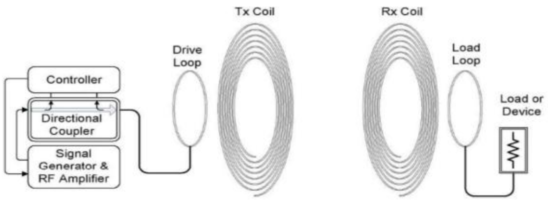

Fig. 1. System Construction

2.2 Working

AC supply from grid is supplied to the AC-DC converter. The DC voltage produced is supplied to high frequency inverter which produces AC voltage with a frequency in the range of 70kHz-75kHz. The high frequency AC is given to the transmitting coil. The high frequency on the coil produces alternating magnetic flux around the coil.

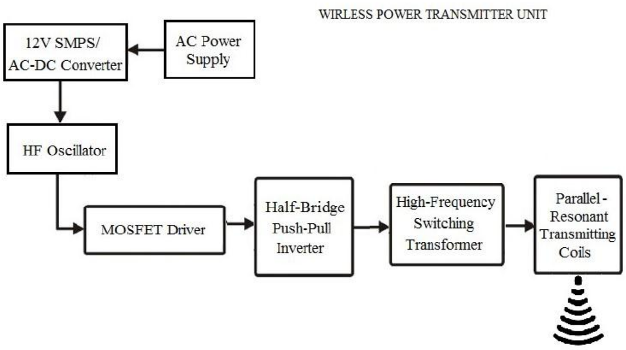

Fig. 2. Transmitter System

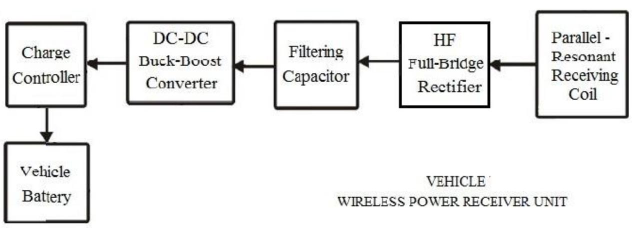

Fig. 3. Receiver System

When the receiving coil gets aligned with the transmitting coil, the flux induces an emf on the receiving coil. This emf is rectified and is used to charge the onboard battery.

3. SYSTEM CIRCUIT

High Frequency oscillator is designed using SG3525 IC. The IC circuit generates PWM switching pulses for driving the MOSFETs. Here the frequency of the oscillator set at 6kHz. High frequency converter consists of a high frequency oscillator which generates PWM pulses and drives the MOSFETs. Here PWM pulses PWM1 and PWM2 are produced and supplied to the MOSFETs gate.

The High Frequency Transformer is a center tapped transformer used for DC isolation.

The resonant transmitter antenna is designed with windings of copper coils which convert the high frequency oscillating electrical current into Electromagnetic waves resonating at a particular frequency.

The resonant receiver antenna receives electromagnetic waves from the transmitter antenna and converts into high frequency electrical output.

Antenna matching Network: It matches the oscillator frequency to the antenna frequency to maintain resonance tuning of the receiver and transmitter.

High Frequency rectifier consists of fast switching rectifier diodes which converts HF voltage into DC voltage and filters the output voltage which is utilized by the vehicle motor.

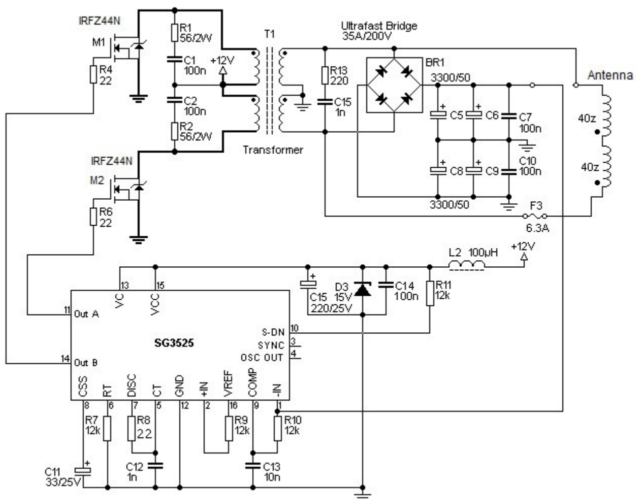

Fig. 4. Circuit Diagram

Two MOSFETs IRFZ44N is used in the half bridge PWM inverter. To produce the PWM, IC SG3525, a PWM control circuit is used. This oscillator IC is capable of producing two PWM signals in the range of 100Hz to 400kHz.

4. OSCILLATOR FREQUENCY DESIGN

The frequency of PWM is dependent on the timing capacitance and the timing resistance. The timing capacitor (CT) is connected between pin 5 and ground. The timing resistor (RT) is connected between pin 6 and ground. The resistance between pins 5 and 7 (RD) determines the deadtime (and also slightly affects the frequency).

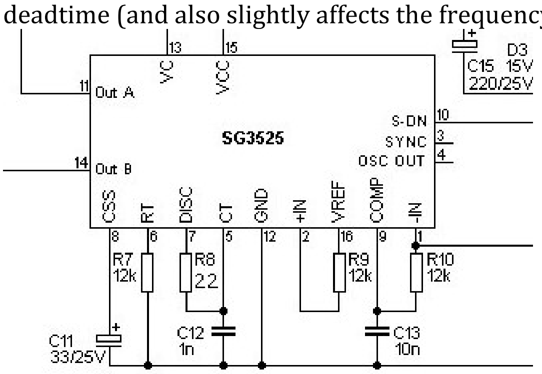

Fig. 5. SG3525 Oscillator

The frequency is related to RT, CT and RD by the relationship:

$$f = \frac{1}{C_T(0.7R_T + 3R_D)}$$

C_T = 1nF
R_T = 12kOhms
R_D = 22Ohms

Therefore,

$$f = \frac{1}{10^{-9}(0.7*12000 + 3*22)}$$

f=118.11kHz

As the oscillator frequency is 118.11kHz, the switching frequency is 0.5 * 118.11kHz = 59.05kHz and this is close enough to the target frequency of 60kHz.

5. SIMULATION RESULT

Simulation of the proposed system of small rating has been done using PSIM.

5.1 Pulse Width Modulation

Analog PWM control requires the generation of both reference and carrier signals that are feed into the comparator and based on some logical output, the final output is generated. The reference signal is the desired signal output, maybe sinusoidal or square wave, while the carrier signal is either a sawtooth or triangular wave at a frequency significantly greater than the reference.

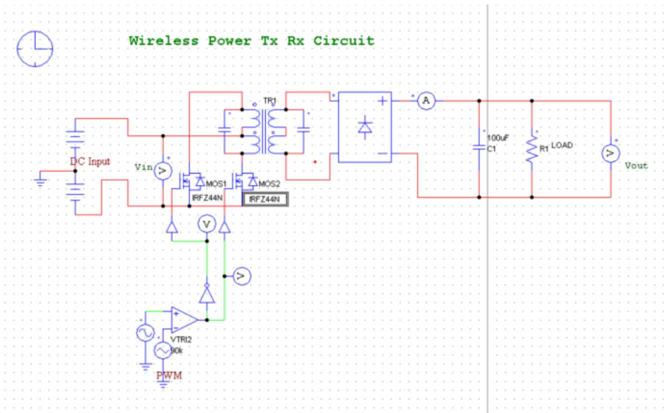

Fig. 6. Simulation Circuit

5.2. Simulated Output

The simulated PWM pulse is shown below in Fig.7 and Fig.8. The comparator circuit generates a triangular wave of amplitude frequency 120 kHz and sine wave of frequency 60 kHz. The generated pulse turns on the MOSFET alternatively and the produced AC voltage is given to the transmitting coil via a High Frequency transformer and then to the receiving coil. For matched resonance the transmitting and the receiving coil must resonates within same frequency range. Selection of appropriate inductance of these coils ensures matched resonance. The parameters of the transmitting and receiving coil is given as equal values. The output voltage at receiving end varies between 18 Volts to 19 Volts.

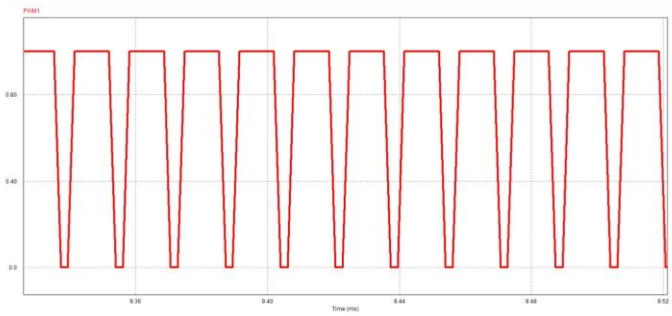

Fig. 7. PWM 1

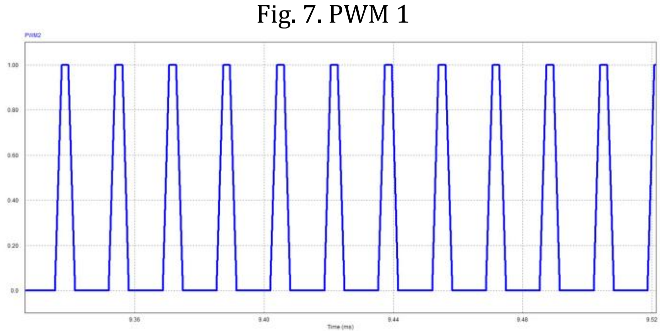

Fig. 8. PWM 2

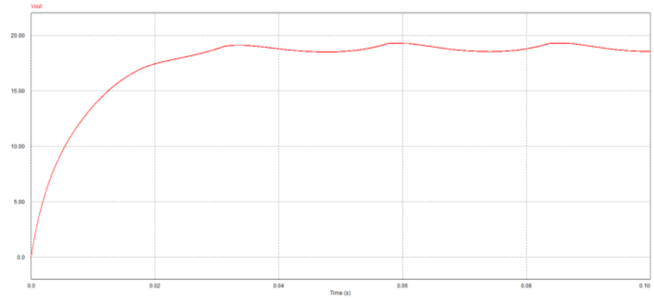

Fig. 9. Output Voltage

6. CONCLUSION

This paper presented an inverter for wireless power transfer for electric vehicles. Dynamic power transfer is not only the most promising alternative for gasoline vehicle but also the most practical approach for the EV. It is clear that vehicle electrification is unavoidable due to environment and energy related issues. In particular, when the roads are electrified with wireless charging capability, it will provide the foundation for mass market penetration for EV regardless of battery technology. The simulation of the inverter is also performed.

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