SMFIR TECHNOLOGY BASED TRANSPORTATION SYSTEM AND APPLICABILITY OF MPPT

Eldhose K A[1], Togis Thomas[2], Thomson P Baby[3], Sujeesh K[4], Sandeep S[5]

[1]*Asst Professor, Dept of. Electrical & Electronics Engineering, Mar Athanasius College of Engineering, Kerala, India*
[2]*UG Student, Dept of. Electrical & Electronics Engineering, Mar Athanasius College of Engineering, Kerala, India*
[3]*UG Student, Dept of. Electrical & Electronics Engineering, Mar Athanasius College of Engineering, Kerala, India*
[4]*UG Student, Dept of. Electrical & Electronics Engineering, Mar Athanasius College of Engineering, Kerala, India*
[5]*UG Student, Dept of. Electrical & Electronics Engineering, Mar Athanasius College of Engineering, Kerala, India*

Abstract

The trend towards electric vehicle is one of the efforts to reduce the consumption of energy and to minimize the negative environmental impact on earth. However, there are several issues to commercialize electric vehicle. The large capacity, weight, expensive price, short life time and charging time of batteries are the most important obstacles. On-Line Electric Vehicle (OLEV) is an innovative electric powered transportation system which remotely picks up electricity from power transmitter buried under ground. The core technology of OLEV is based on SMFIR (Shaped Magnetic Field in Resonance). The input supply frequency is converted to a very high frequency at inverter stage and this high frequency current flow through the power line. The magnetic flux generated from the power lines is gathered at the pick-up module and then rectified. The rectified output energy is stored in a battery and used for driving the motor. OLEV requires only a minimal battery capacity which can consequently minimize the weight and price of vehicle and power station. By improving power supply and pick-up modules the power transfer capability can be extended for driving the train which can even beat maglev. Although OLEV technology is similar to maglev in lack of contact, the two systems use electromagnetic fields in different ways. A magnetic levitation system uses the repulsive force between magnetic flux for motion, whereas OLEV uses magnetic flux, which is converted into electrical energy, to drive motors. The rectified power output in the pickup module can be consider as a variable dc source, like PV cell, because power output will be varied according to the alignment between primary and pick-up module. So by using MPPT algorithm the induced power in the pick-up module can be transfer efficiently to the motor.

Keywords: *On-Line Electric Vehicle, Vertical magnetic flux type, SMFIR technology, Impedance matching, MPPT algorithm. etc*

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1. INTRODUCTION

One of the biggest issues around the world in recent years is environmental problems. Every country tries to adopt green technologies which offer the potential to improve the air quality in currently polluted environment and which will save money by reducing fossil fuel consumption. We already have the technology we need to cure our addiction to oil, stabilize the climate and maintain our standard of living, all at the same time. By transitioning to sustainable technologies, such as solar and wind power, we can achieve energy independence and stabilize human-induced climate change. Increasing transportation efficiency is the best place to start efforts to reduce emissions of carbon dioxide (CO_2), which is a primary culprit in global warming. According to IPCC (Intergovernmental Panel on Climate Change) in the total source distribution of greenhouse gases 50% portion is occupied by the CO_2 gas, which is due to fossil fuel use. So in this situation a method for reducing the CO_2 is of greater importance. Controlling the emission of CO_2 from present transportation system are of little effect since the demand of vehicle is getting incremented day by day. Therefore an alternative energy source for transportation sector apart from internal combustion engine is of greater importance. The transportation with electrified vehicle is the best solution for reducing the global dependence on fossil fuels and emission of greenhouse gases. The transportation sector of our country is depending upon the foreign nations for the fossil fuels. A huge amount of our countries income is spent for the import of petroleum products. Therefore an alternative energy source like electric power is of greater importance for the nation's economic growth. By producing electric power from nation’s available sources a large degree of energy resilience can be achieved. Even though recent developments have been focussed on the development of electric vehicles the commercial deployment of electric vehicles has lagged behind due to technological issues in associated with the battery including: bulky size and weight, low power capacity ,limited range, long recharging time, short life expectancy and high cost, compared to gasoline powered cars within the same range. On-Line Electric Vehicle (OLEV) is an innovative electricity powered transportation system which remotely picks up electricity from power transmitter buried underground by mutual induction. The core technology of OLEV is based on SMFIR (Shaped Magnetic Field in Resonance). The input supply frequency is converted to a very high frequency at inverter stage and these high frequency current flows through the power line. The magnetic flux generated from the power lines is gathered at the pickup module and this is then rectified and stored in a battery. OLEV required only a minimal battery capacity which can consequently minimize the weight and price of vehicle and power station. By improving power supply and pick up modules the power transfer capability can be extended for driving the train which can even beat maglev. About 80% power transfer efficiency can be achieved from a typical OLEV design.

In this paper we describe the energy transfer mechanism using SMFIR technology and application of this technology in transportation sector especially on railway system. We also propose applicability of MPPT algorithm for the efficient transfer of energy, which is obtained using SMFIR technology, from pick-up module to motor.

2. BLOCK DIAGRAM

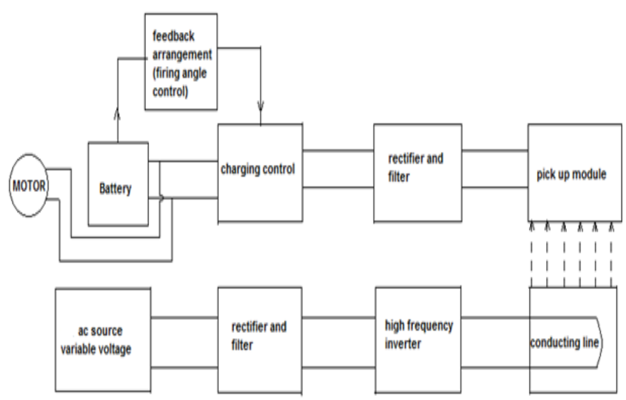

Fig-1: Block diagram of OLEV

The supply to the High frequency inverter is DC which is obtained either from a rectifier and filter stage just before the inverter or from transmitting DC from power house by incorporating rectifier and filter stage in generation stage itself high frequency inverter is the main working component for the occurrence of efficient energy transfer mechanism. For typical design the frequency range of inverter is from 20 to 30Khz.Inverter must be capable of carrying more power, especially current since the flux generation is mainly depending upon the current flowing through the line. According to the current carrying capacity either two conductor cable or single conductor cable can be choose. Single conductor cable is preferred since it reduces the cost. The energy transferred is taking place at resonance and at specific shape of magnetic field. The transferred energy is picked up by the pick-up module which is of E type shape. The pick-up module is incorporated at the beneath of vehicle

The induced voltage is rectified and filtered for driving the DC motor. The capacity of the dc battery is choose based on the rating of the motor which is used for driving. The charge controller circuit will control and protect the battery from the overcharging and deep discharging. An overall efficiency above 80% can be achieved from this mechanism.

3. ENERGY TRANSFER MECHANISM

As already explained, energy transfer mechanism consists of high frequency inverter, power line and pick-up module. The design of power lines and the pickup module are the key technologies for effective power transfer. According to the direction of the magnetic flux at the pick-up module noncontact power transfer can be classified as vertical magnetic flux type and horizontal magnetic flux type.

Fig. 2 shows the vertical and horizontal magnetic flux [1] type of power lines and pickup module. In vertical there are two power lines with opposite current directions underneath the road surface forming a current loop. Due to the current in the power lines, magnetic flux is induced around each power line. Between the power lines, the magnetic fluxes from the two power lines are added. The pickup module catches the vertical magnetic flux through copper coils around the ferrite core. This type has the advantage of efficient power transfer because the direction of the magnetic flux from the power lines is the same as the direction of the flux to the pickup module. Horizontal magnetic flux types are of less efficient as there is no adding of flux in the centre portion.

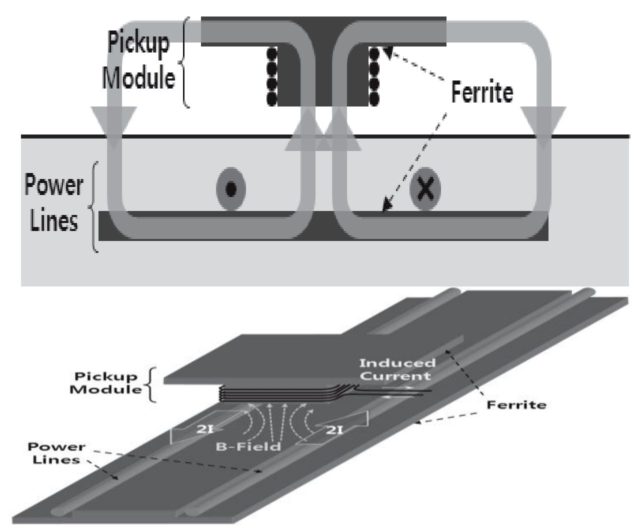

Fig-2: Vertical and Horizontal flux types

4. WIRELESS POWER TRANSFERRED TRAIN

SMFIR technology applied to the electric vehicle system can be extended to train by the improvement of the design. As misalignment problem in OLEV is a major issue this technology will give more efficiency in power transfer if we apply to a railway system.

Wired power transfer type has been generally used for a power transfer. But this type needs much cost of maintenance and has a danger of a disconnection of cables. Also wired power transfer type is not good for a beauty of the city. And the noise from contact is not good for an environment. Especially, wired power transfer type has to pass through a big tunnel because the space of wires is required too. And that situation needs much more money to make a bigger tunnel. By applying WPT [4] to a railway system more efficiency is achieved than an electric vehicle system. In train, continuous energy supply with contactless power transfer between the pick-up coils on the train and the power line underneath the ground. It keeps the vehicle's performance level constant for continuous operation. Efficiency of transferred power can be increased by reducing the air gap because, in the train case possible obstacles are much less than those on a freeway, and the fixed railway ensures the constant and stable power transfer. Although OLEV technology is similar to maglev in lack of contact, the two systems use electromagnetic fields in different ways. Magnetic levitation systems use the repulsive force between magnetic flux for motion, whereas OLEV uses magnetic flux, which is converted into electrical energy, to drive motors. By increasing the number of pick-up module the induced voltage can be increased.

In order to reduce the mount heat loss and also for preventing from energy robbery the power track can be divided into different segments .One powered track is composed of a set of segments with different lengths[3]. One segment is a defined length of powered cable loop, operated with single switching mechanism controlled by the power inverter responding to the vehicle identification sensor when the vehicle is approaching to the segmented cable loop. The length of the segment can be a design variable depending on the road conditions, the vehicle speed, the operating condition of acceleration or deceleration , the presence of heavy traffic volume with possible traffic jams or highways, and the presence of BRT(Bus Rapid Transit) lanes. Upon the identification of vehicle marker, which is incorporated beneath the vehicle, by the vehicle identification sensor that particular track will be switched on.

5. APPLICABILITY OF MPPT

For the effective impedance matching between the solar cell and the load Maximum Power Point Tracking Algorithm (MPPT) is used. Using MPPT algorithm the duty ratio of buck or boost or buck-boost converter is varied. Buck-boost converter is more preferred since it provides greater flexibility. Mainly MPPT algorithms are of 4 types they are Perturb and observe Incremental conductance method, Current sweep method and constant voltage method. Of these Perturb and observe method is the simplest method. Many researches are going in these areas and many of the new MPPT algorithms are the modification of these 4 basic ones.

Fig 3 shows the typical current, powers, voltage characteristics of an RNG-245D solar cell. Different graphs are plotted on the basics of different solar irradiation levels. The black line L1 and L2 shows the load line. From the graph we can see that by shifting the operating point from L1 to L2 (Irradiation level 1000w/m2) more power can be transferred from solar cell to load. At L2 the power is in the peak region. This shifting of operating point is carried by the use of any the 3 dc converters. If Z out is the total load impedance then Z out /D2 is the reflected impedance at the source side, where D is the duty ratio of the dc converter.

When Z IN=Z out /D2 impedance matching is occurred and maximum power is transferred from source to load side according to maximum power transfer theorem, where ZIN is the cell impedance.

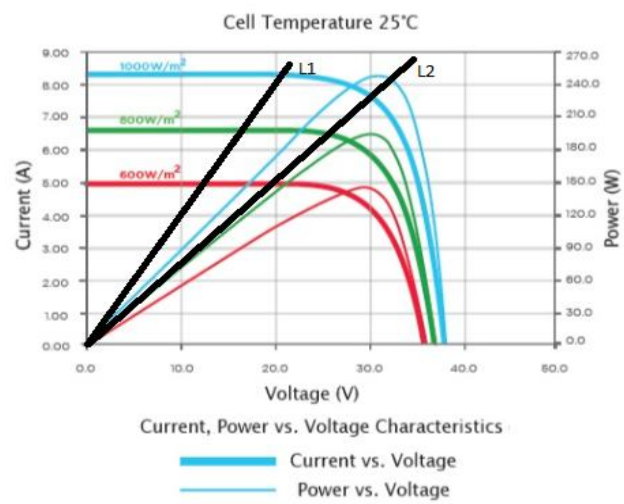

Fig. 3 Characteristic curve of solar cell

Since reflected load impedance is depending on the duty ratio, by varying duty ratio we can match both impedance. This impedance matching is done by using MPPT algorithm. Solar cell is a variable dc source since its output voltage is varied depending upon the shading over the solar cell. This can be considered as similar to the variation the rectified dc voltage in the pick-up module due to misalignment problem. Therefore we can plot V-I characteristics of OLEV based on the misalignment distance and the air gap. In the case of train since misalignment is not a serious issue the problem due to the variation in the mechanical construction of primary and secondary core can be reduced by using MPPT. In case of grid connected PV array load is continuously varying this similar variation in the load is occurring during when speed variation is required in vehicle. This similarity makes the MPPT algorithm applicability on OLEV.

6. EXPERIMENTAL SETUPS & TEST RESULTS

Following are components and its specification we used in our experiment.

On the primary track we placed 12-15 E type core and an inverted E core is placed on the vehicle. The dimension of E-type core used is 65*33*28 mm and has 20 turns on the central limb of the core which placed in the pickup module. Track is made up of wood having 1.8 m length in order to build up an insulated platform.

The rectifier used at the primary side is KBPC 2510 and for filtering purpose, four 315v 1000 µF capacitor is used. For the inverter circuit IRFP 250N MOSFET is used as switching element and IR2110 as the MOSFET driver. PIC 16F73 is used for generating 15 KHz gate pulse.13.5*8.5 cm heat sink is used in each leg of the inverter. A 16 gauge earth wire is used as the primary line. Two 12v 300mA 30rpm dc motor and a 12v 1.2Ah lead acid rechargeable battery are used in the vehicle.

Table 1 shows the readings of our test at different conditions

Table-1: Test results at various conditions

Primary side		Secondary side		Remarks
Voltage (volts)	Current (amperes)	Voltage (volts)	Current (mill amperes)	
10.8	18	10	250	With 0.5 cm air gap and load
9.5	15	18	0	Without load, 0.5 cm air gap
2.3	1	14	30	Without air gap
195	5	0.7	10	Using 50 ohm, 5 A rheostat

Following graphs shows the variation voltage with current at different conditions.

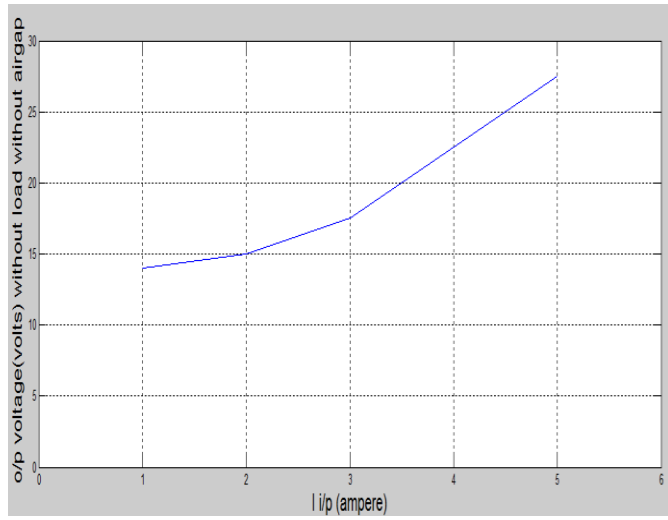

Fig-4: Output voltage without load without air gap vs. Input current

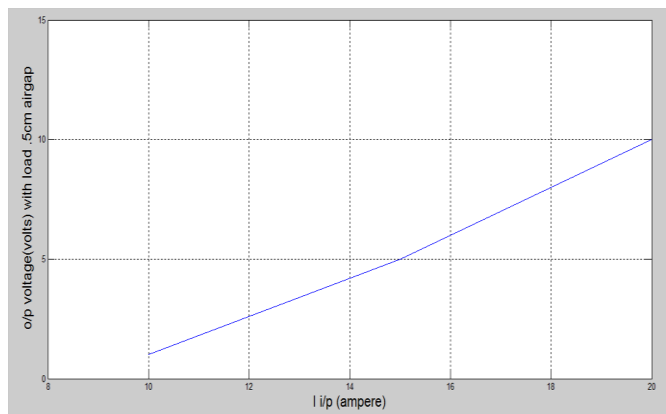

Fig-5: Output voltage with load 5 cm air gap vs. input current

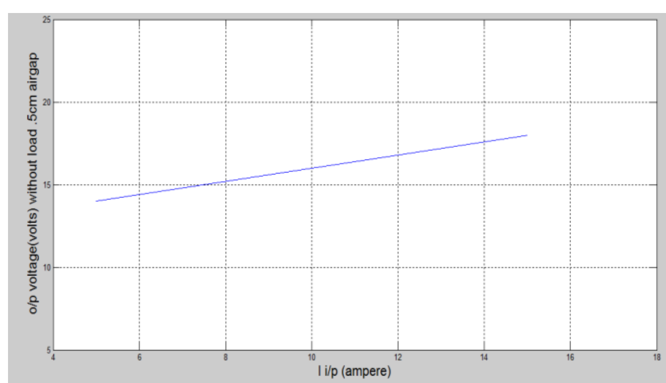

Fig-6: Output voltage without load 0.5 cm airgap vs input current

With the increment in the air gap distance the induced voltage in the pickup module reduces. However with resonance phenomena a large amount of energy can be transferred at higher gap distance. Below graph shows the variation of output voltage with gap distance.

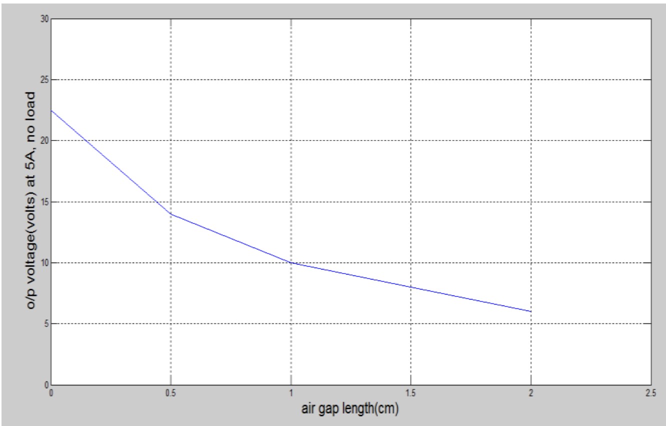

Fig-7: Output voltage at 5A no load vs air gap length

The induced voltage in secondary can be increased by increasing the frequency of inverter. We study the variation of induced voltage by varying the frequency of the driving pulse of the inverter using micro controller. When the frequency of inverter increases the frequency of flux wave in air gap also increases, which results in high induced emf.

A buck converter was developed by using IRFP 460 MOSFET. The duty cycle of buck converter is varied by varying the pot resistor connected to the microcontroller. Result was verified by observing waveform in CRO.

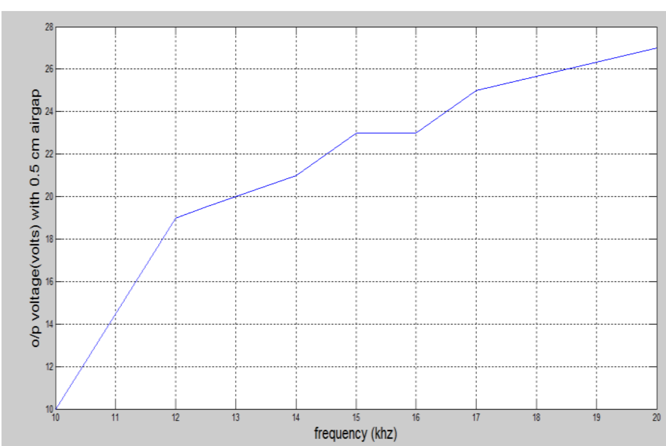

Fig-8: Output voltage with 0.5 cm airgap vs frequency

Fig-9: OLEV prototype on track and core arrangement

7. CONCLUSIONS

Core arrangement in SMFIR technology for vertical magnetic flux type is the efficient way of transfer wireless power transfer. When this wireless power transfer takes place at resonance condition there is a huge increase in the efficiency. This efficiently transferred energy is fully utilized when DC converter is incorporated with MPPT algorithm, in between pick-up module and load. So this energy transfer mechanism will give maximum efficiency power transfer with less loss.

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