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A NOVEL ENERGY MANAGEMENT SYSTEM IN AN ELECTRIC -ELECTRIC HYBRID VEHICLE BY UTILISATION OF BACK EMF OF DC MOTOR

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Abstract

Fossil fuels are the major source to meet the world energy requirements but its rapidly diminishing rate and adverse effects on our ecological system are of major concern. Rapid depletion of fossil fuels has led to the search of an alternate energy vehicle. Electric vehicles serve as a promising technology for the future world transportation domain. But the main disadvantage of electric car is the fear that one may run out of charge when there is no charging station nearby. Due to this drawback the electric vehicles cannot match up with the fossil fuel powered vehicle which made the invention of hybrid technology. This paper presents an overview on utilization of back emf generated in the motor to charge the battery while driving the vehicle.

Keywords: *Back emf, Hybrid vehicle, Energy Management.*

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1. Introduction

Fossil fuels are inherently very inefficient because of the hundreds of millions of years of solar energy and the rare geologic events it takes to produce them whereas Electricity is created more locally than Oil, has an established delivery pipeline - the 'Grid' . All-electric vehicles run on electricity only. They are propelled by electric motors powered by rechargeable batteries. Electric vehicles have several advantages over vehicles with internal combustion engines.

Electric vehicles convert about 59%–62% of the electrical energy from the grid to power at the wheels—conventional gasoline vehicles only convert about 17%–21% of the energy stored in gasoline to power at the wheels. Electric vehicles emit no pollutants and are eco friendly. Electric motors provide smooth operation and stronger acceleration. They require less maintenance than combustion engines. Comparison between the two is shown in Figure 1.

The main drawback of electric vehicles is that the large battery packs are expensive and may need to be replaced one or more times. The range of an electric vehicle is comparatively shorter than other vehicles. To overcome this, efforts are concentrated towards implementing a concept called as Electric – Electric hybrid system by which one system will be charged while the other system provides propulsive power to the vehicle [7].

Why Electric Vehicles Beat Unsustainable Gasoline

This chart compares the financial and environmental costs of gasoline vehicles to those of all-electric and partially electric vehicles.

Vehicle type	Gas cost for 50 miles/day	kWh for 50 miles/day	Annual cost for 50 miles/day	Gas gallons/year for 50 miles/day	Tons of tailpipe CO_2/year	Total CO_2/year, including upstream*
10 mpg gas	$17.50	200	$6,400	1,829	21	27.3
20 mpg gas	$8.75	100	$3,200	915	10.5	13.6
30 mpg gas	$5.85	67	$2,130	609	7	9.1
40 mpg hybrid	$4.40	50	$1,600	457	5.2	6.8
50 mpg hybrid	$3.50	40	$1,275	365	4.2	5.5
Plug-in hybrid with 25 mile all-electric range	$1.75	10	$820	182	2.5	3
Plug-in hybrid with 50 mile all-electric range	$0	22	$396	0	0	0.4
All-electric vehicle	$0	12	$216	0	0	0.2

The main assumptions used to produce the values in the chart are: 1. The average cost of gasoline over the next year will be approximately $3.50/gallon. 2. The Time of Use (TOU) rate for nighttime charging is approximately $0.05/kWh. 3. There are about 40 kWh of energy in a gallon of gasoline. 4. Burning 1 gallon of gasoline produces approximately 23 pounds of CO_2.

*This column includes "upstream" CO_2 emissions for process to find, extract, refine and transport gasoline, as well as CO_2 emissions from the California mix of power plants that produce electricity to charge EVs.

Figure 1 - Comparison between CO_2 emissions of gasoline and electric vehicles [1]

Every electric motor has a force that opposes the propelling electromagnetic field inside it, called 'back emf'. It is possible to recover this back emf, instead of letting it cause resistance, it can be transformed into useful power. This useful power can be used to charge one system while the other system runs the motor.

Brandenburg et al (1994) describes a series hybrid engine with electric traction motor drive of the vehicle wheels and regenerative braking system that converts the motor to a generator for the output of useful electrical energy, the latter being used either to charge the storage battery for power source of traction motor, or if the battery is charged diverting the regenerative energy to a resistive heater located in the cooling circuit of an independently operated accessory driving the internal combustion engine;

the resistive heater providing heat to the coolant to preheat the ICE prior to engine start-up[6].

2. Working of electric vehicles

The components of an electric car as shown in Figure 2 are:

- The **electric motor**
- The motor's **controller**
- The **batteries**

The controller receives power from the battery pack and delivers it to the motor. The accelerator pedals are hooked to a pair of potentiometers. These potentiometers provide the signal that tells the controller how much power it should deliver. The controller can deliver no power (when the car is not moving) and full power (when the car is accelerated) or any level of power in between them.

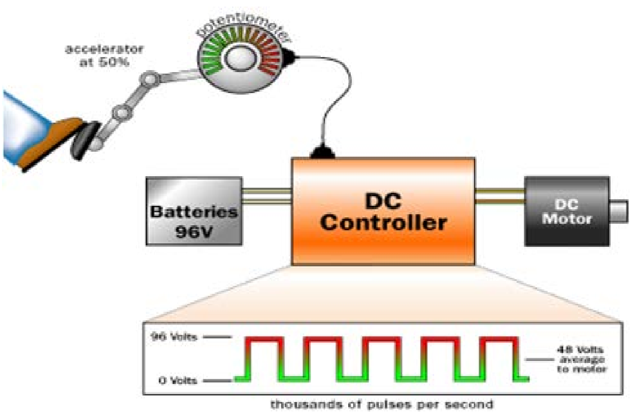


Figure 2 - Components of an electric vehicle [2]

AC or DC motors can be used in electric vehicles. DC motors are preferred mostly than AC motors as they are simple to configure and are not expensive. For AC motors 3-phase motors running at 240 V are used. DC motors, on the other hand requires only (96-192Volts). DC motors can also be overdriven for short duration period.

The weight of the car increases by the use of lead acid batteries. As the number of batteries used range from 50 to more, they occupy a lot of space. They generate lesser driving power compared to gasoline powered cars. They need at least ten hours to get recharged completely. Apart from the battery used for the car propulsion, there is an additional 12 V battery on board to provide power for other components like wipers, radio and air conditioner etc., But the extra expense comes in when we have to recharge the battery[2,3].

3. Concept of back emf

When current flows through the armature conductor of dc motor, it starts rotating inside the magnetic field set up by the stator pole. As the conductors move inside the magnetic field, an emf is induced in them. This emf is built according to Faraday’s law of electromagnetic induction. The direction of the induced emf is given by Fleming’s Right Hand rule and the induced emf will oppose the applied voltage according to Lenz's law as shown in Figure 3. In other words in DC motor the rotating armature will generate an emf opposite to applied voltage and this generated emf is called back emf in dc motor.

$$\text{Net emf} = \text{supply emf} - \text{back emf} \qquad (1)$$

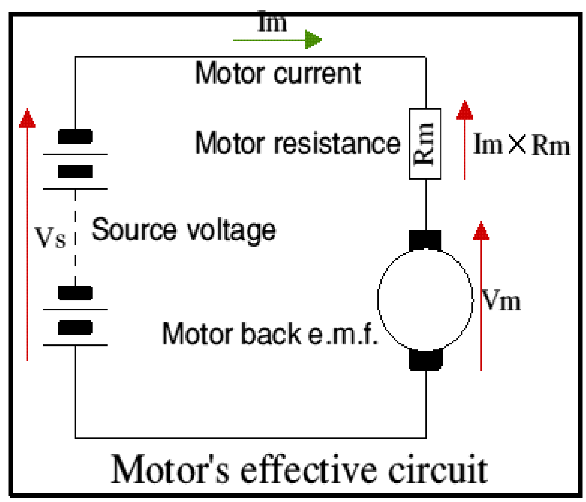


Figure 3- Equivalent circuit of DC motor [3]

Back emf is proportional to speed and field strength.

$$E_b = K \times N \times f \qquad (2)$$

where ,

E_b is back emf

K is voltage constant

N is the speed of the motor

f is the field strength.

4. Back emf capture

The back EMF of the motor winding can be detected during off time of PWM as the terminal voltage of the DC motor is directly proportional to the back emf during this interval. Also, the back emf voltage is referenced to ground to prevent any common mode noise [4,8]. Therefore this back EMF sensing method has an advantage that it is resistant to switching noise and common mode voltage. Hence, no attenuation and filtering necessary for the back EMF sensing. This unique back EMF capture method has better performance to existing methods which depend on neutral voltage information, providing much wider speed range at low cost.
An energy conserving apparatus for driving a load and recovering the otherwise wasted electrical power uses an electric motor with field windings mounted on one or more pole members [5,9,10]. During the first time interval, current is supplied to the field windings from charged battery. The current flowing through switching circuitry to the field of the motor thereby turns the rotor by creating a magnetic field. During the second time interval, the duration determined by motor speed, the rotor' poles confront the poles of the field and the switching circuit disconnects the first battery from the field and clamps a second discharged battery to the field windings for charging the second battery. When the first battery is switched off, the magnetic field developed by the field windings collapses.

The basic capture circuit is shown below

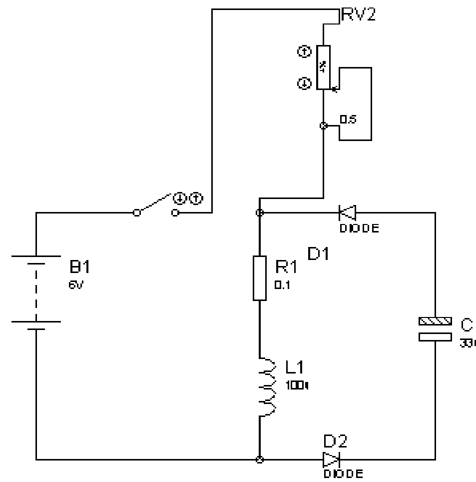


Figure 4 - Basic capture circuit

As a result of Lenz's law, a first current is induced in the windings of the field. This induced current increment opposite in direction to the current which flowed through the windings, is connected through the switching circuit to the second battery to charge it.

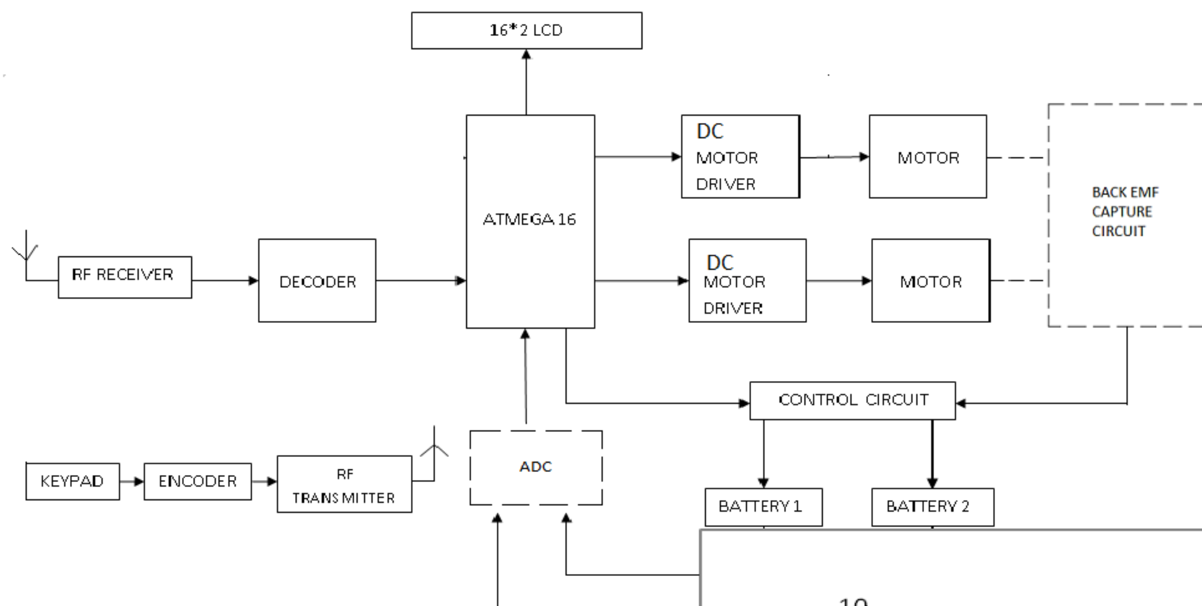
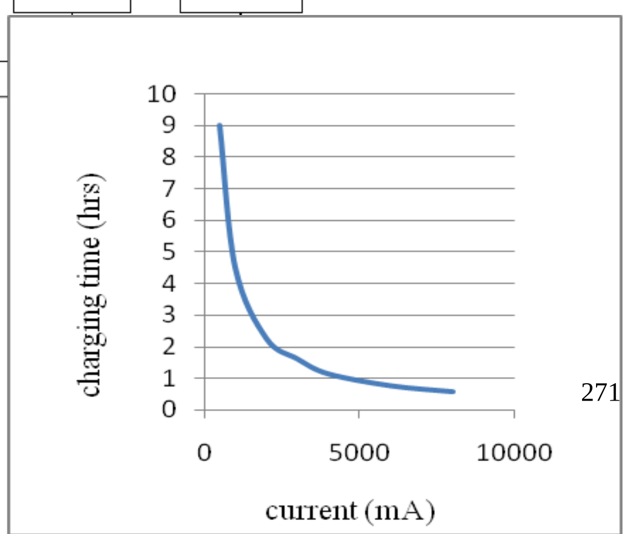


Figure 5 - Block diagram of proposed system

Simultaneously with the generation of the first current, the magnetic field of the rotor links the field windings, developing a second current increment in the field. This



second current flows in the direction of first induced current and is also connected through the switching circuit to charge the second battery. At the end of the second interval, the electrical switching circuitry replaces the second battery with the first battery to the field to again give current to the field winding to drive the rotor. The block diagram for self charging electric vehicle is as shown in Figure 5.

5. Results obtained

5.1. Variation of back emf with speed of DC motor

Speed of the motor is directly proportional to the back emf E_b and $E_b = V - I_aR_a$. That is when supply voltage V and armature resistance R_a are kept constant, speed is directly proportional to armature current I_a. Thus if when resistance is added in series with armature, I_a decreases and hence speed decreases. Greater the resistance in series with armature greater the decrease in speed.
So by varying speed using armature rheostat control, values of back emf obtained were plotted as shown in Figure 6.

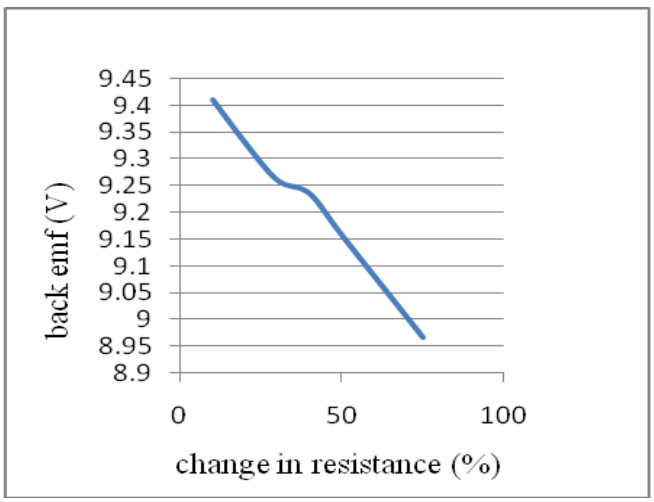


Figure 6 - Change in resistance Vs Back emf

5.2. Variation of Charging time with Current

Self charging by capture and utilisation of back emf takes a longer time when compared to conventional charging techniques. In order to overcome the difficulty faced with the proposed method, super capacitors can be used for instant charging and discharging or current amplification can be done. This improves the efficiency of electric vehicle. The following graph shows how charging time varies with current.

Figure 7 - Current Vs Charging time

5.3. Variation of back emf with supply voltage

The back emf of a dc motor depends on the supply voltage as given below.

$$E_b = V - I_aR_a \qquad (3)$$

The value of back emf for various supply voltages were estimated and tabulated.

Battery Voltage (V)	Estimated Back EMF (V)
6	18
12	30
48	60
220	240

Table 1- Estimated values of back emf for various supply voltages

6. Conclusion

With the wide range of advantages electric vehicle is the best solution to replace the conventional fossil fuel powered vehicles. About more than 70 % of the total range can be regenerated through the back EMF that is produced. In order to overcome the difficulty faced with the proposed method, supercapacitors can be used for instant charging and discharging or current amplification can be done. This improves the efficiency of electric vehicle.

The conclusions from the project are tabulated as follows:

Table 2 - Comparison between ICE vehicles and self charging electric vehicles

Description	**ICE vehicle**	**Self charging electric vehicle**
Efficiency	IC engine efficiency: 20%	Motor efficiency : 87%
	Overall efficiency: 15 %	Overall efficiency: 80 %
CO_2 emissions	21 tons/year	0.2 tons/year
Cost involved	Rs 7.2 per mile	Rs 1.2 per mile

The back emf obtained can also be used to power auxillary parts of an electric vehicle such as Lighting, radio etc., The other applications of back emf reuse includes agricultural irrigation system, medical equipments, military equipments and aircrafts.

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