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Design and Application of Solar Module for Electric Vehicles

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Abstract - *The adaption of solar power is rising as a trusted renewable energy source. Photovoltaic cells are used in conversion of solar energy into useful electrical energy. The objective of this paper is to provide the details if the speed and torque of the vehicle can be controlled. And ultimately construct an efficient solar vehicle, for the daily office commuters of Pune city. This will allow traveling a fixed distance every day in a reliable and economical way, that essentially runs on free renewable solar energy. As overcoming this distance would be the first objective of the solar vehicle to be built[1]. The paper illustrates how the charge generated by an array of solar panels is received and its flow in and out of a battery pack is to be controlled in such a way that to ensure efficient operation of electric vehicle. The stored energy would be transferred to a Brushless DC motor which would run the vehicle.*

Keywords: Solar module, Electric vehicle, BLDC Motor

1. INTRODUCTION

Electric vehicles are set to play a key role in the future of urban mobility, reducing pollution, decreasing dependence on fossil fuels and saving resources. European Commission (EC) together with industrial partners within the European Green Vehicles Initiative (EGVI) set specific objective for the next years for enhancement of the energy transport system efficiency by Fifty percent from 2010 to 2030, including: eighty percent energy efficiency of urban vehicles and +40% energy efficiency of long distance freight transport; a deployment of alternative powertrains like electric and plug-in hybrid technologies; 5million electric & hybrid vehicles in the EU by 2020 (EUR 0.5million by 2016); Battery life-time and energy density doubled, at 30% lower cost, in 2020 compared to 2009 Li-Ion technology[1]-[3].

European Green Vehicles Initiative (EGVI) will help to reach the targets set under the EU's climate, energy and transport policies, preferably the 20-20-20 targets on reducing greenhouse gas emissions (GHG), increasing use of renewable energy and more energy efficiency[1]. Transport is responsible for about a quarter of EU GHG, being the second sector as level of pollution by the energy sector. Only road transport contributes with one fifth of the total CO_2 emissions at European level. Currently, urban transport is the only sector where GHG continues to grow [2].

As a renewable energy source solar energy is set to play a pivotal role in the future of the electric vehicles.

2. NEED OF ELECTRIC VEHICLE

Electric vehicles become popular in less time because of following advantages [2]-[7] [9][4]:

1. Battery Electric Vehicle (BEV) is having very few moving parts as compared to that of in conventional gasoline-powered vehicle.
2. Electric Vehicles are environment friendly because these vehicles don't emit smoke.
3. These vehicles are not having need for liquid fuels or oil changes.
4. Electricity is very cheaper (more than 10 times) than fossil fuels for same power extraction in India[3].
5. In India there are no big fossil fuel sources, so we have to import petroleum oils continuously.
6. Maintenance cost of electric vehicles is negligible when compared to IC Engine vehicles.
7. As per scientific research, all the fossil fuels will be exhausted by 35-40 years[3].
8. Petrol prices are highest in India itself.
9. EV's helps to reduce effect on environment and climate change by fossil fuel used by conventional vehicles.
10. Electric motors are not having requirement of any conventional fuel because those are powered by rechargeable batteries.
11. EV's have a better emissions profile than internal combustion vehicle.

12. EV's are having silent operation.

13. Electric vehicles are not having problem of acceleration and speed of the vehicle because whatever speed and acceleration is required, it can be obtained by increasing the power of the electric motor [3].

14. There are fast growing transportation power requirement problems in India [3].

1.1 Indian Government Initiatives:

Government of India is going to promoting the mass adoption of electric vehicles through the FAME (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) scheme. According to the Society of Manufacturers of Electric Vehicles, total EV sales figure in India are 22000 for FY 2015-16, 25000 for FY 2016-17 and 56000 for FY 2017-18[5].

The Indian Government is providing various subsidies and tax deduction to promote the adoption of electric vehicle large scales. As per the information on official website of FAME-India scheme, total 278704 number of Electric

Vehicles sold up to April-2019, total 278546 number of incentives claimed and total incentive amount is INR 3,433,318,600[5].

3. DIFFICULTIES IN ADAPTION OF ELECTRIC VEHICLES

The promotion of electric vehicle will go in vain if the user is not satisfied with the performance of electric vehicle. Electric vehicles are facing following problems:

1. Batteries are too costly [3].

2. Higher cost of EV which depends mainly on Electric Vehicle.

3. Battery and the range of battery cycle life

4. Frequent recharging is a major drawback.

5. Recharging time is high and waiting for recharging is a big pain.

6. Life of batteries.

7. Need of testing and enhancement of performance of batteries.

8. Need of design of motors with low cost, high acceleration, low weight, high efficiency-high torque at low speed.

4. BLOCK DIAGRAM OF SOLAR MODULE ELECTRIC VEHICLE

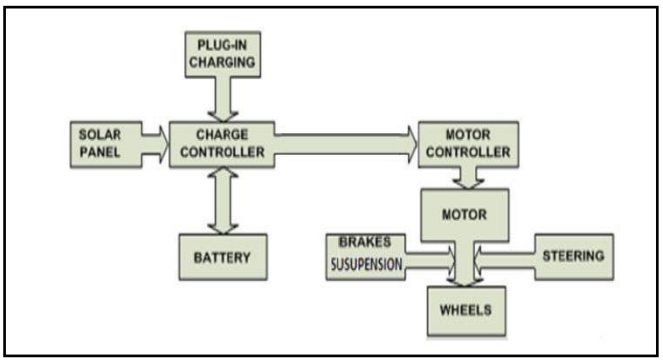

Figure -1: Block Diagram of Solar Module Electric vehicle

4.1 SOLAR PANEL

Solar vehicles are powered by the sun's energy ergo solar panels are the most important part of a solar vehicle since they are solely responsible for collecting the sun's energy. The solar panels used in this project are mono crystalline and flexible. They can be mounted and fitted on top of the vehicle or on the bonnet with ease owing to their thin semi-flexible nature.

Parameters of Solar panel	**Rating**
Max Power Pmax	800Wp (@NOCT – 256.1)
Max Voltage *Vmpp*	48V (@NOTC – 35.61V)
Max Current	9.08A (@NOTC – 7.19A)
Voc	47.26V (@NOCT 43.64V)
Isc	9.68A (@NOCT 7.84A)
Efficiency	17.85
Length*Width*Height	197.6*99.2*40 cm
Price	15000 to 16000

Table-1 Ratings of solar panel

4.2 BATTERIES

The solar panels will collect energy from the sun and convert it into usable electrical energy, which in turn will be stored in the lead acid batteries to be supplied to the motor when necessary. And it is also used for energy storing from the plug in charging.

4.3 MOTOR

Electric motor is used to drive the bike. Now the trend is to supply larger powered brushless motor of larger wattage which can keep an e-bike travelling with higher speed and easily go up high skills [3]...Induction motor, Switched reluctance motor, Brushed DC motor.

BLDC motor is preferred because of no maintenance, high efficiency, low noise, high starting torque, high no-load speed and also because of the absence of brushes we don't find sparking in BLDC motor which increases the life of motor.[6] Hub motors are preferred for light weight electric vehicle. It is the compact electric motor placed inside the wheel and is directly connected to the rotating wheel. It generates high torque at low rpm.

The motor used is a DC-series excitation motor which is rated at 650W, 48V.This DC-series motor is sufficient to get the vehicle up and running as will be shown in details later. The motor controller is designed to control the speed of rotation of the motor as well as the direction of its rotation. In other words, it determines the vehicles speed and forward/reverse direction of motion of the wheels.

Parametersof motor	Ratngs
Model	MY1016 650W
Operating Power	650W
Operating Voltage	48/60 DC.
Rated Current	Full load Current: ≤19.20A. No load Current: ≤2.5A.
No load Speed	3300 RPM
Rated Speed(RPM)	2750 RPM
Rated Torque	1.11 N.m (11.1 kg.cm).
Stall Torque(Kg-Cm	5.55 N.m (55.11 kg.cm).
Weight (Kg)	2.56
Efficiency	≥78%.
Dimensions	25 x 25 x 20 cm

Table-2 Ratings of motor

4.4 MOTOR CONTROLLER

PWM (Pulse Width Modulation) technique is used to control the speed of BLDC motor. Pulse Width Modulation is a technique that manipulates the width of the pulse duration based on controlling information to deliver specific amounts of power to a device. The duty cycle is a parameter in PWM that describes the ratio of the duration for which the voltage/power/current is to be supplied relative to the duration of the period. Example. A 50% duty cycle thus would mean that voltage/power/current is supplied for half the time of the total period.

Duty cycle = $\left(\frac{T}{Td}\right) x100\%$, $\left(\frac{Ti}{Td}\right) * 100$

Where,

Ti= duration of power/voltage/current on.

Td = time period. The average voltage of the resulting output would thus be half of the input.

Type of Motor	Advantages	Limitations
Induction Motor	Simple construction, Low Maintenance, High reliability, Low cost, Ability of operating in hostile environment	Higher cost of controller than that of DC motor, Presence of breakdown limits its extended constant power operation, Less efficiency.
Switched Reluctance Motor	Simple control, Simple and rugged construction, Fault tolerant operation, Higher starting torque, It can operate with an extremely long distance power range.	Suffer from Torque ripple, Accoustic noise is present.
Brushed DC Motor	High torque at low speed, Easy to control and suitable to propel the vehicle	Low efficiency , bulky, High maintenance cost, Low reliability.

Brushless DC Motor	High efficiency and power density, Longer life, Higher starting torque, High power to volume ratio, No load speed is high, Small energy loss.	High initial cost, High magnet cost, Suffer from field weakening capability,

Table-3 Types of motors

4.4 CHARGE CONTROLLER

The batteries are connected to a charge controller which will ensure healthy life of the batteries by preventing it from over charging and over discharging. A microcontroller inside the charge controller is programmed to detect the voltages at the battery terminal and/or the solar panel terminals and accordingly determine what charging current the battery needs to be supplied [5].

4.5 PLUG-IN CHARGING

A critical factor here is that the charge controller will be available with an additional input that can be used to charge the batteries from an AC power supply (simply by plugging in).

Thus the solar vehicle will have this plug-in charging system for use when there is not enough sunshine due to fog, cloud or rain. This provision for an external plug-in system to charge the batteries from the conventional AC power supply will allow the vehicle to increase its overall utility.

4.6 STEERING, SUSPENSION, BRAKES, WHEELS

These four components make up the mechanical part of the solar vehicle. Front wheel steering is used as it tends to be more stable and safe. The suspension used is sophisticated enough to allow the user a stable ride and to protect the vehicle and panels from sudden shocks and blows.

A drum braking system as in conventional vehicles is used to provide the safety features of the vehicle while travelling. The wheel selection is dependent upon the rolling resistance which would determine how far the solar vehicle can travel with the available energy. Since thicker wheels tend to have higher rolling resistance, thinner but strong wheels are opted for.

5. SIMULATION OF CIRCUIT DIAGRAM

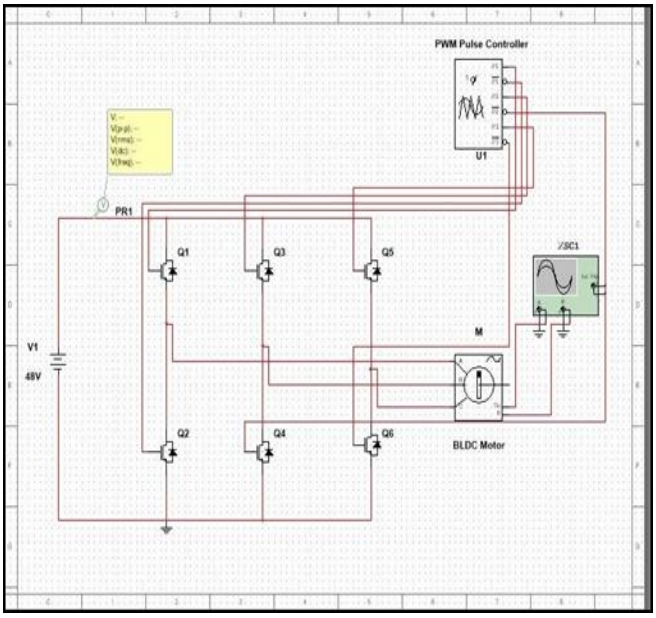

Figure-2 Simulation Circuit for Module

Steps for Simulation Diagram and waveform:

1. In this simulation we have assumed the E-vehicle will be powered by the solar panel and BLDC motor is used as mechanical driver [2].

2. Below figure 3,4 shows the simulation waveform of the accelerating procedure for the BLDC motor from stall state to maximum speed with no load and Constant voltage power supply[4].

3. In this circuit, we have considered the solar panel as a constant voltage source with irradiance is assumed to be standard(1000watts/$m2$).

4. The circuit consists of 3 pairs of Field Effect Transistors (FETs), a solar panel (a constant voltage source), Oscilloscope, 3-phase PWM controller and Brushless DC motor [5].

5. The FETs named as Q1, Q2, Q3, Q4, Q5, Q6 are controlled by the PWM controller.

6. 3 Phase PWM controller generates a three-phase sinusoidal PWM voltage signal which is 120°($electrical$) apart.

7. The reference signal and the control signals have zero offset.

8. The Fig. 3 shows the torque output when the motor is having 6 pole pairs and the Fig. 4 shows the torque output when the motor is having the 12 pole pairs.

9. It can clearly be seen that the torque produced by 12 pole pairs is less distorted compared with torque produced with 6 pole pairs.

10. By controlling the PWM controller output the speed and torque of the brushless dc motor can be controlled.

11. It can be seen from figure that the torque has a degree of slope due to the effect of the trapezoidal torque profile.

12. The variation of phase current and torque is similar starting process.

13. The starting current and torque achieve more than 10 times their rating values, respectively. But the steady current and torque are small at the no-load condition [8].

14. In the Fig.3 and Fig.4 the starting torque profile is damped completely.

15. It can be seen that the response speed of dynamic process of BLDC motor is quick.

16. The torque is found by the equation:

$$Tsh = 60 * (Output\ in\ Watts)/2\pi N$$

17. The torque is found to be 0.98 N-m from the simulation [8].

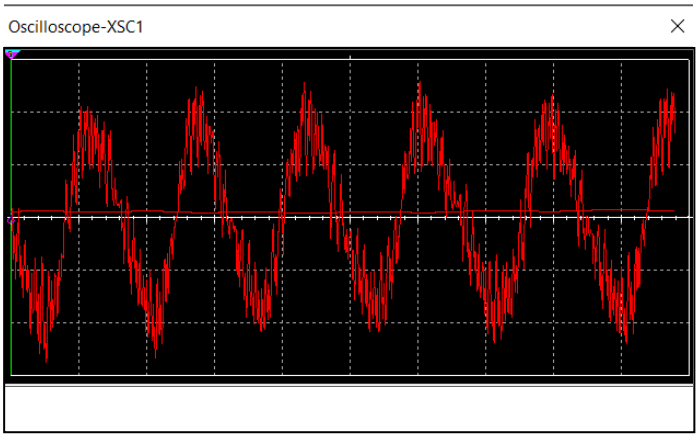

Figure-3 Dynamic response of Electromagnetic Torque($per\ Nm/\mu$sec) For 6 poles

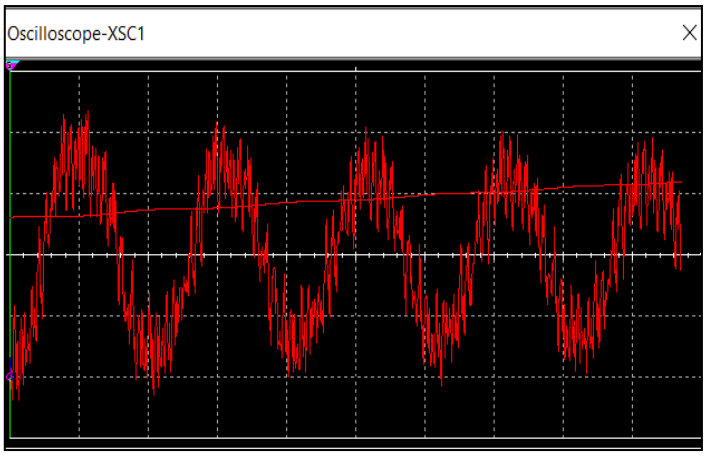

Figure-4 Dynamic response of Electromagnetic Torque($per\ Nm/\mu$sec) For 12 poles.

6. CONCLUSIONS

This can be concluded that, the torque profile of the solar module powered electric vehicle depends upon the number of poles of the BLDC motor. To control the torque and the speed of the electric vehicle one has to control the PWM output. A battery has to be used to compliment the satisfactory performance of the electric module[8].

Solar-powered electric vehicles are safe with no volatile fuel or hot exhausts systems. Since solar vehicles can easily incorporate future technology, we hope that it would not be long before the majority of the world's people would switch to driving this modern vehicle and thereby bring about a positive change in their lives and the environment. This is just the beginning of a new technology and it is assured that future developments will make solar vehicles the predominant mode of transportation over vehicles with internal combustion engines.

In addition, the simulation results show that the torque ripple of the BLDC motor is slightly large. This shortcoming has limited its applications in high-performance driving systems, more research and improvements in this field should be carried out.

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