Drive Cycle Analysis for Electric Vehicle using MATLAB
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Abstract:
Today most of the humans are used the motor vehicles. These motors vehicles are produced the problems such as air pollution & global warms. Also the humans are facing the issue of reduction of oil in the world. In recent years, the researchers studied that problems and found the alternative energy source to drive the vehicle. One good way is to replace the combustion motor with an electric motor, which is called as electric vehicle (EV). In recent days EV’s are gaining more popularity. Solar powered electric vehicles (SEV) are considered the future vehicles to solve the major issue related to the environment. Energy management system (EMS) in SEV is very important because this type of vehicle is highly depends on supply of battery. So, Battery plays an important role in SEV. With the help of renewable sources such as solar energy the efficiency of the SEV may be increased. For an SEV, motor selection is very important parameter. A particular motor may behave differently under different driving conditions. In this paper, solar powered small electric vehicle is designed by using the mat lab and the analysis of different drive cycles for urban or suburban region.

Keywords: Electric Vehicle (EV), Solar panel, Lead acid battery, DC motor, MATLAB.

I. INTRODUCTION
In recent decades demands for vehicles are increased that caused the environmental pollution everywhere. The fossil fuel such as petrol and diesel are expensive. Consumption of fossil fuel for vehicles is more increasing. More than half of world energy consumption is used for transportation. Figure 1 illustrates the differences between fuel demand and world oil production after the year 2020.

![Figure 1. World oil demand by 2050](image)

The use of fossil fuel based vehicle causes the air pollution which is very harmful for the human beings. The noise level of these vehicles is high which is directly affected on human body that causes the heart attack. Fuel gases produced by vehicles consist of 18% solid particles, 27% mixture of volatiles (comprising 28% Pb, 32% NO and 62% CO) and CO2 by 25%. To avoid these problems researchers found a new technology called Solar Electric Vehicle (SEV). There are many renewable sources such as solar energy, Wind energy, Tidal energy for reducing the environmental pollution and saves the electricity. One of the greatest energy sources is the solar energy. In SEV, Solar energy is converted the sun energy in to electrical energy and stored in the batteries and this stored energy is utilized for EV. Battery is the crucial parameter of EV. In this paper, Battery is charged from solar panel as well as power supply. The performance of EV is evaluated for various drive cycles. Here three drive cycles are considered that are flat, slope & rough surface and these drive cycles are analyzes on MATLAB.

II. METHODOLOGY

A. PROPOSED DESIGN

![Figure 2. General Block diagram for EV](image)

Above figure shows the general block diagram of EV having different control units like lightening ECU, Battery ECU, Motor, and Gears etc. In this section, a small solar powered EV is designed using MATLAB software. In this system Solar, battery, and motor plays the important role. To increase the efficiency of EV we used the renewable energy source i.e. solar energy.
Battery is a device which can be charged from either solar panel or power supply. The performance of EV is evaluated by using various drive cycles (flat surface, rough and slope surface) and these drive cycles are analyzed on MATLAB.

**PRINCIPAL OF OPERATION**

1. **Solar panel:**
   Solar panel is used to convert the solar energy to electrical energy. Silicon is one of the materials used in photovoltaic cell to convert sun’s energy into electricity.

2. **Battery:**
   Battery is a device, which maintain current by transferring chemical energy into electrical energy. In this paper battery can stores the solar energy and this energy is given to the motor. So that motor will be run with fast speed and vehicle will be run. In this project we use the lead acid battery.

<table>
<thead>
<tr>
<th>Table.1. Specification of solar panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of solar panel</td>
</tr>
<tr>
<td>Max power voltage</td>
</tr>
<tr>
<td>Max power</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
</tbody>
</table>

From the above given data we can calculate the panel current, $I_p = \frac{C_p \times \text{Efficiency}}{V_p}$

Where,
$I_p$ = Panel Current.
$P$ = panel Capacity.
$V$ = panel voltage.

<table>
<thead>
<tr>
<th>Table.2. Specification of Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery type</td>
</tr>
<tr>
<td>Voltage rating</td>
</tr>
<tr>
<td>Battery capacity</td>
</tr>
<tr>
<td>Fastest possible charging time</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
</tbody>
</table>

Discharge Current formula, Discharge Current= Batt current – Panel current $I_d = I_b - I_p$

When, Battery current > no load current
Battery life calculation formula, Battery life = $\frac{\text{Battery capacity} \times \text{Efficiency}}{\text{Discharge current}} \times \frac{I_d}{I_a}$

3. **Motor:**

The motors used in electric cars can be AC or DC. Mostly DC motors are preferred than AC motors because they are simple to configure, not expensive and lossless than the AC. There are different types of motor used in EV that are Brushless DC motor (BLDC), Induction Motor (IM), Permanent Magnet Motor (PMM) and Switch Reluctance Motor (SRM). In this project DC motor is used.

**Table.3. Specification of DC Motor**

<table>
<thead>
<tr>
<th>Characteristics of DC motor with load and without load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max power voltage</td>
</tr>
<tr>
<td>Stall Torque(Ts)</td>
</tr>
<tr>
<td>Motor Torque</td>
</tr>
</tbody>
</table>

Math formulas:

- **With load**

$T = \text{Torque constant} \times I$

$\text{Torque Load} = \frac{D(F + gWg)}{2}$

where, $D$ = Diameter of wheel,
$F$ = External force,
$W$ = Weight of vehicle,
$g$ = Gravity Acceleration,
$\mu$ = Frictional Coefficient.

Current due to load = $\frac{\text{Torque load}}{\text{Torque constant}}$.

Formula for motor current,

$\text{Motor current} = \text{No load current} + \text{current due to load}$

Graph 2 shows the current vs. torque characteristics for load.

**B. DRIVE CYCLE ANALYSIS**

**Figure.3. Forces acting on moving vehicle**

Drive cycles is important for comparative analysis and motor selection purpose. Drive cycles defines the characteristics curve of speed, torque and current of the vehicle. Various forces acting on a moving vehicle are shown in fig4 and are discussed in this section. First step is to make a tractive force to determine how much load on the electric vehicle to a flat, rough and slope road condition. The traction force ($F_t$) is made up of the different driving resistance forces and is defined as, $F_t = F_r + F_w + F_g + F_a$

Where, $F_t$ = Traction Force
$F_r$ = Rolling Force
$F_w$ = Aerodynamic drag Force
$F_g$ = Grade resistance Force
$F_a$ = Acceleration Force

The $F_r$ is caused by the tire deformation on the road and is defined as $F_r = Mg \cos(\alpha)$

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Where, \( M \) = Mass of the vehicle  
\( g \) = Acceleration due to gravity  
\( f_r \) = Rolling resistance coefficient  
\( \alpha \) = Road angle  
The \( F_w \) is the force on the vehicle that caused by the vehicle aerodynamic and defines as  
\[
F_w = \frac{V^2 \rho A_f C_d}{2}
\]
Where, \( V \) = Vehicle Speed  
\( A_f \) = Vehicle surface area  
\( C_d \) = Aerodynamic drag coefficient  
\( \rho \) = Air density  
The \( F_g \) is the force on the vehicle to move up or move upward with a slope.  
\[
F_g = Mg \sin \alpha
\]
The acceleration force is the force required to increase the speed of the vehicle and defines as  
\[
F_a = \lambda M \frac{dv}{dt}
\]
\( \lambda \) is rotational inertia constant. The total tractive torque ( \( T_w \) ) required at the wheel is given by  
\[
T_w = F_t \times r
\]
Where \( r \) = radius of wheel  
And total tractive power ( \( P_w \) ) required at the wheel is given by  
\[
P_w = F_t \times V
\]
The first step towards the design of the power train is to select the type of motor used in EV. Before plotting the curves, it is important to simulate the vehicle under different driving environment. In this project, there are three cases are considered. These drive cycles are simulated in MATLAB software.

**Drive Cycles:**
- Flat Surface (Highway).  
- Rough Surface (City).  
- Slop Surface.

**Table 4. the Specifications of EV in Electric Vehicle**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>500kg</td>
</tr>
<tr>
<td>Friction Coefficient</td>
<td>1</td>
</tr>
<tr>
<td>Roller diameter</td>
<td>0.508m</td>
</tr>
<tr>
<td>Gravity Acceleration</td>
<td>9.8m/s²</td>
</tr>
<tr>
<td>External Force</td>
<td>100N</td>
</tr>
<tr>
<td>Battery Type</td>
<td>Lead Acid Battery</td>
</tr>
<tr>
<td>Motor Type</td>
<td>DC Motor</td>
</tr>
</tbody>
</table>

**III. RESULT**

The performance of EV is evaluated for various drive cycles. Different drive cycles are analyzed on MATLAB. Following figures shows the general characteristics of motor and battery & Drive cycle analysis.

**a. Battery Discharging Graph**

![Battery Discharging Graph](image)

Above fig3 shows the battery discharging graph. Here battery capacity is 150Ahr taken. From above fig3 it is observed that battery discharged time is 6hr for speed 80km/hr.

**b. Speed vs. Torque**

![Speed vs. Torque Graph](image)

Above fig4 shows the general characteristics of motor used. Here vehicle speed is taken 80km/hr and torque is 3.5Nm for no load. If the speed of the vehicle is increased from 10 to 80 km/hr then torque of the motor is decreased.

**c. Torque vs. Motor Current**

![Torque vs. Motor Current Graph](image)

For the above same condition, the current drawn by the motor is plotted in fig5. If the load is present then the maximum current is 5.5A and the torque load is 2000Nm. From above fig5 it is observed that the torque is directly proportional to the motor current.
d. Drive Cycle for Flat Surface

Figure 7. Different Curves for Flat Surface
From the fig 6 it is observed that for 2 hrs average speeds are 103Km and distance travel is 206.2km/hr. If the vehicle speed is increased from 101 to 105km/hr then torque is low. For the same condition the motor current is 14.5A then the torque is 50Nm.

e. Drive cycle for Rough Surface:

Figure 8. Different Curves for Rough Surface
From the fig 7 it is observed that for 2 hrs average speed is 59Km and distance travel is 119.66km/hr. If the vehicle speed is increased from 50 to 70km/hr then torque is low. For the same condition the motor current is 270A then the torque is 3000Nm.

f. Drive cycle for Slope Surface:

Figure 9. Different Curves for Slope
From the fig 7 it is observed that for 2 hrs average speeds are 75.69Km and distance travel is 151.38km/hr. If the vehicle speed is increased from 50 to 100km/hr then torque is low. For the same condition the motor current is 11.11A then the torque is 11Nm.

IV. CONCLUSION

Energy management system is very important for the vehicle. Many countries are adopting green machine concept in automotive sectors. Electrical Vehicle plays important role to saves the nonrenewable sources such as petrol, diesel. Batteries are easily charged using the solar panel as well as power supply. The performance of EV is evaluated using various drive cycles (Flat, Rough & slope) and these drive cycles are analyzed on Matlab.

V. REFERENCES


[9].S. Williamson, A. Emadi, and K. Rajashekara, “Comprehensive efficiency modeling of electric traction motor drives for hybrid electric vehicle propulsion applications,”


