Mathematical Modeling of the Three Phase Induction Motor Couple to DC Motor in Hybrid Electric Vehicle

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Abstract: Problem statement: With emphasis on a cleaner environment and efficient operation, vehicles today rely more and more heavily on electrical power generation for success. Approach: Mathematical modeling the components of the HEV as the three phase induction motor couple to DC motor in hybrid electric vehicle was introduced. The controller of Induction Motor (IM) was designed based on input-output feedback linearization technique. It allowed greater electrical generation capacity and the fuel economy and emissions benefits of hybrid electric automotive propulsion. Results: A typical series hybrid electric vehicle was modeled and investigated. Conclusion: Various tests, such as acceleration traversing ramp and fuel consumption and emission were performed on the proposed model of 3 phase induction motor coupler DC motor in electric hybrid vehicles drive.

Key words: Hybrid electrical vehicle, induction motor, DC machine

INTRODUCTION

With the oil price shocks of the past few decades, as well as an increasing awareness of the emissions of air pollutants and greenhouse gases from cars and trucks, the interest to investigate alternative vehicle propulsion systems has grown. This challenge of fuel economy standards is promoting optimized and sometimes novel vehicle power-train architectures, which combine the traditional Internal Combustion Engine (ICE) with various forms of electric drives. The different types of the Hybrid Electric Vehicles (HEV) are real competitors of the classical ICE driven cars.

In an all-Electric Vehicle (EV) there is no ICE, but all other components exist including batteries with excessive power. EVs and HEVs are studied by numerous authors in the past, one comprehensive study is that of Chan[1]. First full-scale hybrid vehicle work in Turkey is Doblo/Tofas example realized at Marmara Research Centre[2]. There have been university theses and an industry project constitutes the basics of this study[3-7]. One of the main contribution is that of Gokce[4], energy conservation and energy balance method is adopted. The input-output feedback linearization technique combined with an adaptive backstopping observer in stator reference frame the induction motor[5] using in series hybrid electric vehicle is controlled[8].

This study focus on a new HEV modeling to make a couple two electric motor IM and DCM close loop sinusoidal PWM inverter to control the speed of a three phase induction motor. This compact inverter had its hardware reduced to a minimum through the use of a Programmable Integrated Circuit (PIC) micro-controller (PIC16C73A). In this sense a microcomputer interface was avoided. At the end, a typical HEV is modeled and investigated. Simulation results obtained show the IM and other components performances for a typical city drive cycle.

MATERIALS AND METHODS

The performance of an electric vehicle: The first step in vehicle performance modeling is to write an equation for the electric force. This is the force transmitted to the ground through the drive wheels and propelling the vehicle forward. This force must overcome the road load and accelerate the vehicle as shown in Fig. 1.

The rolling resistance is primarily due to the friction of the vehicle tires on the road and can be written as:

\[ f_{roll} = f \cdot M \cdot g \]  \( \text{(1)} \)

Where:
- \( M = \text{The vehicle mass} \)
- \( f = \text{The rolling resistance coefficient and g is gravity acceleration} \)
The aerodynamic drag is due to the friction of the body of vehicle moving through the air. The formula for this component is as in the following. Dynamic modeling and simulation of an induction motor with:

$$f_{AD} = \frac{1}{2} \xi C_D A V^2$$  \hspace{1cm} (2)

The gravity force due to the slope of the road can be expressed by:

$$f_{\text{grade}} = Mg \cdot \sin \alpha$$  \hspace{1cm} (3)

where, $\alpha$ is the grade angle.

In addition to the forces shown in Fig. 3, another one is needed to provide the linear acceleration of the vehicle given by:

$$f_{\text{acc}} = M \frac{dv}{dt}$$  \hspace{1cm} (4)

The propulsion system must now overcome the road loads and accelerate the vehicle by the tractive force, $F_{\text{tot}}$, as follows:

$$F_{\text{tot}} = f_{\text{roll}} + f_{AD} + f_{\text{grade}} + f_{\text{acc}}$$  \hspace{1cm} (5)

A typical road load characteristic as a function of the speed and mass of a vehicle is shown in Fig. 2. Wheels and axles convert $F_{\text{tot}}$ and the speed of vehicle to torque and angular speed requirements for differential as follows:

$$T_{\text{wheel}} = F_{\text{tot}} r_{\text{wheel}}, \omega_{\text{wheel}} = V / r_{\text{wheel}}$$  \hspace{1cm} (6)

where, $T_{\text{wheel}}$, $r_{\text{wheel}}$ and $\omega_{\text{wheel}}$ are the tractive torque, the radius and the angular velocity at the wheels, respectively.

The angular torque velocity and torque of the wheels are converted to motor rpm and motor torque requirements using the gears ratio at differential and gearbox as follows:

$$\omega_m = G_{ia} G_{gb} \omega_{\text{wheel}}, T_m = T_{\text{wheel}} G_{ia} G_{gb}$$  \hspace{1cm} (7)

where, $G_{ia}$ and $G_{gb}$ are respectively differential and gear box gears ratios.
Fig. 4: Operation of 3 phase induction motor coupler DC motor in electric hybrid vehicles drive. (a): Car run normal condition; (b): Car run in hybrid electric; (c): Car standby (OFF); (d): Starting 3 phase induction motor

RESULTS

First the system is simulated for DCM+IM test cycle. Due to the electric motor has been modeled dynamically in SIMULINK. The data for IM and EV is in the appendix. Figure 5 shows the simulation block diagram. The drive cycle gives the required vehicle speed then the torque and speed requested from the electric motor. The current drawn from IM power supply shows the battery performance.

DISCUSSION

Figure 4 and Table 1 working mode and power flow route of HEV drives the wheel. In parallel mode which is shown in Fig. 4b, both the ICE and the main motor drive the wheels. Parallel mode occurs when high output is needed. The serial and parallel mode is shown in Fig. 4c. When the state of charge of the battery is low, the ICE drags the M/G to charge the battery and drives the wheels at the same time.
Table 1: Operation of three phase induction motor coupler DC motor in electric hybrid vehicles drive

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Operation 1</th>
<th>Operation 2</th>
<th>Operation 3</th>
<th>Operation 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car run use energy</td>
<td>Car run use energy</td>
<td>Car starting engine use</td>
<td>Starting three induction motor</td>
<td></td>
</tr>
<tr>
<td>three phase induction motor</td>
<td>three phase induction motor and adaptive energy DC motor</td>
<td>energy battery to on DC Motor</td>
<td>motor use energy</td>
<td></td>
</tr>
<tr>
<td>Supply from battery</td>
<td>energy DC motor</td>
<td>DC</td>
<td>battery and generator</td>
<td></td>
</tr>
<tr>
<td>Engine</td>
<td>Run</td>
<td>Run</td>
<td>Run</td>
<td></td>
</tr>
<tr>
<td>DC machine</td>
<td>As generator to charger</td>
<td>Run</td>
<td>As generator to charger</td>
<td></td>
</tr>
<tr>
<td>battery</td>
<td>Run</td>
<td>Run as motor and coupler</td>
<td>As motor starter to run engine</td>
<td></td>
</tr>
<tr>
<td>Three phase induction motor</td>
<td>Close</td>
<td>Stop</td>
<td>Start</td>
<td></td>
</tr>
<tr>
<td>Coupler 1</td>
<td>Open</td>
<td>Close</td>
<td>Close</td>
<td></td>
</tr>
<tr>
<td>Torque coupler 2</td>
<td>Close</td>
<td>Close</td>
<td>Close</td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td>Charger</td>
<td>Discharger</td>
<td>Charger</td>
<td></td>
</tr>
</tbody>
</table>

In the regenerative brake mode shown in Fig. 4d, the M/G and the main motor work in generator mode to charge the battery. These will decrease the fuel consumption.

The three-phase induction motor speed control was couple to DC motor in close loop schematic, as shown Fig. 5 and 8 Torque data was acquired through a Hall Effect sensor, with a torque relation speed for each 0.1 Nm shown in scale we have 1500 rpm as resulting speed.

CONCLUSION

Hybrid vehicles are coming on the transportation scene as a means to meet the increasing challenges of fuel economy and low emission of greenhouse gases. Technical and business considerations based on market demands are driving hybrid vehicle architectures to be improved day by day. In this study, the couple of the two electric motors with input-output state feedback controller combined with adaptive back-stepping observer and batteries of a typical series hybrid EV is investigated and simulated by Matlab/Simulink, has been presented and the performance and ability of control strategy is investigated. Steady-state simulation...
tools have been developed for the design and analysis of electric and hybrid electric vehicles. Simulation results have also been shown the IM and IM+DCM, maximum torque in graph Fig. 7 and 8.

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REFERENCES