Development of Independently controlled four wheel drive system for Autonomous Electric Vehicle

UREP21-062-2-022

ABSTRACT
Nowadays, due to the recent emphasis on climate changes and conventional fuel consumption practices, the general interest in electric cars has increased over time. Electric vehicles provide several advantages such as being environment friendly while providing similar performance as gasoline vehicles. This project involves the design and development of an electric vehicle with a 4x4 wheel drive functionality to enable increased control over the vehicle maneuverability.

INTRODUCTION
In this project, various motors options were analyzed, and the Brushless DC (BLDC) motors is chosen because of their several advantages such as (high torque output and high power to size ratio) over other types of motors. Among the studied control techniques for BLDC motors, PWM technique is chosen as it is the most efficient for the project. Simulation for the selected motor along with embedded system design for motor operation was carried out for different control configuration (open loop and closed loop configuration). Conventionally, most of the electric vehicles employ one or two electric motors; however, in order to achieve 4x4 wheel drive functionality, 4 BLDC motors are synchronized by using master and slave controller set up. In addition, a prototype platform is designed to mechanically assemble motors, controllers and other electric vehicle peripherals to realize the given aim.

OBJECTIVES

SYSTEM DESIGN
In order to operate a BLDC motor, the position sequence of the rotor poles is extracted by using Hall Effect sensors to correctly energize the stator with respect to the rotor. The output of the Hall Effect sensors not only helps in determining the position of the rotor poles but also the speed of the rotor. As a result, an embedded system is designed to read the Hall Effect sensor output and the corresponding speed, to produce corresponding stator energizing sequence and to regulate the speed by regulating on the energizing voltage. Pulse Width Modulation (PWM) technique is utilized to control the BLDC energization. The energizing sequence in the form of PWM from the embedded system is supplied to inverter gate switches that energizes the stator. In order achieve 4x4 drive functionality, each motor is controlled in closed loop to regulate the required speed. Each BLDC motor drive consists of BLDC motor powered with battery by means of an inverter. Motor signals (current, voltage and speed) are sensed for controlling the motor drive in correspondence to the command sent by the controller. The set up of the prototype is show in the figures below.

EMBEDDED SYSTEM DESIGN
The embedded system design is implemented by using ARM cortex-M4 STM32F303RE Controller. The system is designed to take two inputs for each motor drive circuit which are reference angle and reference speed. Two potentiometers are connected to ADC channels for turning angle and speed reading.

According to the Hall reading, the reference speed in RPM is calculated. If the actual speed is less than the reference speed, the microcontroller will increase the modulation index of PWM signal by step size, so the speed increases gradually till it reaches the reference speed. On the other hand, if the actual speed is above the reference speed, microcontroller will decrease the modulation index by the same rate. Finally, the microcontroller will send the PWM signals with the calculated modulation index to the appropriate inverter gates. The figures on the right shows the close loop control flowchart.

MOTOR DRIVE CIRCUIT DESIGN
The PCB for two types of inverter boards were printed and tested. The figure on the right shows the four inverter boards which used to energize the motor phases depending on the control signals. As a result, the control of the BLDC motor was achieved by using the designed inverter and embedded system. The output of the inverter gates with the three Hall Effect sensors signals while the motor is running are shown in below figures.

LOAD TEST ON MOTORS
Drives can have certain problems that are not always detectable unless they are put under load. Therefore, load test is important to be performed on the designed motor drive circuit to minimize any unexpected failure from occurring. Various parameters were observed, and the variation of each parameter with respect to the torque applied was studied. The graph on the right illustrates variation of input power, current and speed with torque

RESULTS

CONCLUSION
In this project, BLDC motors are utilized to design and develop an electric vehicle. Several components such as inverter, current and voltage sensors are designed. In order to demonstrate 4x4 capability, the four motors are controlled in closed loop configuration by a slave controllers. A functioning prototype of the vehicle is developed and a proof of concept of controlling four motors together in synchronism is reached.

ACKNOWLEDGEMENT
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ROAD EMULATOR MODEL
In order to calculate the required power to drive the vehicle, the effect of several mechanical forces such as gravity, air resistance, etc., was determined by developing a road emulator model on MATLAB. From the road emulator model output (shown in the table below), the 3.3kW. Assuming symmetric power distribution, each motor of power ranging between 200-400W was selected.

<table>
<thead>
<tr>
<th>Velocity</th>
<th>Velocity</th>
<th>Vehicle Mass</th>
<th>Rolling Coefficient</th>
<th>Air Density</th>
<th>Angle of Inclination</th>
<th>Force on the vehicle</th>
<th>Torque (Nm)</th>
<th>Power Required (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.204</td>
<td>100</td>
<td>0.002</td>
<td>2.2</td>
<td>0</td>
<td>132.1</td>
<td>26.9</td>
<td>132.1</td>
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<td>0.002</td>
<td>2.2</td>
<td>0</td>
<td>148.1</td>
<td>30.0</td>
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<td>0.002</td>
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<td>3.6</td>
<td>125.6</td>
</tr>
<tr>
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<td>250</td>
<td>0.002</td>
<td>2.2</td>
<td>0</td>
<td>28.0</td>
<td>5.3</td>
<td>139.5</td>
</tr>
</tbody>
</table>

SIMULATION
BLDC motor required in the implementation has been simulated using MATLAB model. The open loop operation of the motor was simulated and the relationship between the modulation index and speed of the motor was found to be linear as shown in the figures below. As a result, the need for closed loop speed control is necessary. Hence, a closed loop system was simulated to obtain the best possible output.

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