Design and Implementation of a Three-Phase Brushless DC Motor Controller for Automotive Applications

Undergraduate Student Project

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***Abstract*— This project presents the design and implementation of a Brushless DC Motor Controller primarily to address the need to expand the foothold of electric vehicles here in the country. The developed hardware is capable of over- and undervoltage, overcurrent, and over temperature protection. Aside from its smaller size relative to its power capacity, the hardware has provisions of current sensing, brakes, and analog position sensing for more advanced control algorithms in the future. The algorithm used is trapezoidal control, with open-loop speed control and peak torque limiting. The motor controller speed response is then tested with varying loads using motor coupling and an electronic load.**

I. Introduction

Today's technology allows for alternatives versus the mainstream propeller - the internal combustion engine where it burns diesel or gasoline - for automotive applications. Among the alternatives, Electric Vehicle Technology is seen as a long term solution in reducing oil consumption and carbon emissions.

However, even though there are a lot of manufacturers and distributors of electric vehicles which are locally based, "other components like motors, controllers, Li-ion Batteries and other mechanical parts still have to be imported". The emerging electric vehicle industry now poses another problem - maintenance. In order to jibe with ICE counterparts, EVs should not only be as robust and reliable, but they must also have the kind of maintenance and support that the former has. Indeed, local competence in this emerging technical eld is a must.

This study will help initiate, and ultimately increase the knowledge on the eld of electric vehicles and its components in the country.

II. PROBLEM STATEMENT AND OBJECTIVE

A robust, reliable, and efficient hardware and control scheme is required in an industry level motor controller for automotive applications to be able to cope up with internal combustion engine (ICE) counterparts.

The goal of this project is to design and implement a motor controller for a Brushless DC Motor that aims to optimize the existing solutions in terms of sizing and utilization of components. This project implements an open-loop speed control based on the Trapezoidal Control algorithm. The motor controller is designed to have the specifications as indicated in Table 1.

Constraint	Description
Supply Power	48V Battery (nominal); BMS capable
Motor and Load	48V Three-Phase Brushless DC Motor with Hall Sensors; Running with 2KW Load; 48 poles
Motor Controller Protection Features	Battery Over- and Undervoltage Protection (OVP/UVP), Overcurrent Protection (OCP), Overtemperature Protection (OTP)
Motor Controller Input	Accelerator and Brake Pedal Signal, Battery Bus Voltage, Temperature Sense Signal, Current Sense Signal

Table I. Motor Controller Specifications

III. METHODOLOGY

The project involves four (4) major processes: sizing, hardware design, hardware actualization, and software implementation. Note that the process is not explained in detail, and that this only aims to give an overview of the work done.

A. Motor Controller Sizing

In this process, the motor controller is sized depending on the calculated road load conditions and the actual test vehicle specification to determine how much power will the controller drive. The formula below was used to calculate the maximum power to be delivered to the motor. The continuous tractive power was found to be ~2KW.

$$P_{tractive} = \mu mgV + \frac{1}{2}\rho AC_D V^3 + mrV\frac{dV}{dt}$$

B. Hardware Design and Hardware Actualization

The hardware design includes the pre-calculation of component values in paper, schematic, routing and layouting, and finally, fabrication. The hardware actualization involves the physical assembly of the boards. The overall block diagram and actual image of hardware is showed below.

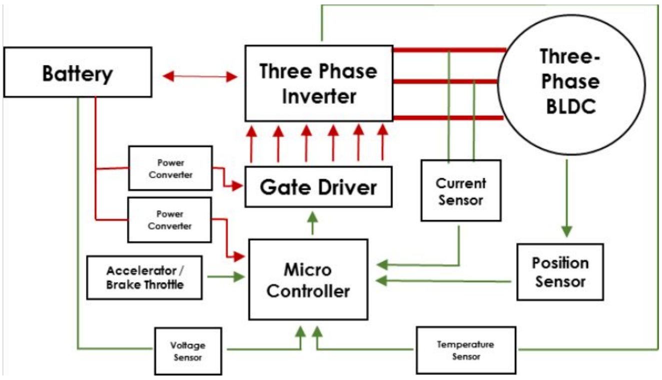

Fig. 1 Overall Block Diagram of the system

Fig. 2 Actual hardware product. Blue (control) and Yellow (power) boards

C. Software Implementation

The software implementation covers the programming process of all the functionality of the motor controller. The microcontroller used is a Microchip dsPIC32E microprocessor, capable of fast digital signal processing for real-time data analytics. The flowcharts below shows how the

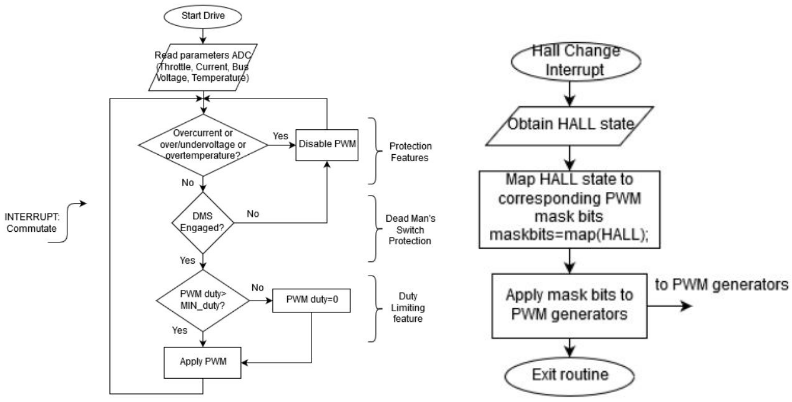

Fig. 2 Software Implementation Flowcharts for Drive (left) and Commutate (right)

IV. RESULTS AND ACTUAL OUTPUT

The motor controller was then tested from light load to nearly the rated output power of 2 Kilowatts. Below is a graph of the speed vs. throttle level to show that speed varies linearly as the throttle in a speed control algorithm.

Meanwhile, the image on the right shows the test vehicle of the motor controller that was joined in Shell Eco Marathon Asia 2016.

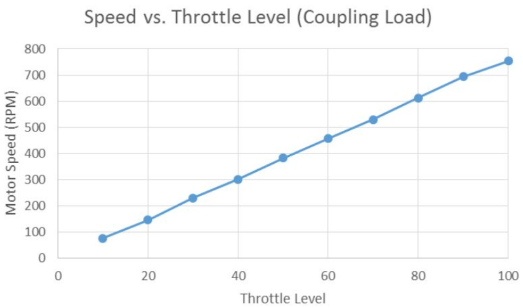

Fig. 3 Motor RPM vs. Throttle Level

Fig. 4 Test Vehicle; Team UP's entry to Shell Eco Marathon Asia 2016