

Electric Drive Optimization

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Introduction

PMBLDC

Shell Eco-Marathon

Problem Statement

Objectives

Methodology

Signal Identification and Measurement System

Vehicle Simulation

Result

Signal Identification and Measurement System

Vehicle Simulation

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Conclusion

Future Work

PMBLDC

- ▶ Permanent Magnet Brushless DC motor



Figure: PMBLDC motor, source: <http://dev.emcelettronica.com/>

Shell Eco-Marathon

- ▶ Race for mileage, not speed
- ▶ Category:
 - ▶ Urban Concept
 - ▶ Prototype
- ▶ plug-in electric
- ▶ 4 laps with 10 seconds stoppage between each lap

Problems

- ▶ Types of torque produced by PMBLDC
 - ▶ cogging torque
 - ▶ reluctance torque
 - ▶ mutual torque
- ▶ Torque ripple
- ▶ Poor Strategy

Objectives

1. To identify the output signal of the controller circuit and the hall effect sensor of the PMBLDC and develop a set of instrument for measuring the mileage of the electric vehicle.
2. To study the track profile of Sepang North Track and create a simulation program for simulating the vehicle dynamics at the Sepang North Track.
3. To compose a set of strategy to increase the mileage of the electric vehicle running on the Sepang North Track using the simulation program.

Signal Identification and Measurement System



Figure: Eclimo's speedometer

Signal Identification and Measurement System



Figure: Scooterputer, source:

<http://www.janspace.com/b2evolution/arduino.php/scooterputer>

Signal Identification and Measurement System

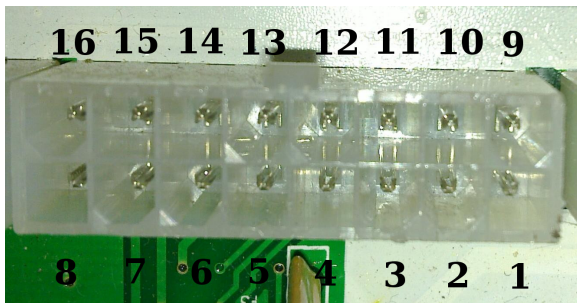


Figure: Controller 16 pin output

Signal Identification and Measurement System

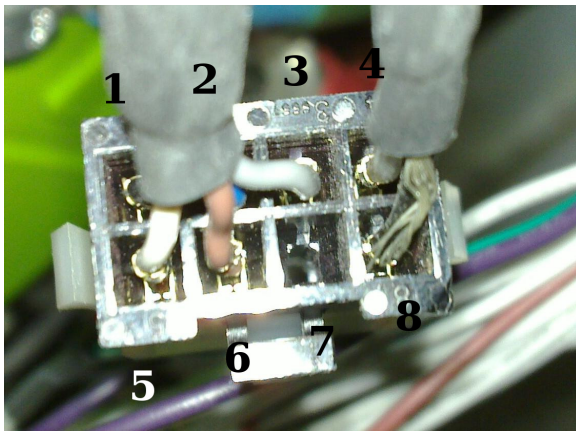


Figure: 8 pin hall effect sensors input/output

Why Vehicle Simulation?

- ▶ Baseline data
- ▶ Strategies creation tool
- ▶ Study effect of a component
- ▶ Proprietary electric motor and controller

Components

- ▶ Track
- ▶ Electric Motor
- ▶ Vehicle Dynamics

Selang North Track

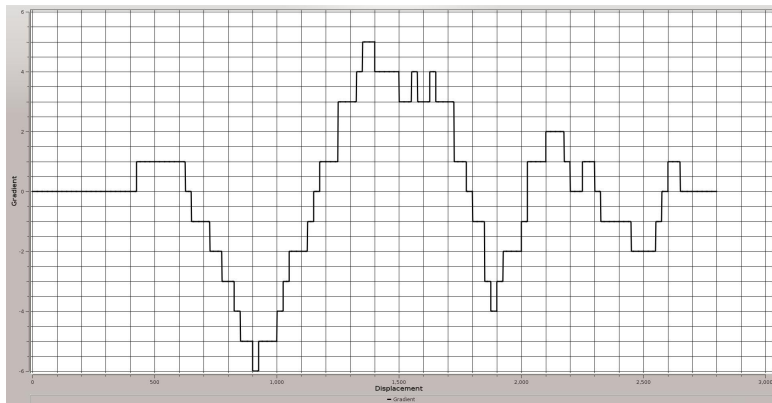


Figure: Sepang North Track gradient graph

Electric Motor

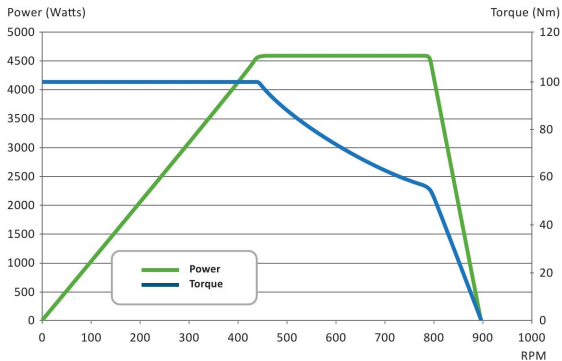


Figure: Torque and power output curve of KLD D1064R, source: KLD

Electric Motor

$$T = \begin{cases} 100N.m, & \text{for (0 - 440 RPM)} \\ [0.0003(RPM)^2 - 0.493(RPM) + 260]N.m, & \text{for (441 - 800 RPM)} \\ [-0.56(RPM) + 504]N.m, & \text{for (801 - 900 RPM)} \end{cases} \quad (1)$$

Vehicle Dynamics

- ▶ Air drag

$$F_{drag} = \frac{1}{2}\rho C_d A v^2 \quad (2)$$

- ▶ Rolling resistance

$$F_{roll} = mgC_{rr} \quad (3)$$

- ▶ Uphill/Downhill

$$F_{slope} = mgsin\theta \quad (4)$$

Vehicle Dynamics

- ▶ Combined

$$\sum F_{resistance} = mgsin\theta + mgC_{rr} + \frac{1}{2}\rho C_d A v^2 \quad (5)$$

- ▶ Vehicle acceleration

$$a = \frac{(\frac{\tau}{R} - \sum F_{resistance})}{m} \quad (6)$$

Speed Signal

Voltage Probe	Ground Probe	Voltage
2	1	-56.6
3	1	-44.2
4	1	0.0
5	1	-55.9
6	1	-56.6
7	1	0.0
8	1	0.0
9	1	-33.4
10	1	-33.4
11	1	-56.6
12	1	-28.3
13	1	-24.0
14	1	-23.3
15	1	-21.1
16	1	-23.7

Table: Result of signal tapping with the ground probe on pin 1 and voltage terminal on pin 2 to pin 16.

Speed Signal

Voltage Probe	Ground Probe	Voltage
1	2	56.8
3	2	12.4
4	2	0.0
5	2	0.0
6	2	0.0
7	2	0.0
8	2	0.0
9	2	22.6
10	2	22.6
11	2	0.0
12	2	29.9
13	2	0.0
14	2	0.0
15	2	0.0
16	2	0.0

Table: Result of signal tapping with the ground probe on pin 2 and voltage terminal on pin 1, pin 3 to pin 16.

Speed Signal

Voltage Probe	Ground Probe	Voltage
1	2	56.7
3	2	12.4
4	2	0.0
5	2	-3.4
6	2	0.0
7	2	0.7-2.4
8	2	0.7-3.2
9	2	22.6
10	2	22.6
11	2	0.0
12	2	27.8
13	2	0.0
14	2	0.0
15	2	0.0
16	2	0.0

Table: Result of signal tapping with the ground probe on pin 2 and voltage terminal on pin 1, pin 3 to pin 16 and the motor rotating.

Speed Signal

- ▶ Pin 1: Battery voltage
- ▶ Pin 2, 6, 11: Ground
- ▶ Pin 3: 12V power supply
- ▶ Pin 5: Speed output signal

Hall Effect Sensors Signal

Voltage Probe	Ground Probe	Voltage
1	8	10.4
2	8	10.4
3	8	10.4
4	8	3.1
5	8	0.2
6	8	0.1

Table: Result of hall effect sensors signal tapping with the ground probe on pin 8 and voltage terminal on pin 1 to pin 6.

Hall Effect Sensors Signal

- ▶ Pin 2, 3, 5: Hall Effect Sensors output
- ▶ Pin 1: Power Supply
- ▶ Pin 8: Ground

Measurement System

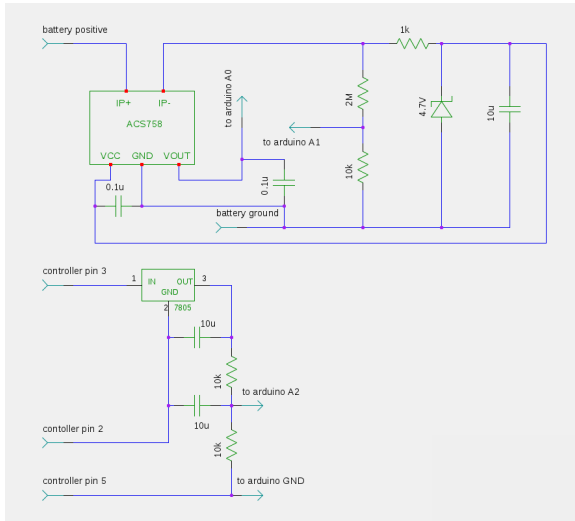


Figure: Schematic of the Measurement System

Measurement System

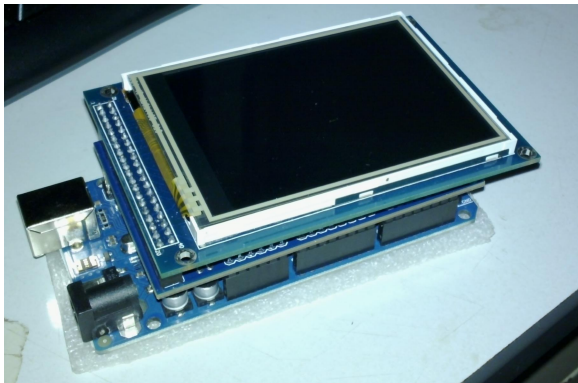
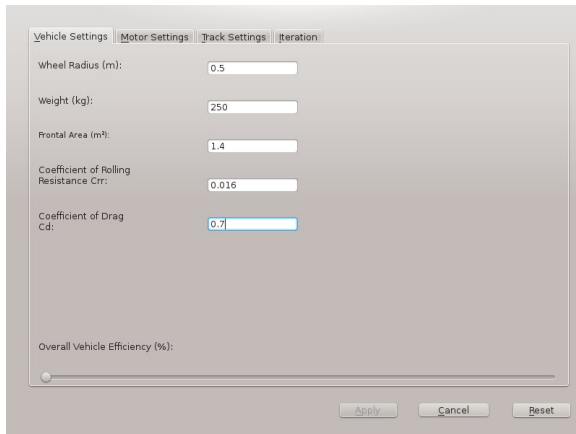


Figure: Arduino Microcontroller, display shield and LCD display

Vehicle Simulation



A screenshot of a software window titled "Vehicle Simulation" with four tabs: "Vehicle Settings", "Motor Settings", "Track Settings", and "Iteration". The "Vehicle Settings" tab is active. It contains five input fields for vehicle parameters: "Wheel Radius (m)" with value 0.5, "Weight (kg)" with value 250, "Frontal Area (m²)" with value 1.4, "Coefficient of Rolling Resistance Crr:" with value 0.016, and "Coefficient of Drag Cd:" with value 0.7. At the bottom, there is a slider for "Overall Vehicle Efficiency (%)" and three buttons: "Apply", "Cancel", and "Reset".

Parameter	Value
Wheel Radius (m)	0.5
Weight (kg)	250
Frontal Area (m²)	1.4
Coefficient of Rolling Resistance Crr:	0.016
Coefficient of Drag Cd:	0.7

Overall Vehicle Efficiency (%):

Apply Cancel Reset

Figure: Vehicle parameter for initializing the vehicle model

Vehicle Simulation

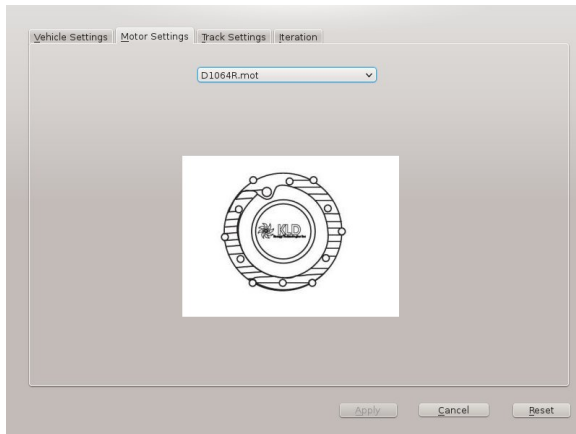


Figure: Choosing the motor model

Vehicle Simulation

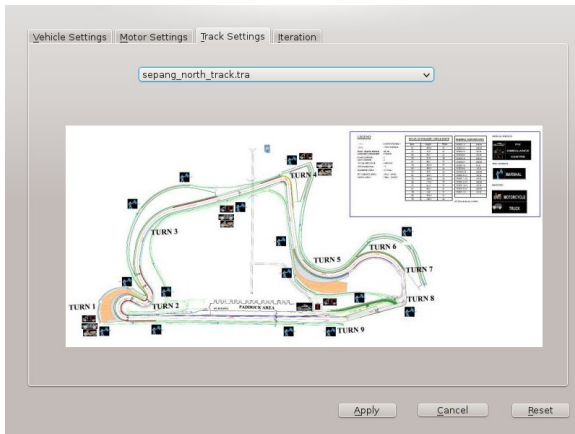


Figure: Choosing the track model

Vehicle Simulation

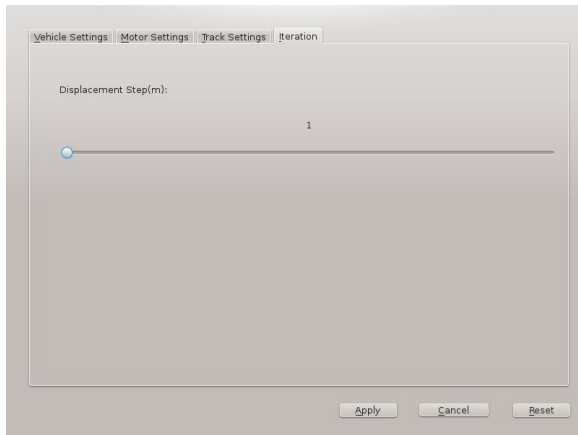


Figure: Setting the displacement interval for iteration

Vehicle Simulation

Parameter	Value
Wheel Radius	0.5 m
Total Vehicle Mass	250 kg
Frontal Area	1.4 m^2
C_{rr}	0.016
C_d	0.7

Table: Parameters for building the electric vehicle model

Strategies

1. Full Throttle Everywhere
2. Preset Strategy 1
3. Preset Strategy 2
4. Preset Strategy 3

Full Throttle Everywhere

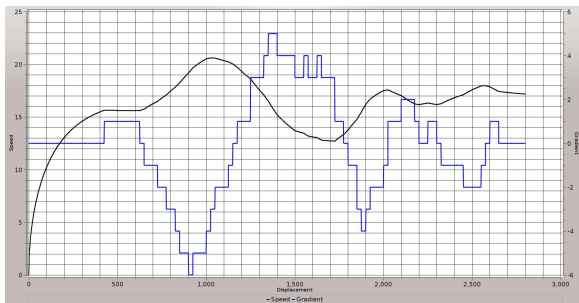


Figure: Graph of speed and gradient versus displacement for "full throttle everywhere"

Full Throttle Everywhere

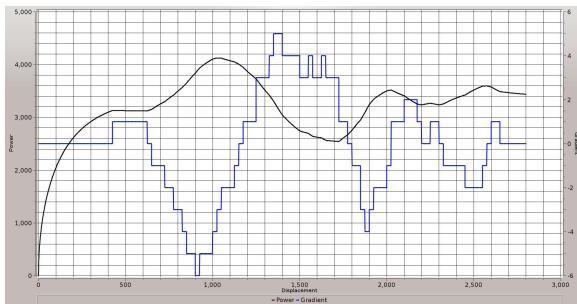


Figure: Graph of power and gradient versus displacement for "full throttle everywhere"

Preset Strategy 1

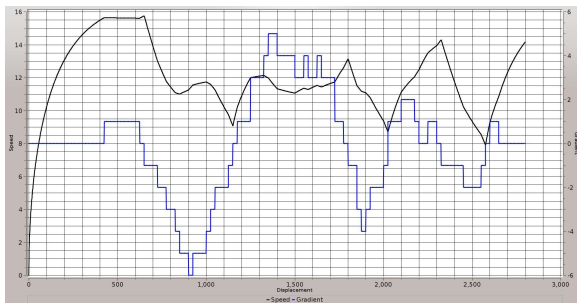


Figure: Graph of Speed and Gradient versus displacement for "Preset Strategy 1"

Preset Strategy 1

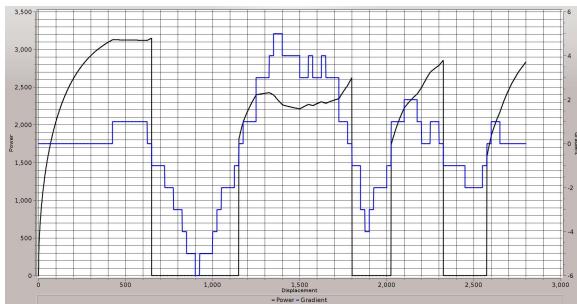


Figure: Graph of Power and Gradient versus displacement for "Preset Strategy 1"

Preset Strategy 2

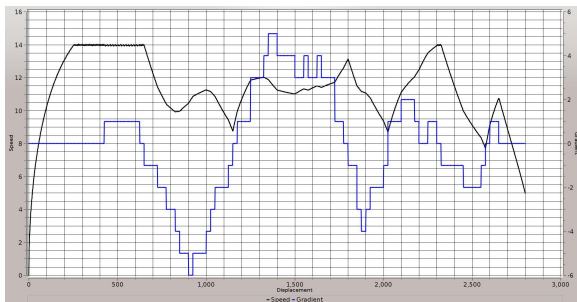


Figure: Graph of Speed and Gradient versus displacement for "Preset Strategy 2"

Preset Strategy 2

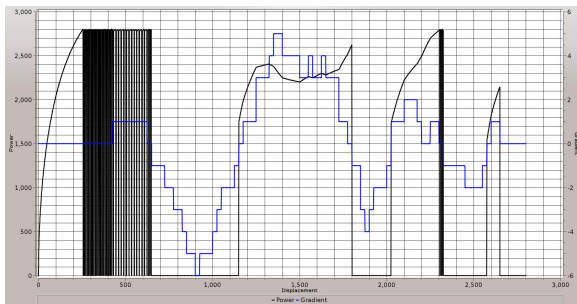


Figure: Graph of Power and Gradient versus displacement for "Preset Strategy 2"

Preset Strategy 3

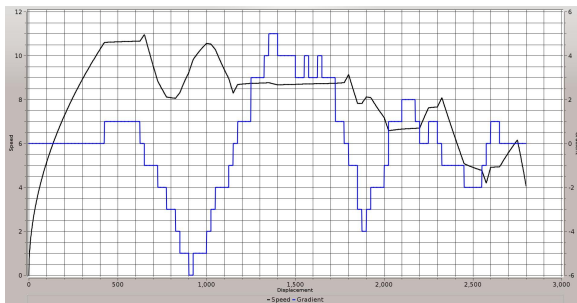


Figure: Graph of Speed and Gradient versus displacement for "Preset Strategy 3"

Preset Strategy 3

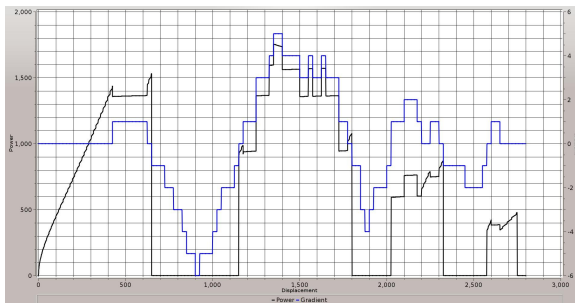


Figure: Graph of Power and Gradient versus displacement for "Preset Strategy 3"

Comparison Between Strategies

Result	FTE	PS1	PS2	PS3
Total Energy Consumption	560003J	365004J	318200J	216385J
Lap Time	186.981s	246.554s	261.699s	390.491s
Mileage	18.0 km/kWh	27.6 km/kWh	31.7 km/kWh	46.6 km/kWh

Table: Result comparison for various strategies

Comparison Between Strategies

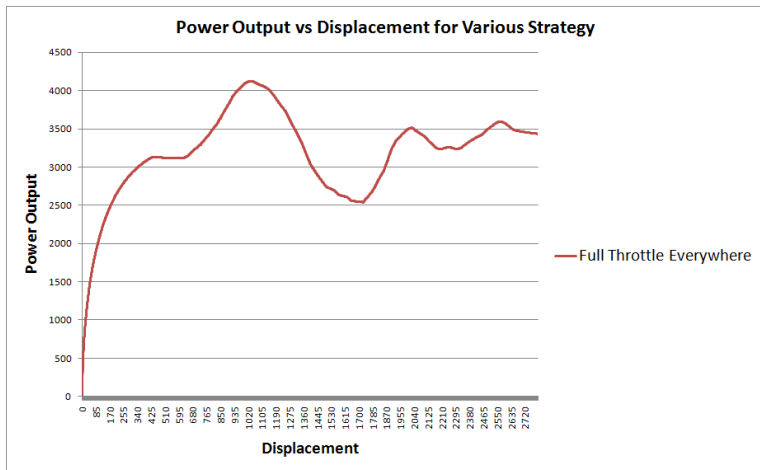


Figure: Graph of power output versus displacement for various strategy

Comparison Between Strategies

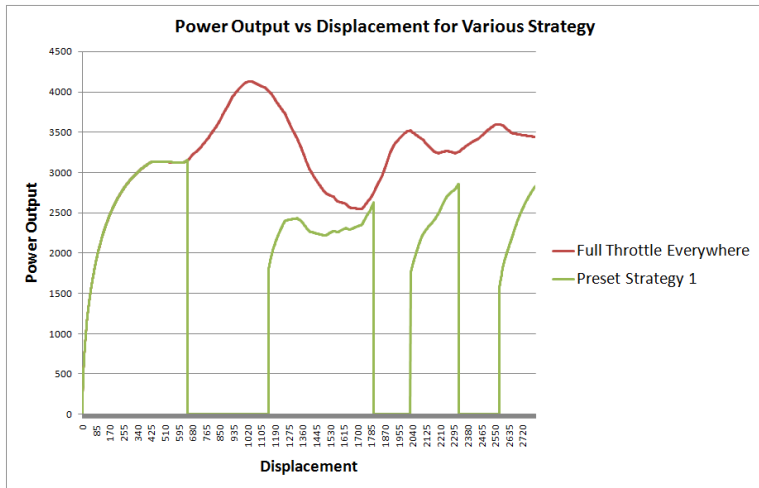


Figure: Graph of power output versus displacement for various strategy

Comparison Between Strategies

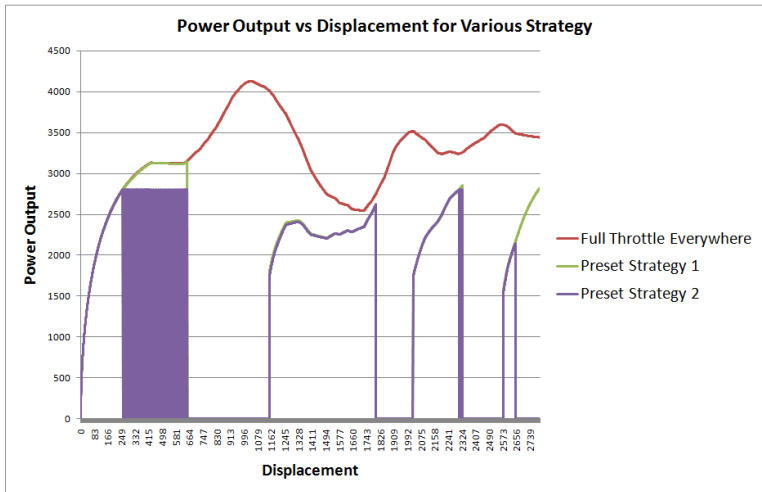


Figure: Graph of power output versus displacement for various strategy

Comparison Between Strategies

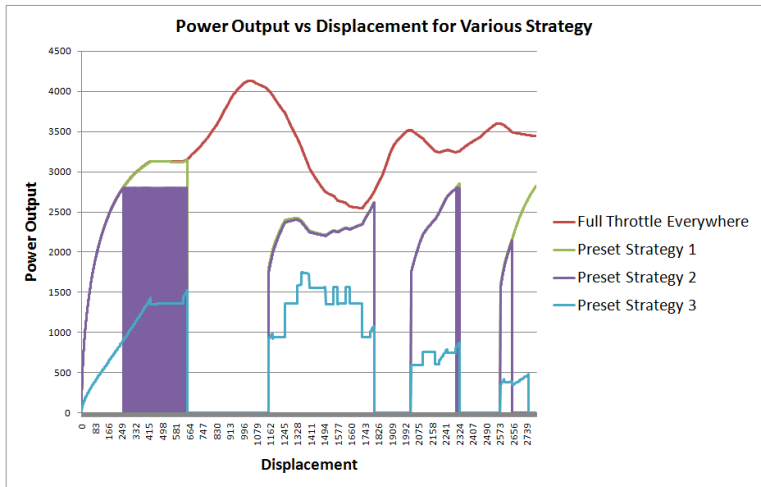


Figure: Graph of power output versus displacement for various strategy

Comparison Between Strategies

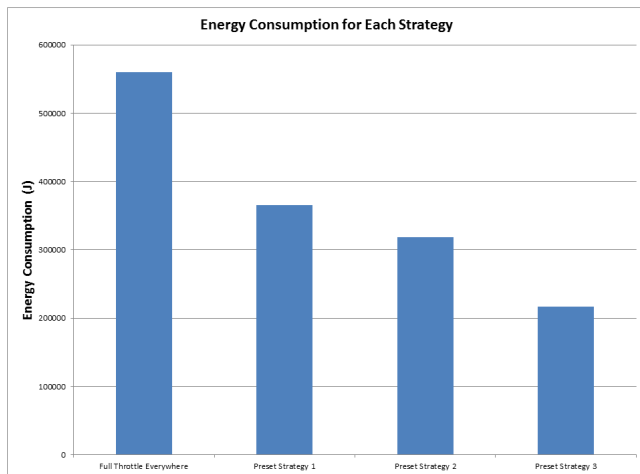


Figure: Graph of energy consumption for each strategy

Comparison Between Strategies

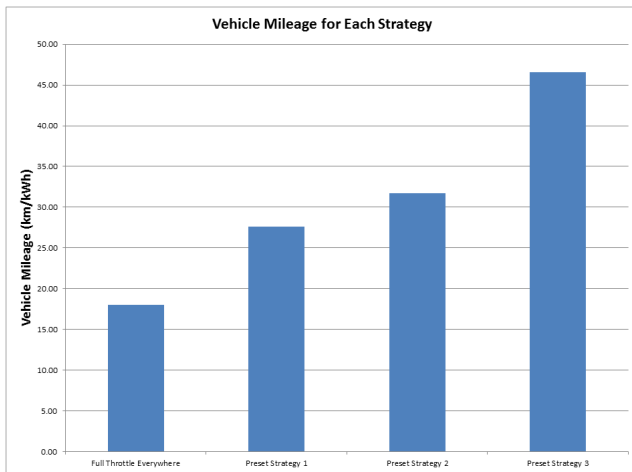


Figure: Graph of vehicle mileage for each strategy

Comparison Between Strategies

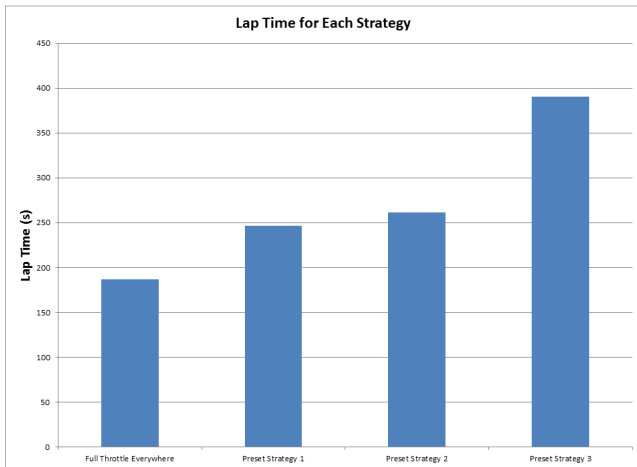


Figure: Graph of lap time for each strategy

Conclusion

1. To identify the output signal of the controller circuit and the hall effect sensor of the PMBLDC and develop a set of instrument for measuring the mileage of the electric vehicle. **(Achieved)**
2. To study the track profile of Sepang North Track and create a simulation program for simulating the vehicle dynamics at the Sepang North Track. **(Achieved)**
3. To compose a set of strategy to increase the mileage of the electric vehicle running on the Sepang North Track using the simulation program. **(Achieved)**

Future Work

1. hall effect sensor signal - controller phase current
2. improve Coefficient of Drag
3. improve vehicle simulation software

Q&A

Thank you