UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

MODELLING, SIMULATION AND SPEED CONTROL OF ELECTRIC VEHICLE

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Master of Mechanical Engineering (Automotive)

2020

MODELLING, SIMULATION AND SPEED CONTROL OF ELECTRIC VEHICLE

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this thesis entitled "Modelling, Simulation and Speed Control of Electric Vehicle" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signatue :

Name : Farahanizan Binti Saahari

Date : 5/3/2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Automotive)

Signature	:	
Supervisor Name	:	DR. FAUZI B. AHMAD
Date	:	5/3/2021

DEDICATION

To my husband,

For his advice, his patience and his faith

Because he always understood

To Adni, Arasy and Addan

for the time taken, for your love, for constantly remind me to take care of my eye health ;)

If it does not challenge you, it will not change you

ABSTRACT

This thesis presents a simulation of an Electric Vehicle using MATLAB-Simulink software. The simulation is made by utilizing a 5 degree of freedom (5-DOF) vehicle longitudinal model and a brushless direct current motor (BLDC) as the electric power train system. In order to strengthen the study and to enhance the reliability of the results, validation was made to the 5-DOF vehicle model by adopting several vehicle behaviours and characteristics of Proton Iswara used by previous researchers. The validation tests performed in this study are acceleration then braking tests at 40 and 60 km/h, while the parameters are vehicle speed, tire longitudinal slip and wheel speed of the vehicle. By using the validated vehicle model and the electric power train system, a nonlinear-proportional integral controller was designed for the electric vehicle speed control. Several simulation tests were performed by employing the same reference speed as the vehicle validation and another reference speed proposed by Society of Automotive Engineer (SAE), namely the New European Driving Cycle (NEDC) and Worldwide Harmonised Light Vehicle Test Procedure (WLTP). Finally, the potential benefits of the proposed EV system together with the proposed speed control method were investigated. The speed control of the proposed system with an appropriate controller was demonstrated to be very promising.

ABSTRAK

Tesis ini bertujuan untuk menjelas dan menerangkan simulasi kenderaan elektrikal menggunakan perisian MATLAB-Simulink. Simulasi ini dibina dan dirancang pengendaliannya dengan memanfaatkan 5 darjah kebebasan (5-DOF) kenderaan darat yang membujur dan "brushless direct current motor" (BLDC) sebagai sistem jajaran kuasa. Bagi mengukuhkan kajian serta meningkatkan kebolehpercayaan terhadap hasil kajian, pengesahan dibuat pada model kenderaan 5-DOF dengan menerapkan beberapa tingkah laku kenderaan dan ciri-ciri yang dikehendaki pada Proton Iswara yang digunakan oleh penyelidik sebelumnya. Semakan dan pengesahan ujian ini dilaksanakan melalui memecut dan berhenti pada kadar kelajuan 40 km/h dan 60 km/h, kemudiannya parameter seperti kelajuan kenderaan, gelinciran pada keadaan tayar membujur, dan kelajuan tayar diambil. Dengan menggunakan model kenderaan yang disahkan dengan sistem jajaran berkuasa elektrik, satu sistem kawalan "nonlinear-proportional integral" telah direkabentuk bagi mengawal atau menetapkan kelajuan kenderaan elektrik dan beberapa ujian simulasi telah dilaksanakan dengan menggunakan input yang sama seperti ujian pengesahan model kenderaan dan disertai dengan dua input tambahan seperti dicadangkan oleh "Society of Automotive Engineer" (SAE) iaitu "New European Driving Cycle" (NEDC) dan "Worldwide Harmonised light Vehicle Test Procedure" (WLTP). Akhirnya, sistem Kenderaan Elektrik dengan kaedah pengawalan kelajuan telah dikaji kelebihan dan potensinya. Kemampuan model kenderaan elektrik ini dalam mengawal kelajuan kenderaan menggunakan sistem kawalan yang dicadangkan ternyata berhasil.

ACKNOWLEDGEMENT

First and foremost, I want to thank my advisor Dr. Fauzi bin Ahmad. It has been an honour to be his Master Project student. I appreciate all her contributions of time, and ideas to make my Master Project experience productive and stimulating. The joy and enthusiasm he has for his research was contagious and motivational for me, even during tough times in the Master pursuit. I am also thankful for the inspiration and encouragement during conducting this thesis.

Lastly, I would like to thank my family for all their love and encouragement. For my parents who raised me with a love of science and supported me in all my pursuits. And most of all for my loving, supportive, encouraging, and patient husband Mohd Adha Ismail whose faithful support during the final stages of this Master Project is so appreciated. For the presence of my children, Adni, Arasy and Addan by my side during tough time Thank you.

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LIST OF ABBREVIATION

EV	=	Electric vehicle
BEV	=	Battery electric vehicle
HEV	=	Hybrid electric vehicle
FCEV	=	Fuel cell electric vehicle
ICE	=	Internal combustion engine
PMSM	=	Permanent magnet synchronous motor
DOF	=	Degree of freedom
CG	=	Centre of gravity
CC	=	Cubic centimetres
DC	=	Direct current
SOC	=	State of charge
WLTP	=	Worldwide harmonised light vehicle test procedure
NEDC	=	New European driving cycle
FTP	=	Federal Test Procedure
SAE	=	Society of automotive engineer
PID	=	Proportional integral derivative
APID	=	Adaptive proportional integral derivative
N-PI	=	Nonlinear proportional integral
FLC	=	Fuzzy logic controller
SMC	=	Sliding model controller

LIST OF SYMBOLS

a	=	Acceleration
γ	=	Longitudinal slip
m	=	Mass of the vehicle body
L	=	Wheelbase of the vehicle
B	=	Distance from the CG and front axle
C	=	Distance from the CG and rear axle
ω	=	Angular velocity of the wheel
R	=	Wheel radius
J	=	Wheel moment of inertia
μ	=	Coefficient of friction
f	=	Front side of the vehicle
r	=	Rear side of the vehicle
l	=	Left side of the vehicle
j	=	Right side of the vehicle
τ	=	Torque
V	=	Voltage
v	=	Velocity/Speed
ρ	=	Density of air
F	=	Force
g	=	Gravitational acceleration

θ	=	Road inclination
H	=	Height CG from ground
F_d	=	Drag force
F_r	=	Rolling resistance force
F_a	=	Aerodynamic resistance force
C_r	=	Coefficient of rolling resistance
C_d	=	Coefficient of drag force
A	=	Frontal area of the vehicle
P_b	=	Brake pressure
K_c	=	Simple pressure gain
ub	=	Brake setting
τbs	=	Brake lag
L_H	=	Inductance
R_a	=	Resistance
V_d	=	Induce voltage
E_b	=	Voltage source
T_d	=	Electromagnetic torque
I_a	=	Current
K_m	=	Motor constant
T_m	=	Mechanical torque
K_p	=	Proportional gain
K_t	=	Integral gain
K	=	Controller gain

LIST OF PUBLICATIONS

Farahanizan Saahari and Fauzi Ahmad (2020) 'Modelling, Simulation and Control of Electric Vehicle', International *Journal of Automotive and Mechanical Engineering (IJAME),* December (Submitted)

CHAPTER 1

INTRODUCTION

1.1 Overview

The electric vehicle (EV) revolution is evolving but it would not have been possible without community acceptance of improved infrastructure and technology. However, the technology's shortcomings continue to bother many consumers, such as the time needed to charge an EV and the already scarce charging infrastructure in some markets. Studies need to be carried out to solve this challenge, but actual vehicle studies entail high costs and safety concerns. Therefore, this research aims to develop an updated vehicle model that can be used to research into emerging technology. The objectives of the thesis are (1) To model and validate the EV longitudinal model using Proton Iswara; and (2) To simulate control of the EV model and thus (3) To evaluate the speed control of the designed EV in variable speed limits. The findings indicate a good prediction for the dynamic battery model through a comparative study of experimental observations and simulation results. The differences between simulation effects and model measurements can be further explored and improved.

1.2 Research Background

Malaysia has an excessively high carbon dioxide emission per capita for its population of 32-million people which are 7.27 tonnes (International Energy Agency, 2017). The explanation behind the comparatively high air pollution in Malaysia lies in the dependence on private cars since the roads in Malaysia held 29.4 million vehicles. The transport sector in Malaysia has become the second most polluting sector after electric power generation (Anonymous, 2019).

As a result, the Ministry of Energy, Science, Technology, Environment, & Climate Change established an agency responsible for decarbonizing Malaysia's transportation sector, known as The Malaysian Green Technology Corporation or GreenTech Malaysia. This agency is committed to three key goals, namely increasing the use of public transit, accelerating the introduction of green energy cars, and improving automotive quality (higher performance and low emission vehicles).

Consequently, due to the issues described above, the automotive industry is experiencing significant changes. Electric, hybrid and fuel cell vehicles have been introduced. Among these types of vehicles, EVs possess certain significant benefits compared to its alternatives. EV does not produce tailpipes emissions like a Hybrid Electrical Vehicle (HEV) since it is battery-powered; this type of vehicle does not contain an exhaust system at all. Most EV's are now equipped with state-of-the-art technologies to reduce operational expenses and conserve electricity.

However, there remains certain disadvantages that prevent people from owning EVs. Since electric vehicles do not get support from internal combustion engines such as HEV, they are only powered by batteries. Therefore, a major restriction is their very limited driving range and the challenge of providing sufficient energy storage for batteries to cover an adequate driving range.

Various efforts to reduce the expense and improve the comfort of EVs have been done in order to overcome these limitations. To optimize the effectiveness of these technologies, researchers used simulation and software modelling to construct virtual vehicles based on data obtained from the vehicles on the road. Design weaknesses can be detected in the concept phase with models that have been validated by actual test data. Improvements for vehicle behaviour can also be obtained through suitable software application in this phase.

1.3 Problem statement

Based on the research background, the study of EV technology has a significant effect on automobile technology. However, the problem statements that arise from this is are follows:

a. In past years, there has been comprehensive study on modelling the electric vehicle, however, a lot of researchers have not completely validated their models experimentally.

b. The key to design an effective driving system for EV with optimum balance of maximum speed, acceleration performance and driving range is the controller which is the pulse of the electric vehicle

c. One of the limitations of an EV is its limited driving range where charging stations are not always available. Therefore, it is critical to improve the speed control of EVs to increase the driving range.

1.4 Objectives

The aims of this study are as follows.

a. To model and validate EV longitudinal model using Proton Iswara experimental data.

b. To simulate the driving performance of EVs by using N-PI controller.

c. To evaluate the speed control of the designed EV and regenerative system in variable speed driving conditions.

1.5 Scope of the research

The scopes of the study are defined as follows.

a. The EV model used for this study is considered a vehicle longitudinal model.

b. The vehicle longitudinal model developed for this study is categorized as 5 Degree of Freedom (5 DOF) which consists of a 4-wheel engine and gearbox.

c. Braking characteristics such as tire longitudinal slip stopping time and stopping distance is not be focused on since this study is limited to the ability of the braking system to generate currents during braking.

d. It is noted that all the simulations are made through the MATLAB Simulink software programme.

1.6 Significance of the research

In order to ensure that the limitations of the EV technology is overcome, continuous study on the potential of electric vehicles should be continued. This allows researchers to gain an enhanced understanding of the whole EV system. EV modelling and simulation are used to obtain results and identify the best energy control techniques as well as the best EV performance. Simulations are used to minimize the cost and duration of EV design through configuration testing and energy storage techniques before prototype development begins. Furthermore, validation of the vehicle model plays a significant role since a good vehicle model should be developed to be almost similar to real vehicle behaviours in the simulation tool.

1.7 Thesis outline

The thesis is organized as follows, each of which contains a substantial amount of knowledge on the study:

Chapter 1 This section includes a general overview, context of the research, statement of issues, objectives, scope, and relevance of the study.

Chapter 2 This section presents a literature review regarding the system of EV. This chapter also highlights the EV modelling and simulation studies that have been conducted by previous researchers.

Chapter 3 This chapter presents the methodology that was used throughout this thesis. There are two (2) phases discussed in this chapter; Phase 1 involves modelling and validation of the EV model and Phase 2 is for the simulation and control of EV. This chapter begins with modelling the EV model by considering the vehicle longitudinal model as a vehicle model. Once the EV model has been validated, we can conduct simulations of EV for various configurations and parameters.

Chapter 4 This chapter discusses the findings and discussions that arise from simulation and testing. It elaborates on the outcomes of the EV simulation. The findings on the relationship between simulation and experimental results are discussed.

Chapter 5 This chapter provides the final comments on new ideas which inspired the creation of this study as a contribution in the EV research area. Finally, recommendations and prospects for future studies are discussed.