ELECTRIC VEHICLE POWER OPTIMIZATION STRATEGIES

AMELIA BINTI MD RASID
B011010216

Bachelor of Electrical Engineering
(Power Electronic And Drives)
June 2014

"I hereby declare that I have read through this report entitle "Electric Vehicle (EV) Power Optimization Strategies" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drives)

Signature	:	……………………………………….
Supervisor's Name	:	DR. KASRUL BIN ABDUL KARIM
Date	:	18 JUNE 2014

ELECTRIC VEHICLE (EV) POWER OPTIMIZATION STRATEGIES

AMELIA BINTI MD RASID

A report submitted in partial fulfillment of the requirement for the degree

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2014

I declare that this report entitle "Electric Vehicle (EV) Power Optimization Strategies" is the result of my own research except as cited in the references. The report has not been accepted any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	………………………………
Name	:	AMELIA BINTI MD RASID
Date	:	18 JUNE 2014

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to my supervisor Dr. Kasrul bin Abdul Karim, a lecturer from Faculty of Electrical Engineering for his supervision, support and encouragement towards completion of this project and report.

I also would like to thank my parents En Md Rasid bin Khalid and Pn Norma binti Saad and my beloved family for their moral support throughout completing this project. Not to forget to my entire friend for their endless support, assistance and ideas.

Lastly, I would like to give a token of appreciation to everyone who had contributed directly or indirectly in completing this project.

ABSTRACT

The rising concern about the global warming, emission of the hazardous gases and limited sources of the fossil fuel has made an electric vehicle one of the most topics that catch the attention of the researchers and automotive companies. However, as everyone concern, electric vehicle is driven or powered by the rechargeable battery that can only withstand certain period of time and the time taken for battery to be fully charged will take quite a long time. Therefore, in this project, the power consumption of the electric vehicle will be calculated and predicted. This will assist the driver to predict how long the vehicle can travel before the battery needs to be charged again. There are two variables that are manipulated in the calculation, the speed of the vehicle and also the gear used. Based on the two parameters, the driver can devise a strategy to optimize the power consumption of the vehicle by selecting the most suitable speed and gear when driving. Besides, this project is focusing on the algorithm development and there will be no simulation or hardware implementation involved. The calculation involves several types of the forces which includes the rolling resistance force, aerodynamic drag resistance force, climbing and downgrade resistance force and also the acceleration force. Beside the forces, the slopes of the roadway are also taken into consideration since the angle of elevation of the roadway is significantly affect the accuracy of the calculation. As a result, the power consumption of the vehicle can be predicted and therefore, the driver can estimate how far the vehicle can travel with fully charged battery. In additions, the driver also can choose the right strategy in order to optimize the power consumption.

ABSTRAK

Kesedaran yang semakin meningkat terhadap isu pemanasan global, pembebasan gas merbahaya dan sumber bahan api yang terhad telah menyebabkan kenderaan elektrik menjadi salah satu topik yang berjaya menarik perhatian para penyelidik dan juga syarikat-syarikat automotif. Walau bagaimanapun, seperti yang semua sedia maklum, kenderaan elektrik dikuasakan oleh bateri yang perlu dicas dan hanya mampu bertahan dalam tempoh masa yang tertentu sahaja serta mengambil masa yang agak lama untuk dicas sepenuhnya. Oleh itu, projek ini memfokuskan kepada pengiraan penggunaan kuasa oleh kenderaan elektrik dan pengiraan ini akan membantu para pemandu untuk meramal berapa lama dan jarak kenderaan itu boleh bergerak sebelum ianya kehabisan tenaga dan perlu dicas semula. Terdapat dua pemboleh ubah yang dimanipulasikan dalam pengiraan penggunaan kuasa kenderaan elektrik ini. Pemboleh ubah tersebut ialah kelajuan kenderaan dan juga pemilihan gear yang digunakan semasa memandu. Berdasarkan kedua-dua parameter tersebut, pemandu dapat membuat strategi pemanduan bagi mengoptimumkan penggunaan kuasa kenderaan dengan memilih kelajuan yang sesuai dan membuat pemilihan gear yang betul ketika memandu. Selain itu, projek ini memberi tumpuan kepada pembangunan algoritma sahaja di mana simulasi serta pelaksanaan prototaip tidak diambil kira. Pengiraan penggunaan kuasa kenderaan elektrik ini membabitkan beberapa jenis daya termasuklah daya rintangan putaran, daya rintangan aerodinamik, daya rintangan memanjat dan menurun serta kuasa pecutan. Selain daripada daya-daya yang dinyatakan, tahap kecerunan jalan juga diambil kira. Hal ini kerana sudut jalan juga memberi kesan kepada ketepatan pengiraan yang dilakukan. Hasilnya, penggunaan kuasa kenderaan tersebut dapat diramalkan dan oleh itu, para pemandu dapat mengagak berapa lama kenderaan tersebut mampu bergerak sebelum perlu dicas semula. Selain itu, pemandu juga dapat menggunakan strategi yang sesuai untuk menjimatkan penggunaan kuasa bateri kenderaan. Strategi yang dimaksudkan ialah pemandu memilih penggunaan gear yang yang bersesuaian dengan kelajuan yang dibawa.

TABLE OF CONTENTS

LIST OF TABLES vii

LIST OF FIGURES viii

LIST OF ABBREVIATIONS ix

CHAPTER 1 1

INTRODUCTION 1

1.1 PROJECT BAKGROUND 1

1.2 PROBLEM STATEMENT 2

1.3 OBJECTIVES 2

1.4 SCOPE OF PROJECT 2

1.5 REPORT OUTLINE 3

2.1 INTRODUCTION TO ELECTRIC VEHICLE 4

2.1.1 ELECTRIC VEHICLE COMPONENTS 5

2.1.2 ELECTRIC MOTOR AND RATINGS 6

2.2 RELATED PREVIOUS WORK 7

2.3 SUMMARY OF REVIEW 15

CHAPTER 3 16

METHODOLOGY 16

3.1 INTRODUCTION 16

3.2 METHODOLOGY OF THE PROJECT 16

3.2.1 WORKFLOW 18

3.2.2 LITERATURE REVIEW 18

3.2.3 OBTAIN THE ROADWAY / ELEVATION PROFILE 18

3.2.4 CALCULATION 27

3.2.5 ANALYSIS OF THE DATA 32

3.2.6 DISCUSSION ON THE RESULT AND REPORT WRITING 33

CHAPTER 4 34

RESULT AND DISCUSSION 34

4.1 RESULT 34

4.2 DISCUSSION 35

CHAPTER 5 38

5.1 CONCLUSION 38

5.2 RECOMMENDATION 39

REFERENCES 40

LIST OF TABLES

Table 1: Parameters for power consumption calculation 29
Table 2: Condition for Calculation..30
Table 3: Condition 1 31
Table 4: Condition 2 31
Table 5: Condition 3 32
Table 6: Condition 4 32
Table 7: Total power consumption and travelling time...35

LIST OF FIGURES

Figure 1: An Electric Vehicle System 4
Figure 2: Power transmission path in an EV 6
Figure 3: Example model of traction chain 9
Figure 4: Forces on a Vehicle 9
Figure 5: Flowchart of the project 17
Figure 6: Google earth application 20
Figure 7: Roadway from UTeM to Petronas Twin Tower 21
Figure 8: Elevation from UTeM to Petronas Twin Tower 22
Figure 9: Add path and new path dialogue box 23
Figure 10: New path dialogue box 23
Figure 11: New path dialogue box 24
Figure 12: Newly drawn path 24
Figure 13: Elevation for newly drawn path 25
Figure 14: Adding 'place mark' on the path 25
Figure 15: Elevation profile 27
Figure 16: Elementary forces acting on a vehicle 27
Figure 17: Suggested velocity of vehicle based on the elevation profile 30

LIST OF ABBREVIATIONS

UTeM	Universiti Teknikal Malaysia Melaka
EV	Electric Vehicle
ICE	Internal Combustion Engine
PM	particulate matter
HC	hydrocarbons
NO_X	nitrogen oxides
CO	carbon monoxide
SO_2	sulphur dioxide
EVs	Electric Vehicles
BMS	battery management system
kW	kilowatt
hp	horsepower
IC	internal combustion
DC	direct current
PLUS	Projek Lebuhraya Utara Selatan
JKR	Jabatan Kerja Raya

LIST OF APPENDICES

APPENDIX A	SPECIFICATION FOR SAGA BLM 1.3 MANUAL
APPENDIX B	EDUCATIONAL ACTIVITIES APPLICATION FORM
APPENDIX C	EXAMPLE OF CALCULATION

CHAPTER 1

INTRODUCTION

1.1 PROJECT BAKGROUND

The environmental concerns, energy challenges and the economical issues have urged the automotive industry to develop a clean and efficient as well as sustainable vehicle for urban transportation. Since then, the automotive industry becomes very proactive in the production of vehicles with an alternative energy to replace the conventional types of vehicles which mostly were driven by the gasoline. As a result, the alternative vehicles like electric vehicle (EV) and hybrid vehicles have been introduced and keep on evolving every day [1].

Recently, EVs have become the focus in research compared to all types of the vehicles. This is because EVs provide the means for a clean, efficient and environmentally friendly urban transportation system since it is powered by alternative energy sources and enabled by high-efficiency electric motor and controller.

Even though EVs are capable of curbing the pollution problem in a very efficient way, it does have its own disadvantages. It cannot travel in a long distances on one full charge of the battery-pack. In addition, the battery-pack itself is very expensive and the time required to recharge the battery is longer compared to filling up a tank gas. Besides EVs also have low energy density.

1.2 PROBLEM STATEMENT

Nowadays, people are more concern about the environment. The usage of fuel such as petrol and diesel to drive the vehicles is not a good choice since the combustion of the fuel produce a lot of pollutant. These pollutants then lead to the greenhouse effect and cause the increase in the temperature of the earth. Besides, fuel can be categorized as a non-renewable energy and will extinct in the future. Therefore, in order to overcome those problems, EV have been invented as an alternative and attractive solution. However, the EV depends solely on the battery as the main source to drive the vehicle and this battery require much longer time for recharge if compared to filling up a gas tank. Besides, the driver also need an additional way to assist and alert them on how longer does the battery can withstand before it needed to be recharged. Therefore, in this study, the power consumption of the electric car are be calculated and the strategy to optimize the power consumption of the EV are proposed based on the analysis of the factors that affect the power consumption of EV.

1.3 OBJECTIVES

The objectives of this project are:

1. To calculate the power consumption of the EV with given roadway profile
2. To analyze the strategy that can optimize the power consumption of EV

1.4 SCOPE OF PROJECT

This project will focus on the calculation of the power consumption of the EV based on the algorithm only. The prediction of the power consumption is essential in order to know how long the battery of the vehicle can withstand and through that, the strategies to optimize the power consumption of the batteries can be done. The parameters involved in the calculation are the rolling resistance force, aerodynamic drag resistance force, climbing and downgrade resistance force and also the acceleration force. There are three factors that are taken into consideration during the calculation which are the acceleration of the vehicle, the slope of the roadway and also the changes of the gear throughout the driving. The journey for the calculation starts from Universiti Teknikal Malaysia Melaka (UTeM) to Petronas Twin Tower and the total journey roughly about 136km. However, the simulation and hardware implementation of the EV will not be covered in this project.

1.5 REPORT OUTLINE

This report consists of five chapters. Chapter one is “Introduction” part. This chapter discuss about the project background, problem statement, objectives and lastly the scope of the project.

Chapter two is about the “Literature Review”. This chapter describe about the theory of the EV and also the past research or study that have been carried out and published. Besides, this chapter also summarizes the ideas of others that are related to this project.

Chapter three is the “Methodology” section. It includes about the calculation of the power consumption of the EV by using the algorithm only. There is no simulation or hardware implementation involves.

“Results and Discussion” is in chapter four. In this chapter, the results from the calculation are analyzed to know the power consumption of the EV.

Chapter five is the “Conclusion and Recommendation”. This chapter concludes the outcome of the project and recommendation to improve the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO ELECTRIC VEHICLE

EV is a new technology that has been rapidly developed. This technology gets the attention due to awareness to the environment and the facts that fuel is non-renewable energy and EV is able to curb the pollution problem since it does not have emission of pollutant. Therefore, EV has become the alternative way to overcome those problems.In order to be classified as an EV, the vehicle must have the following features:

1. The energy source is portable and electrochemical or electromechanical in nature
2. Traction effort is supplied only by an electric motor

The block diagram of an EV system driven by a portable energy source is shown in Figure 1. The electrochemical energy conversion linkage system between the vehicle energy source and the wheels is the powertrain of the vehicle. The powertrain has electrical as well as mechanical components [3].

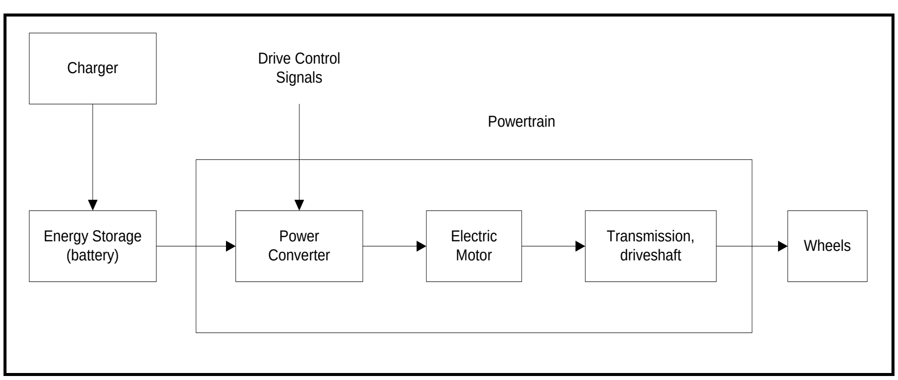

Figure 1: An Electric Vehicle System

The energy storage device like battery –pack stores the fuel for the EV for energy delivery on demand. The primary source of energy for electricity generation for EVs is varied, ranging from fossil fuel to solar-based energy. For the battery-based EV, the electric power transmission system is the system required in order for the fuel to be delivered in the form of electricity to the vehicle. As for solar EVs, the solar panel and a power converter is used to charge the batteries on the vehicle. The special feature of these EVs is that these are zero emission vehicles (ZEVs) as far as pollution within the vehicle is concerned [3].

2.1.1 ELECTRIC VEHICLE COMPONENTS

The system for the automobile is very complex. This is due to numerous hardware component and software algorithms interconnected through mechanical links and electrical communications network. The system level design extends to intricate details of subsystem or component design in the automobile design. The system design fundamental includes the physics of motion, energy, power and the energy conversion principle. The primary hardware components for automobile are the energy conversion and the power transmission devices.

Internal combustion (IC) engine, energy storage device and electric machine are the primary energy conversion devices for EV. IC engine is a heat engine that converts chemical energy to mechanical energy. As for electric machine, it can be used either as motor or generator. The electrical energy will be converted as mechanical energy in a motor state and in contrast, the mechanical energy will be converted to electrical energy once it is used as generator.

The energy storage devices and electrical-to-electrical power or energy conversion is very important in EVs and the most common energy storage device for EV is a high-energy capacity battery pack. In order to control the electric machine and also to deliver the power required and as requested by the demands and feedback signals, electric drive is needed. The drive is electrical to electrical energy conversion devices that convert steady voltages with fixed frequency. The results from the conversion are variable voltage supply for the electric machine.

The drives also can process the electrical power in other way round when the machine operates as generator. In order to convert the high voltage to low voltage levels convert the DC other way round, DC-DC converter is required. This converter can be bidirectional and it is made up from power electronic devices and energy storage inductors. This component is very important and it acts as the key component for the fuel cell interface with electric motor drive.

Powertrain is the path for the flow of energy in a vehicle starting from the energy source and ends at the wheels with the deliver propulsion. In EV, the power transmission path is electrical except for the coupling devices between the wheels and electric propulsion motor. This path is known as electric power transmission path as shown in Figure 2. The difference of this path compared to IC energy vehicle is the power and energy flow can be directional. This means that when the vehicle brakes to slow down or stops, the kinetic energy is processed back to energy storage device.

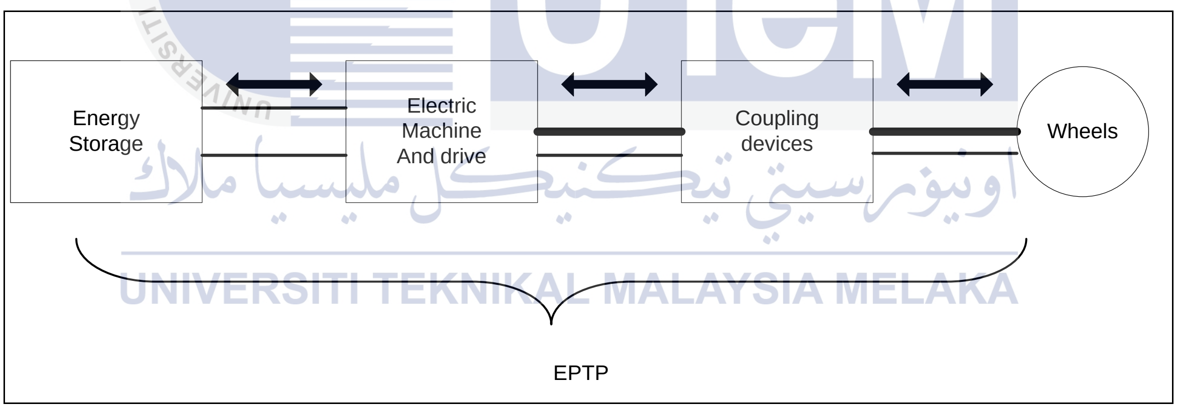

Figure 2: Power transmission path in an EV

2.1.2 **ELECTRIC MOTOR AND RATINGS**

Electric motor capability is described by using kilowatt (kW) or horsepower (hp) ratings. Rated power is the power that an electric motor can continuously deliver without overheating, which is typically a derated figure. The motor can deliver two to three times the rated power within a short period of time. Because of that, higher power and torque is available from an electric motor for acceleration and the torque can be maximum under stall condition which is at zero speed.

The types of the motor determines whether maximum torque is availabe at zero speed or not. High torque is available at The peak or rated power from a motor is obtained at base speed (ω_b) when the motor characteristics enter the constant power region from constant torque region once the voltage limit of the power supply is reached.

The motor rated speed (ω_{rated}) is at the end of the constant power region. High torque is produces by electric motor even at zero speed and typically, it has constant power characteristics over a wide speed range. Because of that, electric motor can be attached directly to the drive wheels to accelerate the vehicle from zero speed to its maximum speed. Therefore, the speed of the vehicle and the motor can be controlled directly through the power electronic converter feeding the current into the motor. Essentially, there is no requirement for a transmission with an electric motor other than a fixed gear for appropriately sizing the motor.

There are several important characteristics of an EV motor. They includes the flexible drive control, fault tolerant, high efficiency and low acoustic noise. Besides, the motor drive also should be able to handle voltage fluctuations from the source.

2.2 RELATED PREVIOUS WORK

The research paper by Haddoun, Benbouzid, Diallo, Abdessemed, Ghouili and Srairi entitle “A Loss Minimization DTC Scheme for EV Induction Motors” proposes a strategy to minimize the losses of an induction motor propelling an EV. The proposed control strategy is based on a direct flux and torque control scheme. The stator flux is utilized as a control variable and the flux level is selected in accordance with the torque demand of the EV to achieve the efficiency-optimized drive performance [2].

Since the vehicle dynamics influenced the energy efficiency, the EV dynamics are taken into account in the research. There are several forces that are included for the vehicle dynamics analysis follows:

Nomenclature:

F_{ω} Road Load

F_{ro} Rolling resistance force

F_{sf} Stokes' force or viscous friction force

F_{ad} Aerodynamic drag force

F_{cr} Climbing and drag force

P_{v} Vehicle driving power

Mathematical equation:

$$F_{\omega} = F_{ro} + F_{sf} + F_{ad} + F_{cr} \tag{2.1}$$

where;

$$F_{ro} = \mu mg \cos \alpha \tag{2.2}$$

$$F_{sf} = k_{A} \upsilon \tag{2.3}$$

$$F_{ad} = ½\, \xi\, C_{\omega} A_{f} (\upsilon + \upsilon_{o})^{2} \tag{2.4}$$

$$F_{cr} = \pm\, mg \sin \alpha \tag{2.5}$$

Besides, the formula for the power required to drive a vehicle in the motor ratings and transmission also provided as below:

$$P_{v} = \upsilon F_{\omega} \tag{2.6}$$

In the paper "High Level Optimization of Electric Vehicle Power-Train with Doehlert Experimental Design" written by Jaber, Fakhfakh and Neji, an optimization is reported for the determination of Time Response (T_r) and Power (P) of EV. Several factors that are able to influence the T_r and P are selected. They are back-electromotive-force, stator d- and q- axes inductances, switching period, battery voltage stator resistance and torque gear ratio [4].

Figure 3 shows the chain of electric traction. The traction chain determines the performance of EV. High level modeling of electric traction chain is described using VHDL – AMS and it is then simulated using Simplorer 7.0 software.

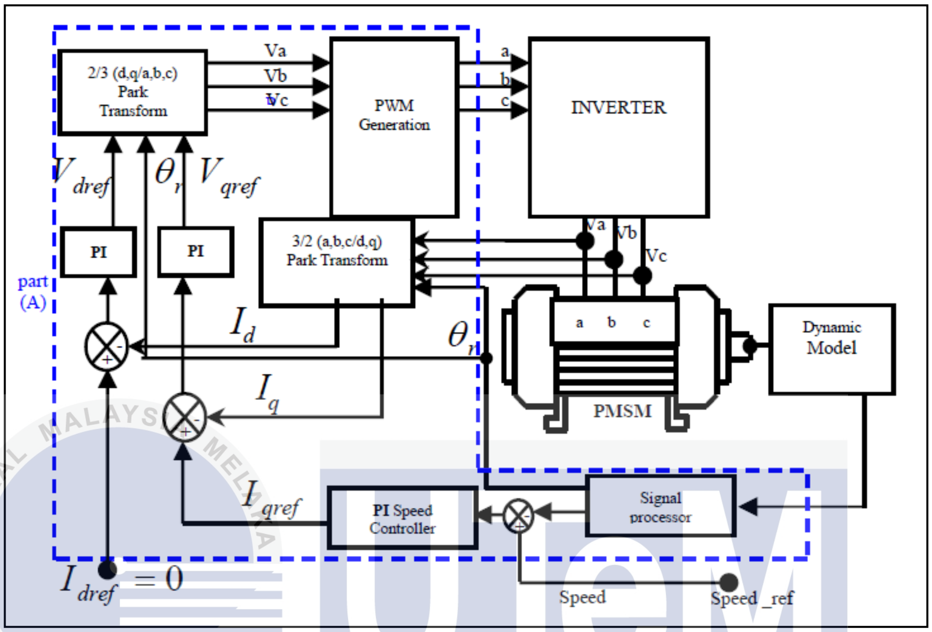

Figure 3: Example model of traction chain

Besides, in this paper, simple motion equation is derived in order to discuss the ecological driving of an electrical vehicle. In order to maintain the simplicity, acceleration resistance is the only resistance that is taken into consideration. Other resisting forces like rolling, aerodynamics and incline force are neglected. Figure 4 illustrates one wheel model used in order to derive the simple mathematical model of the EV.

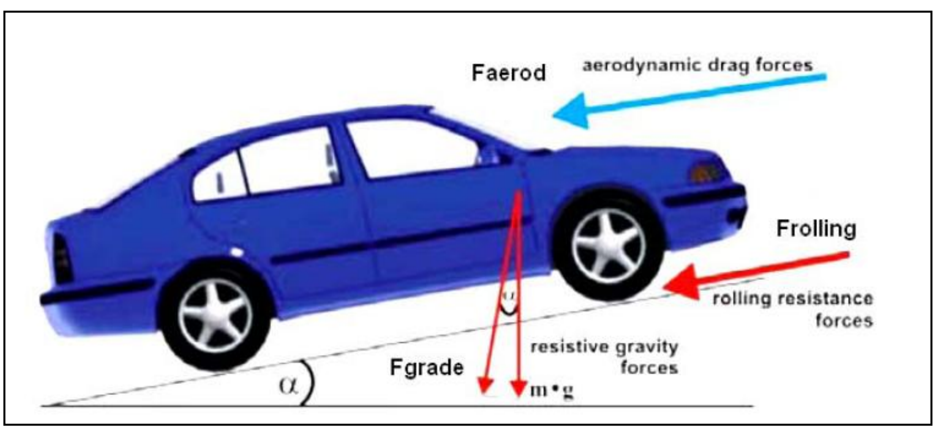

Figure 4: Forces on a Vehicle

Nomenclature:

$F_{rolling}$	Rolling force
F_{aerod}	Aerodynamics force
F_{grade}	Incline force
P_a	Power EV must develop at stabilized speed
P_m	Power available in the wheels
γ	Acceleration of the vehicle (s-2)
T_1	Load torque (N.m)
W_m	Angular speed of the motor (rad/s)
f	Coefficient of rolling friction
Mv	Total mass of the vehicle (kg)
g	Acceleration of terrestrial gravity (m/s^2)
l	Density of the air (kg/m^3)
S	Frontal surface of the vehicle (m^2)
Cx	Drag coefficient of the vehicle
V	Speed of the vehicle (m/s)
α	Angle that make the road with the horizontal (in °)
r_m	Torque gear ratio
R_{wheels}	Wheels radius (m)
T_{em}	Electromagnetic torque of the motor (N.m)
T_l	Load torque (N.m)

Mathematical model:

$$F_{rolling} = f \, x \, M_v \, x \, g \tag{2.7}$$

$$F_{aerod} = ½. \, l.s.c_x.V^2 \tag{2.8}$$

$$F_{grade} = M_v.g \sin\alpha \tag{2.9}$$

$$P_a = V. \, (F_{rolling} + F_{aerod} + F_{grade}) \tag{2.10}$$

$$P_m = T_{em}. \, r_m. \, (V/R_{wheels}) \tag{2.11}$$

Based on the fundamental principle of dynamics, an acceleration of the vehicle is given by:

$$\gamma = (P_m - P_a / M_v V) \tag{2.12}$$

$$\gamma = [T_{em} . r_m - R_{wheels} . (F_{Rolling} + F_{aerod} + F_{grade}) / M_v . R_{wheels}] \tag{2.13}$$

$$T_1 = R_{wheels} . (F_{Rolling} + F_{aerod} + F_{grade}) \tag{2.14}$$

$$W_m = (r_m / R_{wheels}) . (d\gamma/dt) \tag{2.15}$$

EV with high energy efficiency have been develop since fuel consumption has been a key issue in the performance of cars in recent years. However, EV has small battery energy stored. This caused problems related to the running distance per charging, long charging time and many more.

Therefore, Tanaka, Ashida, and Minami have produced a paper concerning “An Analytical Method of Electric Vehicle Velocity Profile Determination from Power Consumption of Electric Vehicles”. In this paper, a method to obtain the performance of the EV from the equations between the measured acceleration, a and the input or the regenerated electric power, P is described analytically. This method is used because it can demonstrate possibilities to predict the performance of EVs using stored electric energy and the driving root [7].

The equations or the mathematical model involved in this analytical are:

Nomenclature:

F	Force [N]
F_a	Acceleration resistance
F_r	Rolling resistance
F_k	Air resistance
F_t	Inclination resistance
p	Output power
ηP	Input efficiency
η	Efficiency

P	Input power
E	DC motor's back – electromotive force
I	Current
a	Acceleration
m	Vehicle weight (kg)
μ	Rolling resistance constant
k	Air resistance constant (kg/m)
v	velocity (m/s)
g	Gravitational force
θ	Angle
r	Coil resistance (Ω)
ϕ	Magnetic flux on the armature
N	Reduction ratio caused by gears and others
R	Radius of the tire
E	Back-electromotive force
t	Time

Mathematical equations:

$$F = F_a + F_r + F_k + F_t\,[N] \tag{2.16}$$

where;

$$F_a = ma \tag{2.17}$$

$$F_r = mg\mu \tag{2.18}$$

$$F_k = kv^2 \tag{2.19}$$

$$F_t = mg\,sin\theta \tag{2.20}$$

Other equations involves are as below:

$$p = Fv \tag{2.21}$$

$$\eta P = p = Fv \tag{2.22}$$

$$\eta = (P - I^2r) / P \tag{2.23}$$

$$P = I^2r + Fv \tag{2.24}$$

$$F=(Ka\phi N / R)\,.\,I = KI \tag{2.25}$$

$$E = (Ka\phi N / R) \,.\, v = Kv \tag{2.26}$$

$$I=F/K \tag{2.27}$$

$$P= (r / K^2).F^2 + Fv \tag{2.28}$$

$$a = [-2r(kv^2 + mgu) – vK^2 \pm K(\sqrt{v^2K^2+4Pr})] / 2mr \tag{2.29}$$

$$v_{t+\Delta t} = v_1 +a.\Delta t \tag{2.30}$$

Ren, Crolla and Morris have produced a research paper concerning "Effect of Transmission Design on Electric Vehicle (EV) Performance". This paper investigates whether it is possible to manage the efficiency of the electric motor, so that by using an intermediate gearbox, the motor is operated more often in its higher efficiency region [6].

Therefore, a simple EV model is developed and its energy consumption with a variable and fixed ratio gearbox over a standard driving cycle is predicted in order to understand whether this could offer significant efficiency gains.

The EV performance is modeled by using the QSS toolkit. It is a quasistatic simulation package based on the collection of Simulink blocks and the appropriate block can be run in any Matlab/Simulink environment [4].

The paper "Real-Time Prediction of Battery Power Requirements for Electric Vehicles" written by Kim, Lee and Shin proposed an efficient way of predicting the power requirements of EVs based on a history of their power consumption, speed, and acceleration as well as the road information.

The battery management system (BMS) uses the predicted power requirement to prevent the damage of battery cells that might results from the discharge rates. The prediction also helps BMS to efficiently schedule and allocate battery cells in real-time to meet an EV's power demand [5].

During the power requirement prediction, the forces that acting on the vehicles are being considered. The forces are the acceleration, aerodynamic, load related to steepness and rolling resistance. The equations used are as follows:

Nomenclature:

P_{total}	Power requirement
F_a	Acceleration force
F_{air}	Aerodynamic force
F_c	Load related to steepness
F_r	Rolling resistance
V	Vehicle's forward speed
m	Mass of the vehicle
a	acceleration
ρ_{air}	Air density
C_d	Drag coefficient
A	Frontal area
g	Gravitational acceleration
θ	Road slope
K_r	Rolling resistance coefficient

Equation:

$$P_{total} = F_a.\ V + F_{air}.\ V + F_c.\ V + F_r.\ V \tag{2.31}$$

where ;

$$F_a = m_a \tag{2.32}$$

$$F_{air} = ½\ \rho_{air}.\ C_d.\ A.V^2 \tag{2.33}$$

$$F_c = mg \sin \theta \tag{2.34}$$

$$F_r = mg\ K_r \tag{2.35}$$

2.3 SUMMARY OF REVIEW

Based on all the literature review, it shows that there are some research have been done are concern about the power consumption of the EV. There are some that proposed the strategy to minimize the losses of the induction motor and some are concern about the EV powertrain. In order to obtain the result, the researchers have been done by using simulation method. The simulations have been done by using Simplorer 7.0 software and also Matlab/Simulink environment. There are also research that have been done in order to predict the power requirement based on the history of the EV power consumption, speed, acceleration and also the road information.

Majority of the research that have been done concerned about the power of the EV. The power includes the delivering power at the motor itself and also the power consumption. The similarities between all the research paper that have been done and this project is the mechanics and aerodynamic of the vehicles are taken into account. The basic forces that acting on the vehicle must be included during the calculation. The forces are the resistance force, acceleration force, aerodynamic force and also the climbing force.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the details of the project are explained step by step. The project is discussed starts from the beginning until to the end of the process. Since this project focus on the algorithm only, the hardware implementation and software will not be involved and discussed in this chapter.

3.2 METHODOLOGY OF THE PROJECT

Figure 5 shows the flowchart of the overall activities for this project. Flowchart is very important and crucial in doing the project. This is because, if any problems occur during the implementation of the project, it may be easily solved by referring to the flowchart. Furthermore by using the flowchart, the step and procedure can be easily followed since it shows the whole process in graphical terms instead of long words explanation.

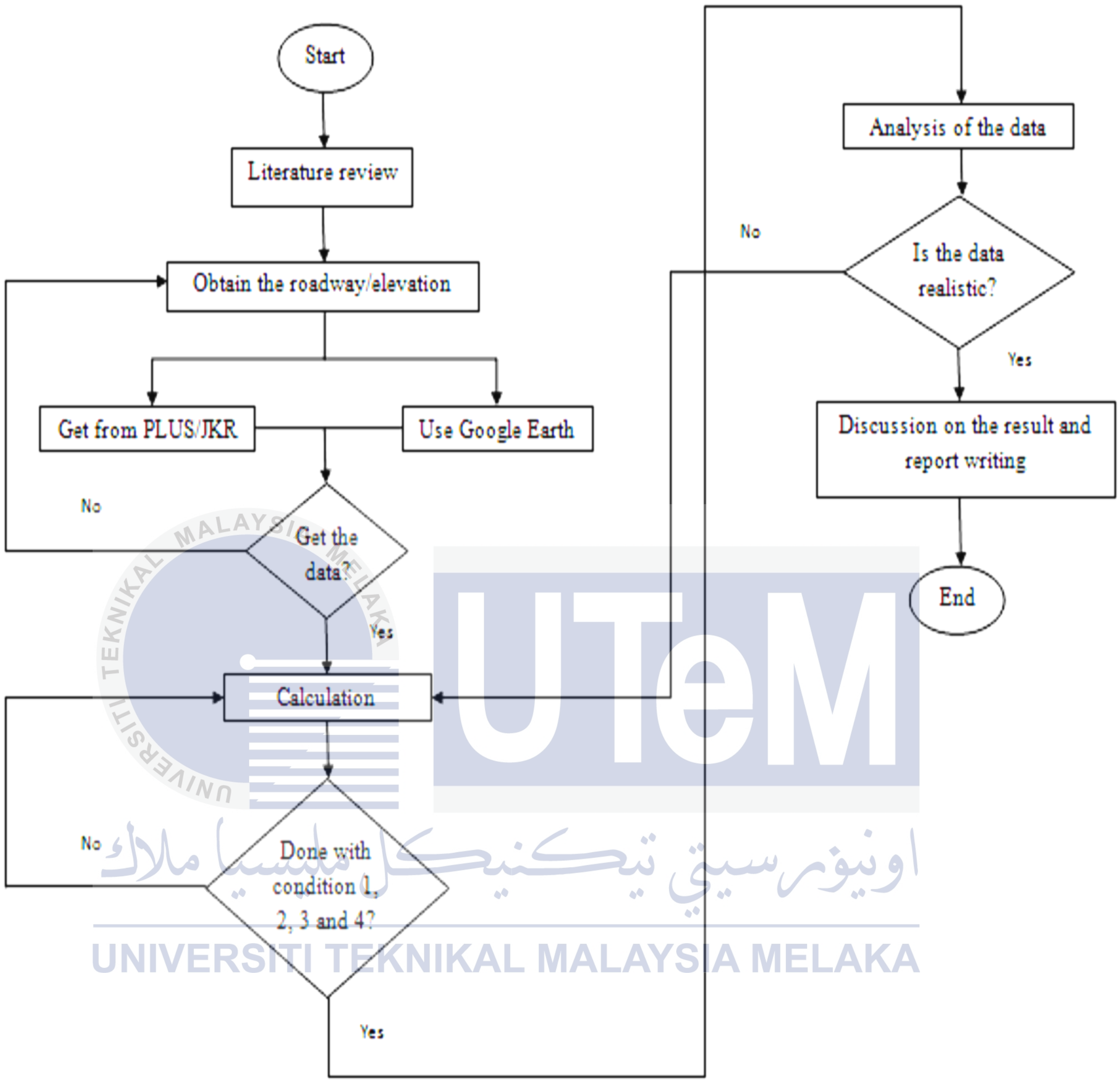

Figure 5: Flowchart of the project

3.2.1 WORKFLOW

The procedure for completing the project is explained in more details in the next subsection.

3.2.2 LITERATURE REVIEW

Literature review is very important because through literature review, student can understands more about the project. This is because literature review is about collecting and gathering as many information as possible that is related to the proposed project.

Therefore several conference papers, research papers, and journal that is related to EV is read and summary about it had been done. Based on the summary, the principle of the EV can be understood and the formula used to calculate the power consumptions of the EV can be obtained.

3.2.3 OBTAIN THE ROADWAY / ELEVATION PROFILE

In order to calculate the power consumption of the EV, roadway or elevation profile is very important. This due to the calculation involves the angle of the road. Without the roadway or elevation profile, the calculation is not accurate because naturally the angle of the real roadway not always 0°or flat surface. Therefore, two methods have been used to get the roadway or the elevation profile; first is trying to get the data from Projek Lebuhraya Utara Selatan (PLUS) or Jabatan Kerja Raya (JKR) and second is through the Google Earth application.

3.2.3.1 OBTAIN DATA FROM PLUS OR JKR

Several procedures have to be followed in order to get the data from PLUS since it is a big organization and has several divisions. Below are the procedures needed to be taken in order to get the information from the PLUS:

1. Write a formal letter to PLUS or email to Human Resource (HR) Department to inform PLUS about the types of data needed.
2. HR manager email all the forms and requirement in order to get the permission to obtain the information
3. Fill up and hand over the form (recommendation letter from University, project proposal and application form) to HR manager of PLUS.
4. Application will be process within two weeks.
5. HR manager of PLUS will inform the status of the application
6. After two weeks the HR manager confirmed that PLUS is unable to provide that kinds of information (roadway / elevation profile) because PLUS does not update the status of the roadway since the first time the road being build. Therefore, the information that PLUS have is not up to date and additionally, the road has also been repaired for several times.
7.

Besides PLUS, Jabatan Kerja Raya (JKR) also has been contacted to ask for the required information and unfortunately JKR is also unable to provide the required information for the project.

3.2.3.2 USE GOOGLE EARTH APPLICATION

Google Earth is one of the applications provided by Google. Google Earth which was created by Keyhole Inc is a virtual globe, map and also geographical information program that was originally called EarthViewer 3D. Google Earth maps the Earth by the superimposition of images obtained from various sources such as from the satellite imagery, aerial photography and geographical information system (GIS) 3D.

By using the Google Earth, the roadway profile is finally managed to be obtained. The procedures that have been done in order to obtain the information required are as follows:

1. The Google Earth Application is started.

Figure 6: Google earth application

2. The location of desired destination is typed at the 'Search' section. Example is 'From: Universiti Teknikal Malaysia Melaka To: Petronas Twin Tower' and the 'search' button is clicked. Google Earth will display the point from UTeM to Petronas Twin Tower. The road is highlighted with blue color. Other information such as the direction to go to Petronas Twin Tower and the distance between the two points also been displayed.

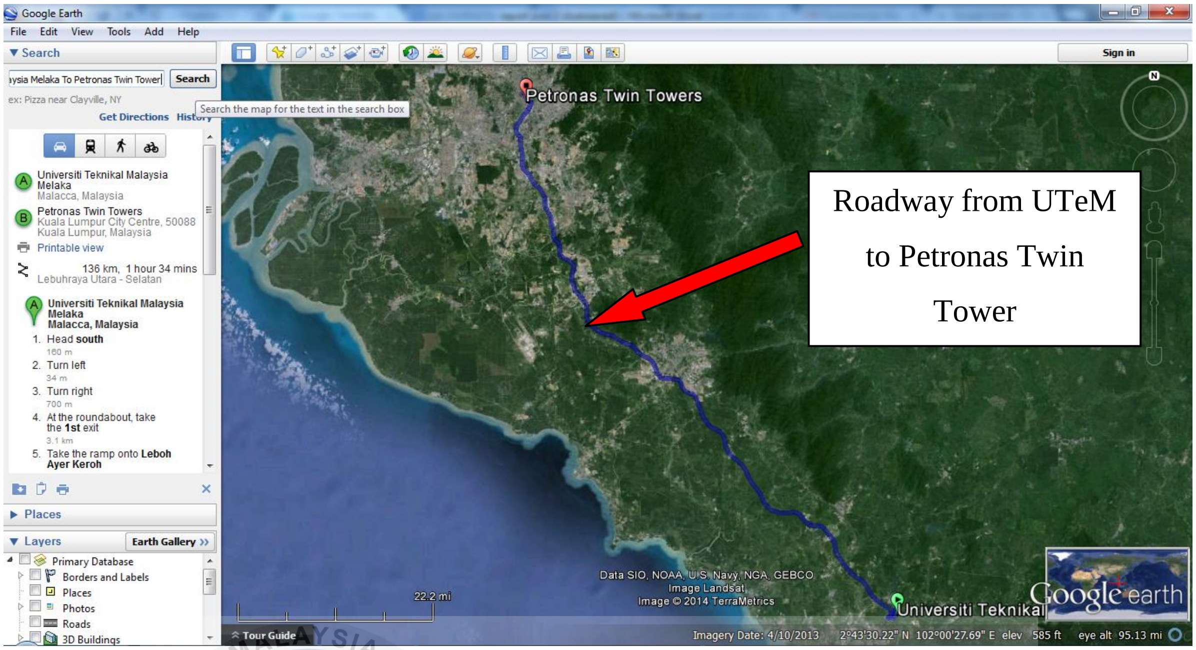

Figure 7: Roadway from UTeM to Petronas Twin Tower

3. Next, point the cursor at any point of the road that is highlighted with blue color and right clicks the mouse. The 'Show Elevation Profile' dialogue will appear and then right click the mouse. Google Earth will show the elevation profile from UTeM to Petronas Twin Tower. The mouse can be move at any point of the road or the elevation profile in order to know the specific height of the place.

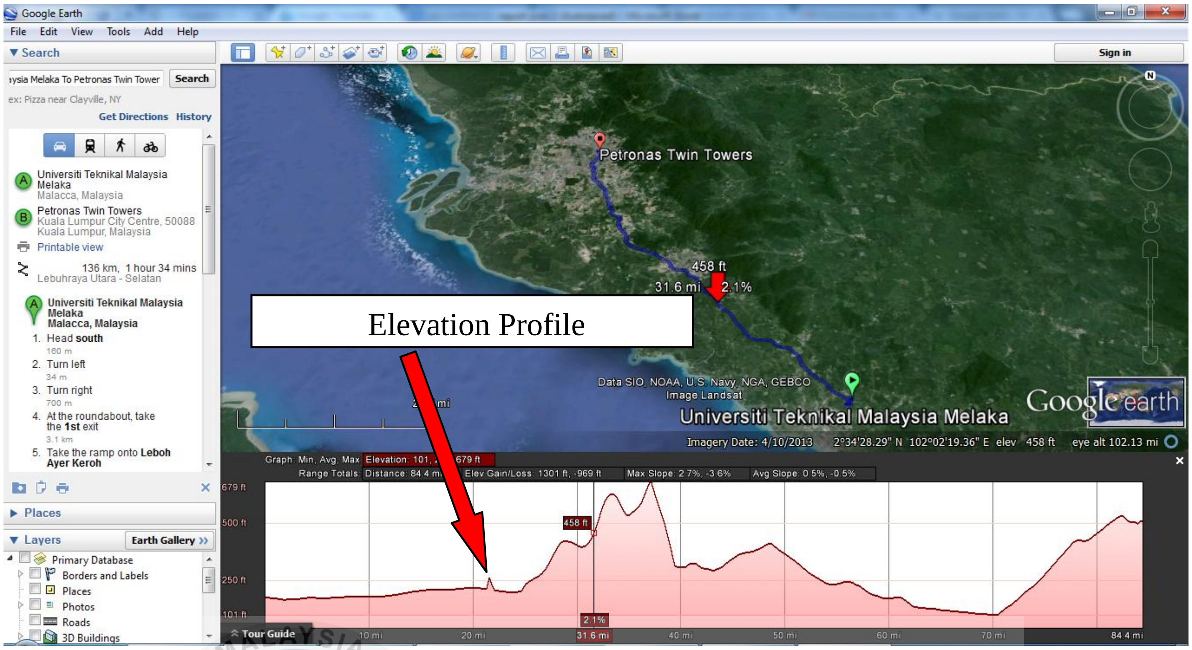

Figure 8: Elevation from UTeM to Petronas Twin Tower

4. The elevation shows by the Google Earth is directly from UTeM to Petronas Twin Tower which is about 136km. The get more accurate result of the elevation profile, the road can be drawn manually. In this case, elevation is divided into 1km distance in order to get more accurate results.

5. Zoom in specific location (UTeM). Next, click on the 'add path' and 'New Path' dialogue will appear. At 'Name' section, write any name. For example UTeM.

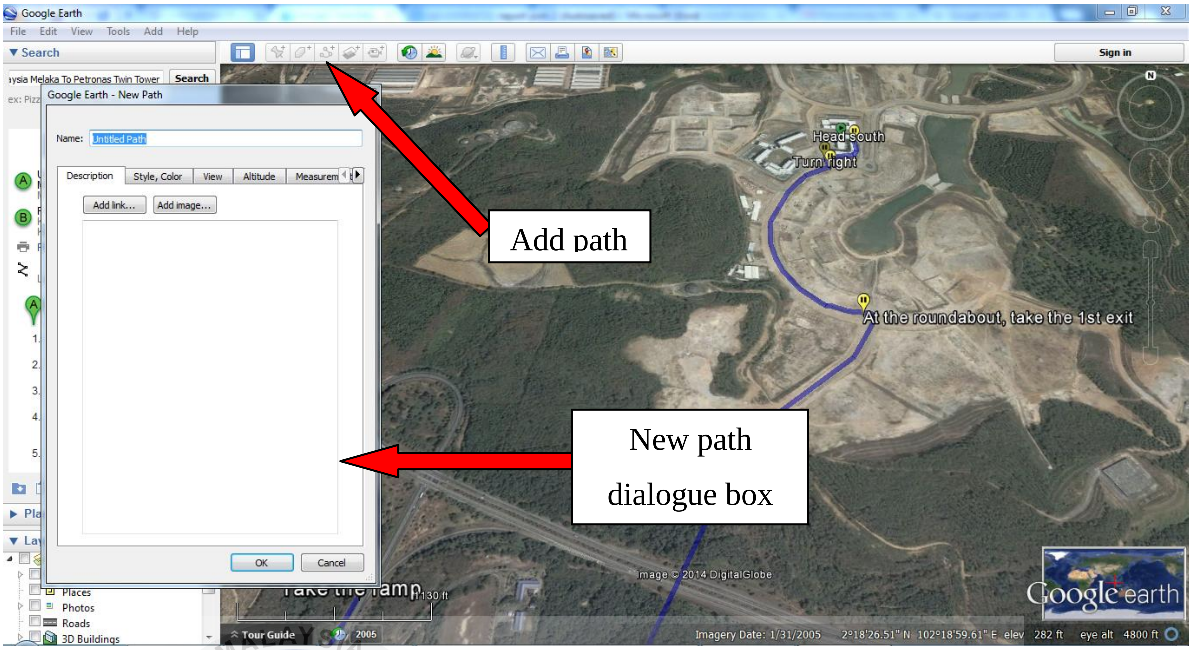

Figure 9:Add path and new path dialogue box

6. On the ‘New Path’ dialogue box, click on the ‘style, colour’ to change the path colour and the width to 5. Next, click on the ‘measurement’ to change the unit from miles to kilometer (km) or meter (m). Starts draw the path of from the first point until the measurement shows 1.00 km and then click ‘ok’.

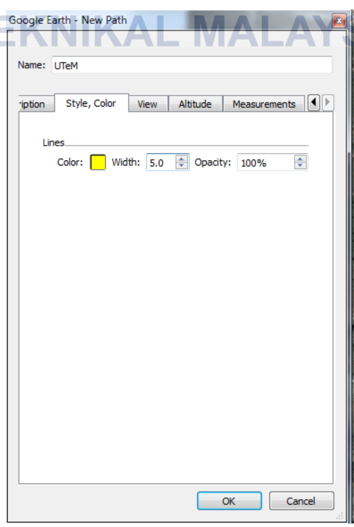

Figure 10:New path dialogue box

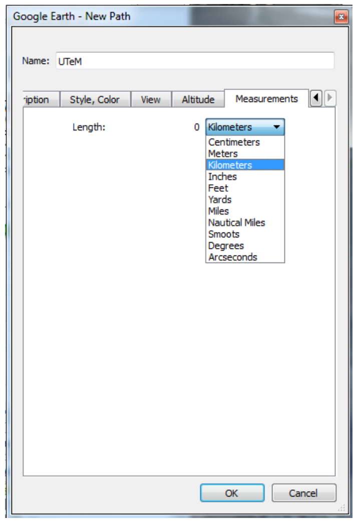

Figure 11: New path dialogue box

7. The newly drawn path will appear overlap with the original blue path. Left click on the yellow path and the 'show elevation profile' will appear. Right click on the 'show elevation profile' and the new profile will appear at the bottom of the window. The distance is only 1.00km as drawn before and therefore the elevation is more accurate compared to elevation directly starting from UTeM to Petronas Twin Tower.

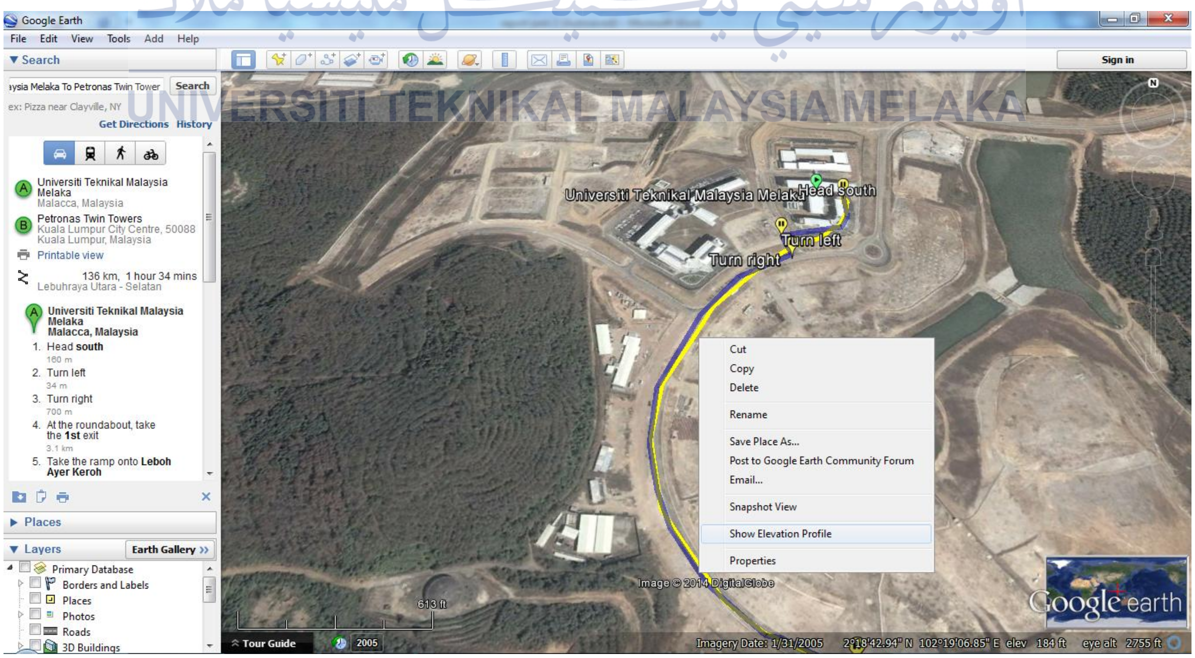

Figure 12: Newly drawn path

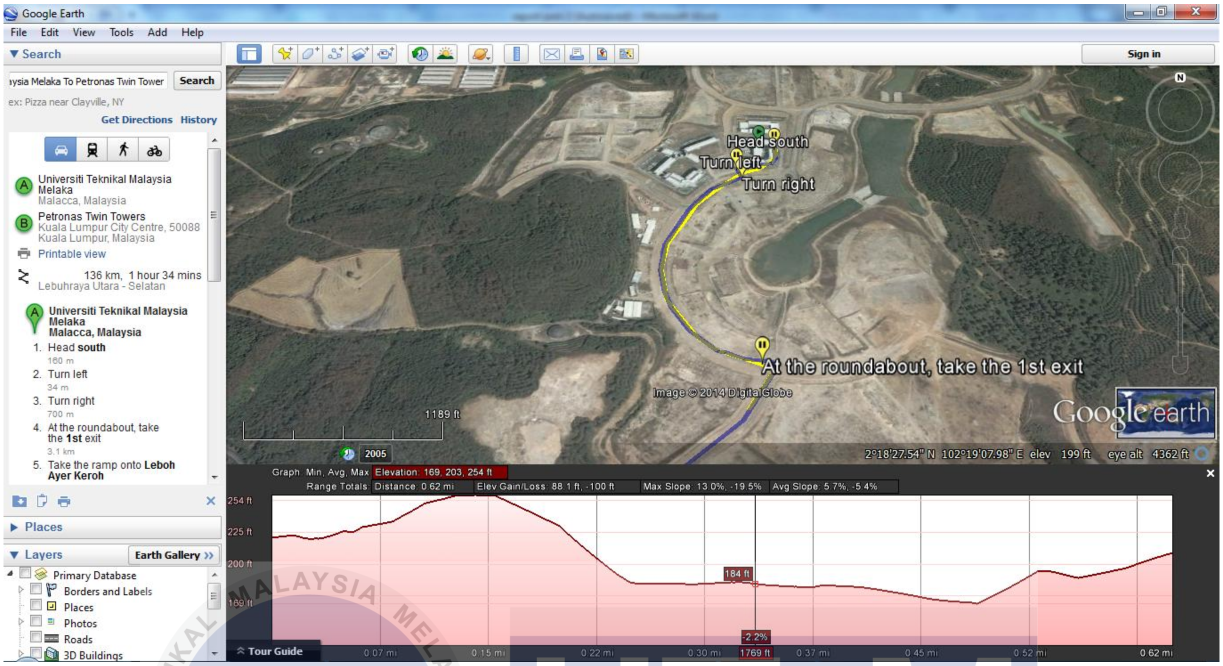

Figure 13: Elevation for newly drawn path

8. ‘Place mark’ is added to indicate the last point. After that, the ‘OK’ button is click.

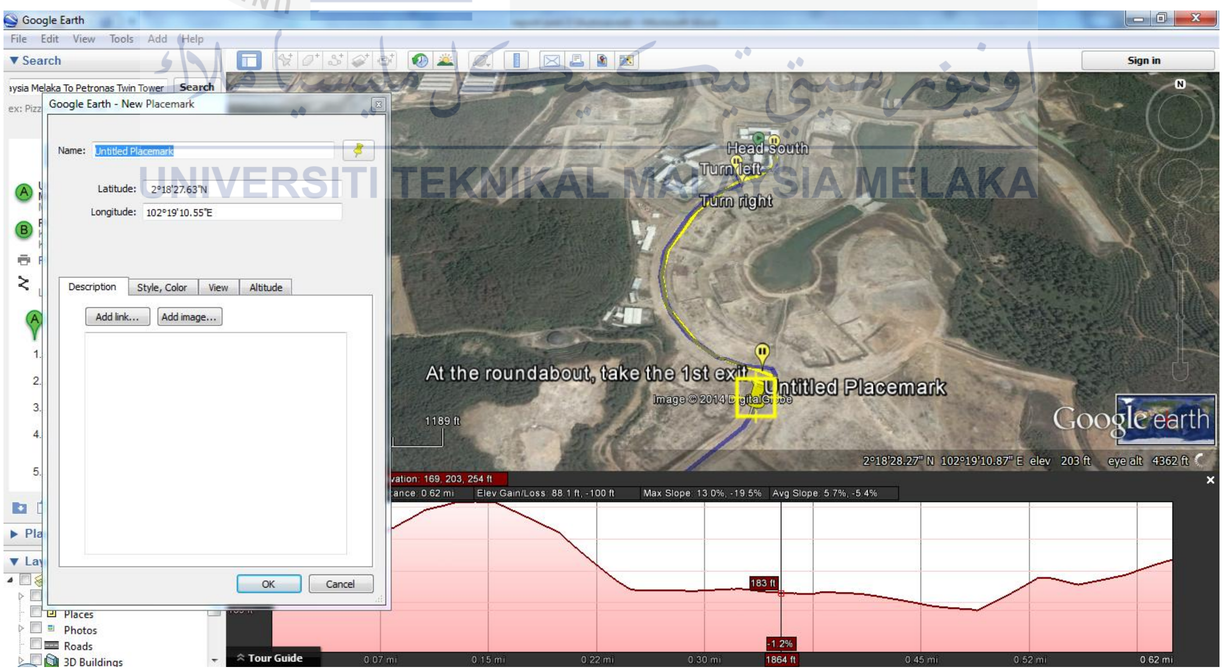

Figure 14: Adding 'place mark' on the path

9. Step 5 until 8 are repeated in order to get the elevation profile for each kilometer.
10. All the obtained data are recorded.

After manage to obtain the data, the angle of elevation of the roadway from UTeM to Petronas Twin Tower is calculated. Then, all the data are transferred in the Microsoft Excel for further calculation.

3.2.4 CALCULATION

The calculation is carried out using Microsoft Excel. Based on the data obtained from the Google Maps, the elevation profile is plotted. The total distance of the elevation profile is 136km which is starts from UTeM to Petronas Twin Tower. Figure 15 below show the elevation profile by plotting the height of the road versus the distance.

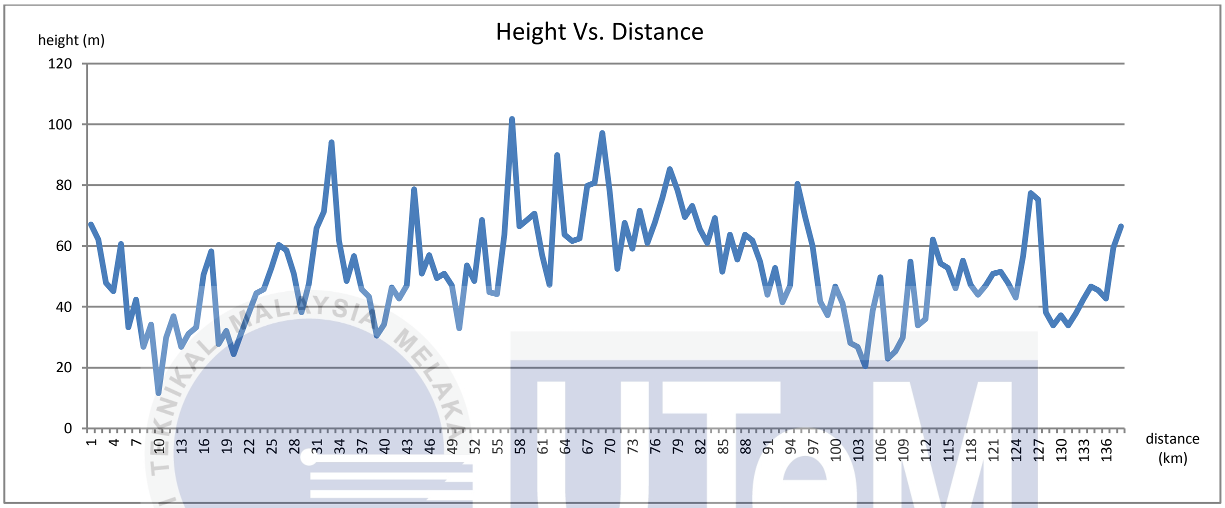

Figure 15: Elevation profile

According to the principles of vehicles mechanics and aerodynamics, there are some forces that must be taken into consideration in order to ensure the vehicle operation [4]. The forces are the rolling resistance force, aerodynamic drag force, climbing and downgrade resistance force and acceleration force. The elementary forces acting on the vehicle is illustrated as in Figure 16 [1].

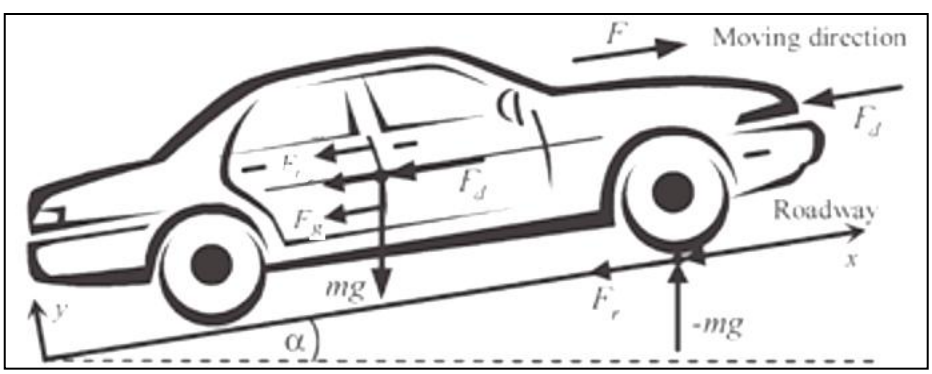

Figure 16: Elementary forces acting on a vehicle

Below are the formulas used in order to calculate the power consumption of the EV.

Mathematical equation:

$$F_v = F_a + F_r + F_d + F_g \tag{3.1}$$

Where;

$$F_a = ma \tag{3.3}$$

$$F_r = f_d mg \cos \alpha \tag{3.2}$$

$$F_d = ½ \rho C_\omega A_f (\upsilon f + \upsilon_i)^2 \tag{3.4}$$

$$F_g = \pm mg \sin \alpha \tag{3.5}$$

Meanwhile the total power and the power delivered for the gear part is calculated as below:

$$P_v = \upsilon F_t \tag{3.6}$$

$$P_g = T_{em} \,.\, r_m \,.\, (V/R_{wheels}) \tag{3.7}$$

Nomenclature:

F_v	Road Load
F_a	Acceleration force
F_r	Rolling resistance force
F_d	Aerodynamic drag force
F_g	Grading force
P_v	Vehicle driving power
Pg	Power for the gear
m	Mass of vehicle
g	Gravitational force
v	Velocity
C_w	Aerodynamic drag coefficient
ρ	Air density
A_f	Frontal area
f_d	Rolling resistance coefficient
α	Angle
υf	Final speed

υ_i Initial speed

T_{em} Motor Torque

r_m Gear ratio

R_{wheels} Radius of the wheels

The total power consumed by the EV can be obtained by combining both the vehicle driving power and also the power for the gear. It can be illustrated as:

$$P_t = Pv + P_g \tag{3.8}$$

Apart from that, in order to complete the calculation of the power consumption, all the parameters below must be determined.

Table 1: Parameters for power consumption calculation

Parameter	Notation	Value
Mass	m	1034
Gravity	g	9.8
Velocity	V	Refer velocity profile
Aerodynamic drag Coefficient	C_d	0.5
Air density	ρ	1.2
Frontal area	A	2.3
Rolling resistance Coefficient	f_d	0.01[1+(Vv/100)]

The calculations are divided into four conditions which indicate four driving strategies. The parameters that will are considered in the calculation are the speed of the vehicle and also the gear used while driving. The suggested speed of the EV basically depends on the elevation profile of the road. Basically, if the vehicle is climbing the road, the speed will be reduced as it goes against the gradient and vice versa. Therefore, figure 17 shows the suggested velocity profile of the EV for condition 2 and also condition 4. For condition 1 and condition 3, the velocity will be kept constant which are 90km/h throughout the journey.

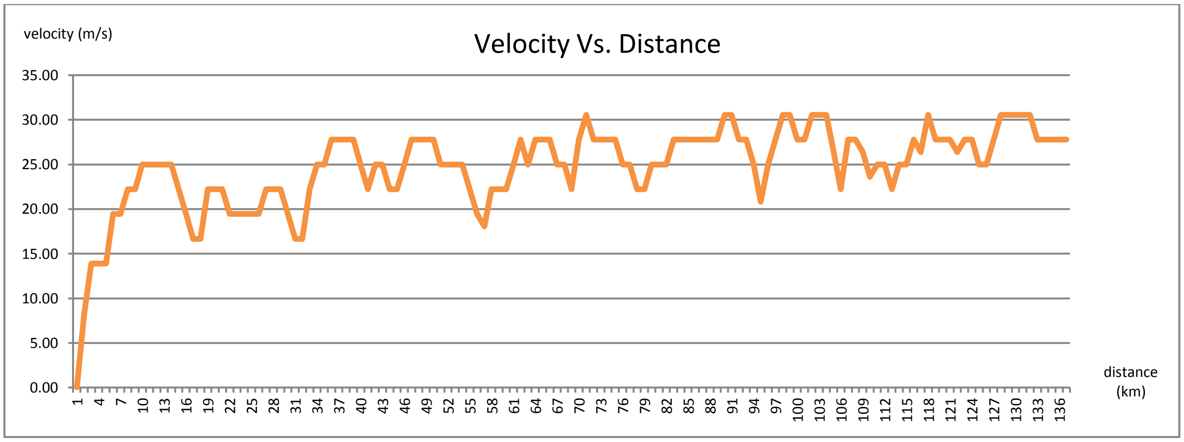

Figure 17: Suggested velocity of vehicle based on the elevation profile

Based on the calculation of all the four conditions, the total power used by the EV are determined. Below are the four conditions that are considered.

Table 2: Condition for Calculation

	Speed	**Gear**
Condition 1	Constant	Constant
Condition 2	Change	Constant
Condition 3	Constant	Change
Condition 4	Change	Change

3.2.4.1 Condition 1

For condition 1, both the speed of the vehicle and the gear of the vehicle during driving process will not be changed. Both parameters are kept constant. The speed used for this condition is fixed to 90km/h from starting until the end and only gear 3 is used. The parameters and the value for condition 1 are as in Table 3.

Table 3: Condition 1

Parameter	Value
Speed	90km/h
Gear	Gear 3

3.2.4.1 Condition 2

As for condition 2, the parameter that are kept constant is the gear meanwhile the speed of the EV will varies from 0km/h to 110km/h. The maximum speed of the EV can be up to 110km/h because it is driven on the highway. Gear 3 will be used throughout the journey and the parameters are shown in Table 4.

Table 4: Condition 2

Parameter	Value
Speed	0km/h – 110km/h
Gear	Gear 3

3.2.4.3 Condition 3

For the third condition, the speed of the EV is set into constant of 90km/h but the gear of the vehicle will keep on changing. The suggested gear to be used is from gear 1 until gear 5. Table 5 below shows the parameters and also their values for condition 3.

Table 5: Condition 3

Parameter	Value
Speed	90km/h
Gear	Gear 1 – gear 5

3.2.4.4 Condition 4

As for the last condition, both the speed and the gear used are varies. The suggested speed is based on the elevation of the road and the gear used is depends on the speed of the EV. The speed range from 0km/h to 110km/h and the gear applied is from gear 1 until gear 5. Table 6 below shows the parameters and also the value for condition 4.

Table 6: Condition 4

Parameter	Value
Speed	0km/h – 110km/h
Gear	Gear 1 – Gear 5

3.2.5 ANALYSIS OF THE DATA

The result obtained from the calculation is analyzed whether it is acceptable and logic or not. If the results seem to deviate from the prediction, the calculation processes need to be done again and again. During the recalculation, all the parameter involved is checked one by one to make sure it is in SI unit and the formula are correct. Once the results are close to the prediction, then only it will be accepted and recorded.

3.2.6 DISCUSSION ON THE RESULT AND REPORT WRITING

Discussion and report writing is the last part of the methodology. Once the results are obtained and have been analyzed, it will be discussed. The factors like the acceleration and the changes of the gear will be analyzed in order to determine whether it affect the power consumption of the EV. Besides, the four conditions considered during the calculation also will be compared and based on that, the best driving method by referring to the acceleration and the changes of the gear will be known.

CHAPTER 4

RESULT AND DISCUSSION

4.1 RESULT

A calculation of total power consumption and travelling time of the EV from UTeM to Petronas Twin Tower has been conducted based on the four operating conditions explained before. The total power and also the total time taken for the EV to arrive from UTeM to Petronas Twin Tower for all four operating conditions can be seen as tabulated in Table 7.

From the table, it is clearly shows that for condition 1 which the speed and the gear are constant, the total power consumed by the EV is 20.52kW/h. On the other hand, the total power consumed for condition 2 is 11.62kW/h. For condition 2, the speed is varies but the gear used is kept constant. For condition 3, when the speed is kept constant and the gear is change, the total power consumed is 20.02kW/h. Lastly for condition 4 where both the speed and the gear is varies, the total power is the lowest which is 11.10kW/h only.

As for the travelling time from UTeM to Petronas Twin Tower, the EV took about 1 hour and 31 minutes for condition 1 and also condition 3. However, it took only 1 hour and 22 minutes to arrive to the destination for condition 2 and condition 4. The total power and also the total time taken for the EV to arrive from UTeM to Petronas Twin Tower for all four conditions can be seen as tabulated in table 7 below.

Table 7: Total power consumption and travelling time

	Speed	Gear	Total power	Time taken to arrive to the destination
Condition 1	Constant	Constant	20.52kW/h	1 hour 31 minutes
Condition 2	Change	Constant	11.62kW/h	1 hour 22 minutes
Condition 3	Constant	Change	20.02kW/h	1 hour 31 minutes
Condition 4	Change	Change	11.10kW/h	1 hour 22 minutes

4.2 DISCUSSION

Based on the results from the calculation, it shows that total power consumed by the EV is not the same for all four conditions. The EV consume the most power for condition 1 which is 20.52kW/h and followed by condition 3 which is total of 20.02kW/h. For both condition 1 and condition 3, the speed of the vehicle is constant which is 90km/h. However, the gear used for condition 1 is gear 3 only but for condition 3, the gear keep on changing from gear 1 until gear 5. Besides, the total time taken for the vehicle to arrive to the destination for both condition are the same which is 1 hour and 31 minutes. This is because the speed used is the same.

On the other hand, when the speed of the vehicle is changing, the total power consumed by the vehicle also reduced. This can be clearly seen based on condition 2 and also condition 4. For both condition, the speed of the vehicle is changing based on the elevation profile of the road. When the vehicle is climbing the road, the speed will become slow and in contrast if the vehicle is going down the road, the speed will be increase. For condition 2, the total power consumed is only 11.62km/h and for condition 4, the total power consumed is 11.10km/h.

The difference between condition 2 and condition 4 is the gear used. For condition 2, the gear is kept constant. Which means throughout the journey, the gear used is only gear 3 regardless the speed of the vehicle. In contrast, the gear used in condition 4 is varies based on the speed of the vehicle. The gear used ranging from gear 1 until gear 5.As for the overall time taken for the vehicle to arrive to the destination, the total time for condition 2 and condition 4 is the same. The vehicle took about 1 hour and 22 minutes to arrive.

Roughly, it can be seen that based on the tabulated results, between the two parameters which are the speed and the gear used, the speed will give the big influence to the power consumption of the vehicle compared to the gear. The gear used also effect the power consumption of the vehicle but in a small difference only. However, by adjusting and manipulating both the speed and the gear used, the power consumption of the vehicle can be reduced to the lowest and in this condition, the power consumption of the vehicle is only 11.10kW/h.

If analyzed based on the four main forces that are taken into account which are the acceleration force, rolling resistance force, aerodynamic force and also the grading force, acceleration force is the most dominant force that affect the total power consumption for all four condition. First of all when the speed is constant as in condition 1 and condition 3, automatically the acceleration will become zero. This is because the vehicle move on with the same speed throughout the journey and therefore, the vehicle do experience neither the acceleration nor the deceleration. Therefore, the acceleration force for the vehicle will become constant which is zero.

Referring to the condition 2 and condition 4, the speed of the vehicle keeps on changing from the start until the end of the journey. The suggested speed varies from 0km/h to 110km/h depending on the elevation of the road. Since the elevation of the also different and the speed used is different, the vehicle will experience the acceleration and deceleration. If the vehicle accelerates, the acceleration force is big and on the other hand, when the vehicle decelerates, the acceleration force is small and sometimes can be negative. Since the speed of the vehicle is related to the acceleration, that is why the speed influenced the total power consumption of the vehicle the most compared to others.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the calculation that have been done, it can be concluded that the power consumption of the vehicle is affected by several factors. However, the speed gives the biggest impact to the power consumed by the vehicle. Therefore, the best strategy to optimize the power consumption of the vehicle is by drive it using the most suitable speed depending on the elevation of the road itself. Besides, the right selection of the gear during the driving also can reduce the power consumption of the vehicle. The selection of the gear must suite the speed of the vehicle.

However, the power consumption of the EV obtained based on the calculation may be different when it is done practically. This is because during the calculation, there are several factors that are kept constant. For example are the wind speed and also the air density. Practically, under normal condition, these two parameters will keep on changing. The wind speed will differ based on the weather and the air density changes with variation in temperature, humidity and also the altitude.

In addition, besides to know the best strategies to optimize the power consumption of the EV, this project also focus on the calculation of the power consumption of the EV in order to assist the driver on how long the battery can withstand. By referring to the best strategy which is condition 4, the total power consumed is 11.10kW/h and if the driver is driving the Nissan Leaf, the car is able to reach the destination without need to charge the battery while on the journey since the battery capacity of Nissan Leaf is 24kW/h.

5.2 RECOMMENDATION

In this project, the calculation of the power consumption of the EV is depend on the four forces only which are the acceleration force, rolling resistance force, aerodynamic drag force and also the grading force only. Besides, there are only two parameters that are manipulated in this calculation which are the speed and the selection of the gear. As a recommendation for the next project or further study in the power consumption of the EV, maybe a lot more factors that affect the calculation and power consumption need to be included and considered in the calculation such as the types of the road that used by vehicle along the journey and also the efficiency of the motor used inside the vehicle. With that, the results will become more accurate.

REFERENCES

[1] Beretta, J. (2010). *Automotive Electricity: Electric Drives*. United States: John Wiley & Sons, Inc.

[2] Haddoun, A., Benbouzid, M. E., Diallo, D., Abdessemed, R., Ghouili, J., & Srairi, K. (January 2007). A Loss-Minimization DTC Scheme for EV Induction Motors. *IEEE Transaction on Vehicular Technology*.

[3] Hussain, I. (2011). *Electric and Hybrid Vehicles.* United States of America: CRC Press.

[4] Jaber, K., Fakhfah, A., & Neji, R. (2010). High Level Optimization of Electric Vehicle Power-Train with Doehlert Experimental Design.

[5] Kim, E., Lee, J., & Shin, K. G. (2013). Real-Time Prediction of Battery Power Requirements for Electric Vehicles.

[6] Ren, Q., Crolla, D., & Morris, A. (2009). Effect of Transmission Design on Electric Vehicle (EV) Performance.

[7] Tanaka, D., Ashida, T., & Minami, S. (2008). An analytical Method of EV Velocity Profile Determination from the Power Consumption of Electric Vehicles. *IEEE Vehicle Power and Propulsion Conference (VPPC).* Harbin, China.

[8] Westbrook, M. H. (2001). *The Electric and Hybrid Car*. United Kingdom: SAE International.

[9] Westbrook, M. H. (2001). *The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars*. United Kingdom: The Institution of Engineering and Technology.

APPENDIX A

SPECIFICATION FOR PROTON SAGA BLM 1.3 MANUAL

Specification

Engine	
Engine capacity	1,332 cc
Engine type	4-cylinder in-line 16-valve DOHC
Compression ratio	10
Bore x Stroke	(76 x 73.4) mm
Power	94 bhp
Torque	120 Nm
Performance	
Acceleration	13s (0-100kmh)
Top speed	160kmh
Fuel consumption	16.6 km\L
Misc technical data	
Transmission	5-speed (M)
Drive type	FWD
Measurements	
Body type	Sedan
Dimensions (L x W x H)	(4257 x 1680 x 1502)mm
Wheelbase	2,465mm
Min turning radius	5,300mm
Kerb weight	1,035kg
Fuel tank capacity	40L
Brakes	
Brakes (Front)	Ventilated disc
Brakes (Rear)	Drum
Suspension	
Suspension (Front)	MacPherson strut with coil spring and stabilizer bar
Suspension (Rear)	Torsion beam with coil spring and absorber

****

Top Speed

****

Make : Proton
Model : Saga BLM 1.3 (Manual)

Tyre Size : 185/60R14 (57.76 cm)
Redzone RPM : 6500

Gear Ratio

1st : 3.333
2nd : 1.954
3rd : 1.285
4th : 0.926
5th : 0.755

Final Reduction Gear Ratio

1st : 4.705
2nd : 4.705
3rd : 4.705
4th : 4.705
5th : 4.705

Speed & RPM

1st : 45.13Kmh / 28.03Mph @ 6500 RPM
2nd : 76.98Kmh / 47.81Mph @ 6500 RPM
3rd : 117.05Kmh / 72.70Mph @ 6500 RPM
4th : 162.43Kmh / 100.89Mph @ 6500 RPM
5th : 199.22Kmh / 123.74Mph @ 6500 RPM

****

110 KM/H

****

Make : Proton

Model : Saga BLM 1.3 (Manual)

Tyre Size : 185/60R14 (57.76 cm)

Redzone RPM : 6500

Gear Ratio

1st : 3.333

2nd : 1.954

3rd : 1.285

4th : 0.926

5th : 0.755

Final Reduction Gear Ratio

1st : 4.705

2nd : 4.705

3rd : 4.705

4th : 4.705

5th : 4.705

Speed & RPM

1st : 110.00Kmh / 68.32Mph @ 15840 RPM

2nd : 110.00Kmh / 68.32Mph @ 9280 RPM

3rd : 110.00Kmh / 68.32Mph @ 6100 RPM

4th : 110.00Kmh / 68.32Mph @ 4400 RPM

5th : 110.00Kmh / 68.32Mph @ 3580 RPM

APPENDIX B

SERIAL NO. : HCD /

EDUCATIONAL ACTIVITIES APPLICATION FORM

Please

☐	Practicum	☐	Internship	☐	Conduct Survey
☐	Conduct Research	☐	Academic Visit	☐	Others:

Starting Date ____________________ Ending Date ____________________

Dura...

SECTION A : DETAILS OF PROGRAMME *(Not applicable for Practicum and Internship programme)*

Project Title

Objectives

Data Collection Methodology ☐ Primary ☐ Secondary ☐ Mixed / Combination

Area of Interest

SECTION B : DETAILS OF APPLICANT *(Please use a separate of paper if the space provided is sufficient)*

Name ____________________ I/C / ____________________

Matric No

Age

Gen
der

National
ity

Relig
ion

Instituti
on / Organisation

Posit
ion

Faculty /
Department

Field
of Study

Grade /
CGPA

Tel.
No.

Email

Mailing
Address

Languages : 0 = poor, 5 = Average, 10 = Excellent		
Language	W ritten	S poken

Emergency Reference			
Name	Address	R elation	Co ntact No.

Qualification History *(Applicable for Practicum and Internship programme only)*					
Qual ification	Field of Study	Major	Institute/ University/ School	Gr ade / CGPA	Gra duation Date
High est					
2nd Highest					
3rd					

Highest					
Prof essional					
othe rs					

SECTION C : OTHERS *(Please tick (√) to indicate that you have included the applicable of following document with your*

Your applications and duly verified documentations shall reach our office at least 2 months before the programme date. All applicants must provide the following documentations for approval:

Checklist :

- [ ] **Letter from Institute / University / Organisation**
- [ ] **Curriculum Vitae** ***(Practicum & Internship programme only)***
- [ ] **Current Studying Examination Result Slip for every Semester** ***(Practicum programme only)***
- [ ] **One (1) Recent Photo** ***(passport size)***
- [ ] **Research / Survey Proposal**
- [ ] **Others :** ____________________

Please send the application to:

PLUS Malaysia Berhad (PMB)
Human Resource Development Department
Menara Korporat, Persada PLUS
Persimpangan Bertingkat Subang
KM 15, Lebuhraya Baru Lembah Klang
47301 Petaling Jaya, Selangor
General line :03-7666 4666
Fax No.: 03-7666 4599

Company may at it discretionary to reject / deny approval on the ground that; in the judgment of the management it would be inappropriate to conduct the proposed activities/study due to changes when the company unable to provide input to meet the applicants objectives, proposed data collection method and identified are of interest.

SECTION D : ACKNOWLEDGMENT

I declare that all information to the best of my knowledge is true and if it is found that I have made false, PEB reserves the right to terminate my application or during the ongoing programme.

____

____

Applicant Name :	Witness Name :

Date :	Date :

APPENDIX C

EXAMPLE OF CALCULATION

CONDITION 1

time (s)	constant		variable						acceleration force	rolling force	aerodynamic drag force	grading force	total force	Power	Gear	total power
	distance (m)	angle (θ)	acceleration, a (m/s^2)	average velocity, (m/s)	velocity (m/s)	speed (Vv) (km/h)	gear used	gear ratio	Fa=ma	Fr=mgfd cosθ	Fd=(1/2)ρaAvCa ((Vv-Vw)(Vv-Vw))	Fg=mgsinθ	Ft=Fa+Fr+Fd+Fg	Pa=Vv*Ft	Pw=Tem*rm*(Vv/rwheels)	Pt+Pw
0.00	0	0.28	0.00	0.00	25.00	90.00	3.00	1.26	0.00	192.71	0.00	49.50	242.21	6055.29	23505.88	23505.88
40.00	1000	0.82	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.70	11.27	145.34	349.30	8732.48	23505.88	372804.98
80.00	2000	0.16	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.72	11.27	27.79	231.78	5794.40	23505.88	255281.90
120.00	3000	0.89	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.69	11.27	157.66	361.62	9040.39	23505.88	385121.31
160.00	4000	1.57	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.64	11.27	278.11	482.02	12050.59	23505.88	505529.39
200.00	5000	0.52	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.71	11.27	92.74	296.72	7417.98	23505.88	320225.15
240.00	6000	0.89	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.69	11.27	157.60	361.56	9039.06	23505.88	385068.23
280.00	7000	0.42	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.71	11.27	74.19	278.17	6954.25	23505.88	301676.07
320.00	8000	1.29	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.67	11.27	228.77	432.71	10817.67	23505.88	456212.67
360.00	9000	1.05	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.68	11.27	185.46	389.41	9735.34	23505.88	412919.61
400.00	10000	0.40	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.71	11.27	71.09	275.07	6876.82	23505.88	298578.57
															TOTAL POWER (w/s)	3716923.766
															TOTAL POWER (w/h)	1.032478824
															MECHANICAL EFFICIENCY (w/h)	1.29059853
															MOTOR EFFICIENCY (w/h)	1.613248162

CONDITION 2

time (s)	constant		variable						Acceleration Force	Rolling Force	Aerodynamic Drag force	Grading Force	Total Force	Power		Gear	total power
	distance (m)	angle (θ)	acceleration,a (m/s^2)	average velocity, (m/s)	velocity (m/s)	speed (Vv) (km/h)	gear used	gear ratio	Fa=ma	Fr=mgfd cosθ	Fd=(1/2)paAvCa ((Vv-Vw)(Vv-Vw))	Fg=mgsinθ	Ft=Fa+Fr +Fd+Fg	Pa=Vv*Ft	power over time (Pt)	Pw=Tem*rm* (Vv/rwheels)	Pt+Pw
0.00	0	0.28	0.00	0.00	0.00	0.00	3.00	1.26	0.00	101.43	0.00	49.50	150.93	0.00	0.00	0.00	0.00
240.00	1000	0.82	0.03	4.17	8.33	30.00	3.00	1.26	35.94	131.85	1.88	145.34	315.00	2624.97	629992.60	7835.29	637827.89
180.00	2000	0.16	0.03	11.11	13.89	50.00	3.00	1.26	31.94	152.14	5.01	27.79	216.89	3012.36	-180741.32	13058.82	-167682.49
216.00	3000	0.89	0.00	13.89	13.89	50.00	3.00	1.26	0.00	152.13	6.26	157.66	316.04	4389.46	158020.55	13058.82	171079.38
288.00	4000	1.57	0.00	13.89	13.89	50.00	3.00	1.26	0.00	152.09	6.26	278.11	436.46	6061.94	436459.54	13058.82	449518.36
300.00	5000	0.52	0.02	16.67	19.44	70.00	3.00	1.26	19.17	172.42	7.51	92.74	291.85	5674.77	68097.25	18282.35	86379.61
308.57	6000	0.89	0.00	19.44	19.44	70.00	3.00	1.26	0.00	172.41	8.76	157.60	338.78	6587.30	56462.53	18282.35	74744.88
336.00	7000	0.42	0.01	20.83	22.22	80.00	3.00	1.26	8.56	182.57	9.39	74.19	274.71	6104.58	167440.03	20894.12	188334.15
360.00	8000	1.29	0.00	22.22	22.22	80.00	3.00	1.26	0.00	182.53	10.01	228.77	421.31	9362.55	224701.10	20894.12	245595.22
381.18	9000	1.05	0.01	23.61	25.00	90.00	3.00	1.26	7.54	192.68	10.64	185.46	396.33	9908.26	209821.90	23505.88	233327.78
400.00	10000	0.40	0.00	25.00	25.00	90.00	3.00	1.26	0.00	192.71	11.27	71.09	275.07	6876.82	129445.97	23505.88	152951.85
																TOTAL POWER (w/s)	2072076.627
																TOTAL POWER (w/h)	0.575576841
																MECHANICAL EFFICIENCY (w/h)	0.719471051
																MOTOR EFFICIENCY (w/h)	0.899338814

CONDITION 3

time (s)	constant		variable							acceleration force	rolling force	aerodynamic drag force	grading force	total force	Power		Gear	total power
	distance (m)	angle (θ)	acceleration,a (m/s^2)	average velocity, (m/s)	velocity (m/s)	speed (Vv) (km/h)	gear used	gear ratio		Fa=ma	Fr=mgfd cosθ	Fd=(1/2)paAvCa ((Vv-Vw)(Vv-Vw))	Fg=mgsiNθ	Ft=Fa+Fr +Fd+Fg	Pa=Vv*Ft	power over time (Pt)	Pw=Tem*rm* (Vv/rwheels)	Pt+Pw
0.00	0	0.28	0.00	0	25	90	1.00	3.33		0.00	192.71	0.00	49.50	242.21	6055.29	0.00	62277.51	62277.51
40.00	1000	0.82	0.00	25	25	90	3.00	1.29		0.00	192.70	11.27	145.34	349.30	8732.48	349299.10	24010.38	373309.48
80.00	2000	0.16	0.00	25	25	90	3.00	1.29		0.00	192.72	11.27	27.79	231.78	5794.40	231776.01	24010.38	255786.40
120.00	3000	0.89	0.00	25	25	90	3.00	1.29		0.00	192.69	11.27	157.66	361.62	9040.39	361615.43	24010.38	385625.81
160.00	4000	1.57	0.00	25	25	90	3.00	1.29		0.00	192.64	11.27	278.11	482.02	12050.59	482023.51	24010.38	506033.89
200.00	5000	0.52	0.00	25	25	90	5.00	0.76		0.00	192.71	11.27	92.74	296.72	7417.98	296719.27	14107.27	310826.54
240.00	6000	0.89	0.00	25	25	90	5.00	0.76		0.00	192.69	11.27	157.60	361.56	9039.06	361562.34	14107.27	375669.61
280.00	7000	0.42	0.00	25	25	90	5.00	0.76		0.00	192.71	11.27	74.19	278.17	6954.25	278170.19	14107.27	292277.46
320.00	8000	1.29	0.00	25	25	90	5.00	0.76		0.00	192.67	11.27	228.77	432.71	10817.67	432706.78	14107.27	446814.05
360.00	9000	1.05	0.00	25	25	90	5.00	0.76		0.00	192.68	11.27	185.46	389.41	9735.34	389413.72	14107.27	403520.99
400.00	10000	0.40	0.00	25	25	90	5.00	0.76		0.00	192.71	11.27	71.09	275.07	6876.82	275072.69	14107.27	289179.95
																	TOTAL POWER (w/s)	3701321.69
																	TOTAL POWER (w/h)	1.028144914
																	MECHANICAL EFFICIENCY (w/h)	1.285181142
																	MOTOR EFFICIENCY (w/h)	1.606476428

CONDITION 4

time (s)	constant		variable						acceleration force	rolling force	aerodynamic drag force	grading force	total force	Power		Gear	total power
	distance (m)	angle (θ)	acceleration,a (m/s^2)	average velocity, (m/s)	velocity (m/s)	speed (Vv)	gear used	gear ratio	Fa=ma	Fr=mgfd cosθ	Fd=(1/2)paAvCa ((Vv-Vw)(Vv-Vw))	Fg=mg sinθ	Ft=Fa+Fr +Fd+Fg	Pa=Vv*Ft	power over time (Pt)	Pw=Tem*rm* (Vv/rwheels)	Pt+Pw
0.00	0	0.28	0.00	0.00	0.00	0	1	3.33	0.00	101.43	0.00	49.50	150.93	0.00	0.00	0.00	0.00
240.00	1000	0.82	0.03	4.17	8.33	30	3	1.29	35.94	131.85	1.88	145.34	315.00	2624.97	629992.60	8003.46	637996.06
180.00	2000	0.16	0.03	11.11	13.89	50	3	1.29	31.94	152.14	5.01	27.79	216.89	3012.36	- 180741.32	13339.10	-167402.21
216.00	3000	0.89	0.00	13.89	13.89	50	3	1.29	0.00	152.13	6.26	157.66	316.04	4389.46	158020.55	13339.10	171359.65
288.00	4000	1.57	0.00	13.89	13.89	50	3	1.29	0.00	152.09	6.26	278.11	436.46	6061.94	436459.54	13339.10	449798.64
300.00	5000	0.52	0.02	16.67	19.44	70	5	0.76	19.17	172.42	7.51	92.74	291.85	5674.77	68097.25	10972.32	79069.57
308.57	6000	0.89	0.00	19.44	19.44	70	5	0.76	0.00	172.41	8.76	157.60	338.78	6587.30	56462.53	10972.32	67434.85
336.00	7000	0.42	0.01	20.83	22.22	80	5	0.76	8.56	182.57	9.39	74.19	274.71	6104.58	167440.03	12539.79	179979.82
360.00	8000	1.29	0.00	22.22	22.22	80	5	0.76	0.00	182.53	10.01	228.77	421.31	9362.55	224701.10	12539.79	237240.89
381.18	9000	1.05	0.01	23.61	25.00	90	5	0.76	7.54	192.68	10.64	185.46	396.33	9908.26	209821.90	14107.27	223929.17
400.00	10000	0.40	0.00	25.00	25.00	90	5	0.76	0.00	192.71	11.27	71.09	275.07	6876.82	129445.97	14107.27	143553.24
																TOTAL POWER (w/s)	2022959.672
																TOTAL POWER (w/h)	0.561933242
																MECHANICAL EFFICIENCY (w/h)	0.702416553
																MOTOR EFFICIENCY (w/h)	0.878020691