ELECTRIC MOTOR PROPULSION SYSTEM FOR ELECTRIC VEHICLES (EV)

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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I hereby declare that the work in this report is my own research except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

In a bid to perform electric vehicle modeling in terms of propulsion system of the electric motor, the calculation and the analysis of vehicles dynamics have been done. Its will concluded the suitable motor that will used to move the specific vehicles, ISWARA. Through the literature review, this thesis presented the introduction of electric vehicles and the major components of its system. Besides that, it will discuss the propulsion system for electric motor of the electric vehicles. Next, calculation and analysis been done to find the requirement power and force to move the vehicle in fixed velocity. Results get from the calculation will be used to find the characteristics of electric motor and finally the suitable electric motor are selected. Simulation done to analysis the suitable motor either it can perform and give the similar results compare to calculation made before or not. At the end of this thesis, conclusion is made due to the results get from the simulation analysis. Recommendation in improving the results from whole of the project will also be discuss.

ABSTRAK

Dalam langkah menghasilkan model kenderaan elektrik yang terdiri daripada pembahagian sistem dalam motor eletrik, pengiraan dan analisa berkaitan dengan dinamik kenderaan harus dibuat. Ia akan member jawapan kepada motor yang sangat sesuai digunakan untuk menggerakan kenderaan yang telah ditetapkan iaitu ISWARA. Melalui gambaran penulisan, kajian akan memperjelaskan tentang pengenalan untuk kenderaan elektrik dan komponen-komponen penting dalam system kenderaan tersebut. Selain itu, ia akan membincangkan pembahagian system untuk motor elektrik dalam kenderaan elektrik. Selanjutnya, pengiraan dan analisa akan dilakukan untuk mencari keperluan kuasa dan tenaga bagi menggerakkan kenderaan dalam kelajuan yang ditetapkan. Hasil daripada pengiraan akan digunakan untuk mencari ciri-ciri tertentu elektrik motor dan akhirnya elektrik motor yang sesuai akan dipilih. Simulasi dilakukan untuk menganalisa adakah elektrik motor yang sesuai itu akan menjalankan dan memberikan keputusan yang serupa dengan hasil pengiraan yang dilakukan sebelum ini atau tidak. Diakhir kajian ini, keputusan akan dibuat berdasarkan hasil yang diperolehi daripada simulasi analisa. Cadangan untuk mebaikpulih hasil keputusan daripada keseluruhan projek akan dibincangkan.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATIONS

EV	-	Electric vehicle
HEV	-	Hybrid-electric vehicle
BEV	-	Battery-electric vehicle
FCEV	-	Fuel cell-electric vehicle
SB	-	Supercapacitor bank
PWM	-	Pulse-width modulation
T	-	Torque
F	-	Force
$\mathbf{F_{TR}}$	-	Tractive force
$\mathbf{F_{AD}}$	-	Aerodynamic drag
$\mathbf{F_{roll}}$	-	Rolling resistance force
$\mathbf{F_{gxT}}$	-	Gravitational force
$\mathbf{F_{la}}$	-	Force gives linear acceleration
$\mathbf{F_{\omega a}}$	-	Force gives angular acceleration to rotating motor

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Todays, as a human being transportation become an important role for getting a comfortable life. But, human not realize that next 50 years, global population will increase from 6 billion to 10 million and in order aspects, the number of vehicles will increase from 700 million to 2.5 billion. If all these vehicles are propelled or get their sources energy by internal combustion engines (ICEs), then where will the oil come from? Where should the emission be disseminated? Would the sky be permanently blue? The gloomy answer to these hard questions compel human to strive for sustainable road transportation for 21st century [4].

Electric Vehicles (EV) is the vehicles that implemented the energy gain from the propulsion electric source which can also be delivered by an electric machine. It definitely emphasizes the benefits of electro-mechanical solutions. Nowadays, in automotive industry the find that EV is the most suitable being on the road because it is friendly environment and can reduce the pollution according to reducing the application of fuel or petrol. Beside that, EV is an extraordinary and different from other road vehicles. It involve with electric propulsion and give a variation technology in order to save the world for pollution. EV are include with battery electric vehicles (BEVs), hybrid-elctric vehicles (HEVs), and fuel-cell electric vehicles (FCEVs) [5]. The idea of EV can be described as a multidisciplinary subject which covers broad and complex aspects. The core of this advance technologies are consist of chasis and body technology, propulsion technology, and energy source technology. That why it become a tough task to write a thesis based on this multidisciplinary and advance studies.

Development of BEVs, HEVs and FCEVs are forwards and get very well attention from this wide world. But compare to this deviation of EV they give different stages of development, different problem that appears, and different strategy to solve the problem. In BEVs, the main problem is about it batteries. BEVs system suitable for small EV because it just give a short range and can be used for low-speed community transportation. For HEVs, it become and reach a consumers need but the major challenge is about the cost. Besides that, for FCEVs technology, it seem to give long-term potential for future mainstream vehicles but its technology are little bit new and still early development stage and major problem that going to be faced was about it cost and refueling system.

One of the well known type of EV is HEV or hybrid electric vehicles. A hybrid electric vehicle (HEV) is a vehicle that used two or more distinct power sources to propel the vehicle such as an on-board rechargeable energy storage system (RESS) and a fueled power source (internal combustion engine or fuel cell) for vehicle propulsion, air and internal combustion engines. It is also called a bi-energy vehicle, human powered bicycle with electric motor or gas engine assist, or a human-powered or sail boat with electric power. The term most commonly refers to Hybrid-electric vehicle (HEV) which includes internal combustion engines and electric motors (generally powered by electric batteries or other rechargeable energy storage system -RESS-).

The idea of hybrid vehicles is not a recent development, early 1960s, several companies attempted to develop bipolar lead (acid batteries) for hybrid-electric vehicles [J.L. Arias, J.J. Rowlett, E.D. Drake, Journal of Power Sources, 40 (1993) 63–73.]. Hybrid vehicles have the potential to increase fuel economy by using a primary engine operating at a constant power to supply average power requirements and a surge power unit for peak power demands and to recover braking energy. But until now, there have no detailed system optimization analysis has been performed for hybrid electric vehicles [8].

Transportation becomes the major contributor to multiple global environmental problems such as greenhouse effect-gas emissions and urban pollution. The hybrid vehicle typically achieves greater fuel economy and lower emissions than conventional internal combustion engine vehicles (ICEVs), in terms of fewer emissions being generated. These savings are primarily achieved by four elements of a typical hybrid design. First, recapturing energy normally wasted during braking. Second, having significant battery storage capacity to store and reuse recaptured energy. Third, shutting down the gasoline or diesel engine during traffic stops or while coasting or other idle periods and last one is relying on both the gasoline (or diesel engine) and the electric motors for peak power needs resulting in a smaller gasoline or diesel engine sized more for average usage rather than peak power usage.

These features make a hybrid vehicle particularly efficient for city traffic where there are frequent stops, coasting and idling periods. In addition noise emissions are reduced, particularly at idling and low operating speeds, in comparison to conventional gasoline or diesel powered engine vehicles. For continuous high speed highway use these features are much less useful in reducing emissions. Vehicles which have significant idle periods and only occasional needs of peak power like railroad switching locomotives or repeated lifting and lowering cycles like Rubber Tyred Gantrys are also good candidates for hybrid systems resulting in potentially significant fuel and emission savings.

1.2 PROJECT BACKGROUND

These studies are coming to analyze the characteristics of the vehicles which is PROTON ISWARA. By pick up one parameter of velocity, a lot of vehicles dynamics calculation will be consider in finding a required power to move it. After that, this project will describe type of electric motor and used the required power for moving the ISWARA (which define by calculation before) to choose one suitable electric motor. Finally, the application of the results from the calculation to propose the most suitable motor driver either from AC motor or DC motor, will be proven by done a simulation of the vehicles drivetrain system. Then this project summarize either the recommended electric motor is suitable or not and describe any error on finding the required power for moving ISWARA as a vehicle.

1.3 PROJECT OBJECTIVE

To build one system in determine the power and force required to move the vehicles (power demand).

To choose a most suitable motor considering from the power and force requirement system (algorithm) done in objective one.

1.4 PROJECT SCOPE

Scope is the way how to define problem by putting a wall around it. Scopes for this thesis are supposedly being:

1) This thesis is about Electric Vehicles (EV) and learning about EV. But major studies done for motor in EV
2) Characteristics (physical) of the vehicle that been considering in choosing a suitable motor for fixed vehicles which is PROTON ISWARA.

3) Find the demand power and force requirement to move the vehicle (PROTON ISWARA) based on calculation in vehicles dynamics.
4) Using the force requirement and demand power that been calculated, propose a suitable motor for this vehicle.
5) Done a simulation and analysis to prove propose motor can running the vehicle.

1.5 SOURCE OF KNOWLEDGE

Adaptation of the knowledge that been used in supporting the thesis are exactly get from some sources that consider very truth and valuable. Source that been used are from:

1) Science direct articles regarding to the method of controlling
2) PROTON Sdn. Bhd., in terms of vehicles specification of ISWARA
3) IEEE INDUSTRY APPLICATION MAGAZINE regarding information to choose the motor
4) Previous thesis based on motor, EV and vehicles dynamics:
    - PHD thesis
    - MASTER thesis
    - Inventors technical report
    - Books
    - journal

1.6 THESIS OUTLINE

CHAPTER 1 is about the explanation and introduction for Electric Vehicle (EV) and the purpose of this thesis written to give an explanation about the title of the project which is “Electric Motor Propulsion System For Electric Vehicle”.

CHAPTER 2 represented the idea of propulsion system in electric vehicles which consists of the vehicles modeling, electric motor characteristics, calculation in vehicles dynamics and vehicles specification that will consider off.

CHAPTER 3 described the methods that are used to determine power and torque required to move the ISWARA in desired velocity. This chapter also explained the comparison in vehicles dynamic characteristics

CHAPTER 4 explained about the other methods to prove the calculation been made are valid which is SIMULATION method. This chapter come out with the results from the propose electric motor that will get from the chapter 3 before and this chapter will estimated either that will be the most suitable electric motor or not.

CHAPTER 5 presents the summary and conclusions due to the final results of this project.

CHAPTER 2

LITERATURE REVIEW

2.0 PROPULSION SYSTEM FOR ELECTRIC VEHICLE

2.1 ELECTRIC VEHICLES (EV)

EV propulsion system consists of three major deviations which is batteries, electric traction motor and last one is, geartrain. This major deviations are disperse in many significance ways such as vehicles performance, vehicles specifications, and many things.

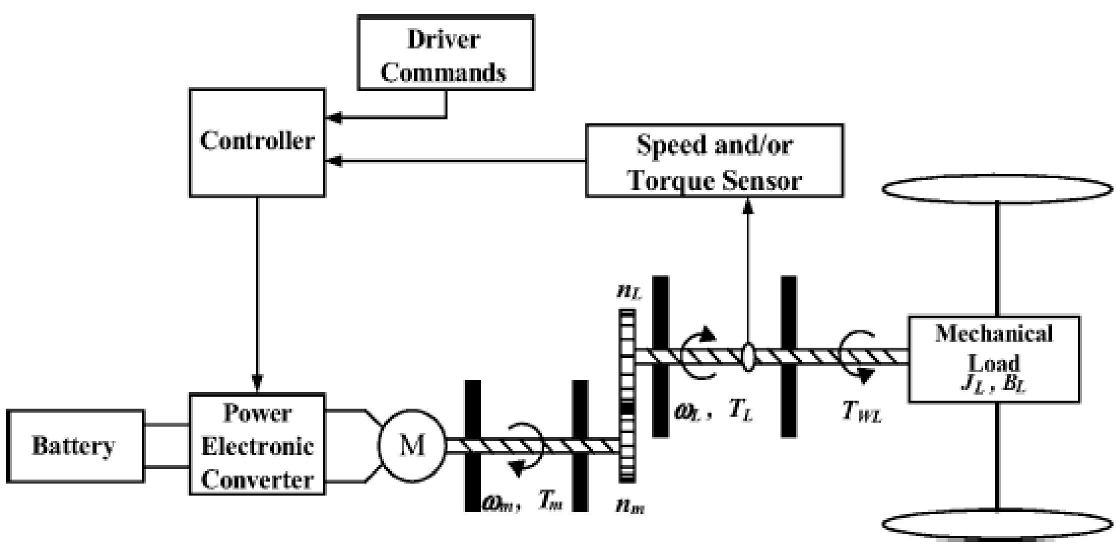


FIGURE 2.1: ELECTRIC VEHICLE SYSTEM.

2.1.1 HEV-HYBRID ELECTRIC VEHICLES (HEVs)

HEV systems are provided by two significant sources of energy which is from internal combustion engine and electric motor. Both of these sources will generate torque to drive the vehicles through the controllable torque transfer unit. For electric motor, there will be two major applications in order to increase the efficiency and performance to supply the energy to the motor. First, electric motor will charge or discharge the battery and second, to regenerative the braking system for optimize the usage of power. In low speed condition, HEV propel itself by using electric motor as a power source in other words, using the power which stored in batteries to move. Internal combustion engine (ICE) becomes a major source to supply a power in order to move the HEV in steady state or constant speed. It is because ICE will operate at its maximum fuel efficiency in that type of speed. Then, in high speed condition, HEV will used both of it source to generate power. There are several term of HEV modes of operation such as low speed running, steady state running, acceleration or hill climbing, battery charging, braking, and last one engine starting[4].

2.2 BATTERY

Electric vehicles (EV) are the vehicles that totally get a power source from it batteries. Then it show that, battery give an important role of moving the EV. There are several characteristics before choosing a suitable battery. There are high specific energy density, high power density, higher life time, high volumetric energy density, ease of charging, and stable performance at low temperature[6].

Nowadays, there still have a problem in making, build and choosing a most suitable battery for EV. This situation happen because battery have been affected by many factor that give a negative impact of battery efficiency and totally performance of EV. Factors that affected the batteries are environment temperature which is non-uniform, driving pattern such as start the EV, city driving, highway driving and speed of moving, and last one is charging patterns such as variation in battery characteristics and over or under charge cycle.

2.2.1 BATTERY FORMATION

One of the main scope of learning battery process is about it formation. Several external factors that affect formation of the batteries for EV are electrolyte temperature, concentration of the forming electrolyte and current density during the formation cycle.

2.2.2 BATTERY CAPACITY

Capacities of battery give the most important role and function in estimate the driving range of an EV. The capacity measured in ampere hour (Ahr) at a specified rate of discharge and temperature. One of the factors that give high effect to capacities of this item in EV is temperature.

The problem is how to give a maintain temperature especially in Malaysia which have dry and wet weather along the season or year. This problem of maintain uniform temperature of the modules affects the battery life and as a results, it will affect the EV performance. These kind variation of the battery pack temperature are brought by the effects of elevated ambient temperature conditions, inconsistent impedance characteristics among the batteries in the pack and non-uniform pack thermal characteristics.

Two condition that briefly explain is under cold temperature condition and under hot temperature conditions. In cold conditions, the capacities of the battery only at 70% of its rated capacity and under hot conditions, the capacity improve to 20-30%

of the rated capacity. this comparison be made under ideal room temperature conditions. In solving this major problem, in other words to uniform the temperature, some method of thermal management are essentially be used then obtain the peak battery performances.

2.3 ELECTRIC MOTOR

Nowadays, there have two major type of electric motor that often used in Malaysia-AC motor (alternate current motor) and DC motor (direct current motor). From these two type of motor, the suitable one will be chosen. The characteristics or requirement for the motor are the peak power must be 70 to 100 KW (kilowatt), ruggedness (the motor can maintain their performance in rough condition), high torque to inertia, high peak torque capability, high speed operation, low noise be produce, minimum maintenance (in terms of cost to repair or upgrade the motor), small size (suitable for our respective vehicles) and last one, ease to control. The characteristics of AC motor and DC motor described details in table below:

TABLE 2.1: COMPARISON BETWEEN AC MOTOR AND DC MOTOR[7]

AC MOTOR	CHARACTERISTICS	DC MOTOR
HIGH	EFFICIENCY	LESS THAN AC MOTOR
MORE EXPENSIVE THAN DC MOTOR	COST	LESS EXPENSIVE
INVERTER (HIGH COST)	MOTOR COMPONENTS	CONVERTER (LOW COST)
SINGLE-SPEED	TRANSMISSION	MULTI-SPEED
• FAVOURABLE POWER TO SIZE OR WEIGHT RATIO • REGENERATE BRAKING ENERGY (INCREASE EFFICIENCY)	OTHERS	• INHERENT STABILITY • EASE CONTROL • FAST TRANSIENT RESPONSE

2.3.1 SINGLE-PHASE INDUCTION MOTOR (AC MOTOR)

Why single-phase induction motor been choose in this thesis? It is because it have a simple and very robust structure, the structure can perform without the controller, the price more cheaper that other familiar motor, it is a primary source of motive power and speed control where dc machines either cannot do and lastly either it has low efficiency compare to other motor but the efficiency are continuous increasing by new development from inventor. This single-phase induction motor are used extensively for adjustable-speed drives' applications which very suitable to HEV. There have two method to increase it efficiency- first, time-stepping finite element method which solve the electromagnetic coupled field in single-phase induction motor. Second, Maxwell stress tensor. It used to investigate the mechanism of torque production-in order words to find way to maximize torque production and increase the efficiencies. In Table 2.2 stated that the specification for the single-phase induction motor:

TABLE 2.2: SPECIFICATION OF MOTOR[7]

Symbol	Quantity	Value
P	Rated output power	0.79 kW
V	Input voltage	115 V
f	Supply frequency	60 Hz
p	Number of pole pairs	1
n_s	Number of stator slots	24
n_r	Number of rotor bars	33
T_L	Rated load torque	2.16 N-m
C	Capacitance	60 μF

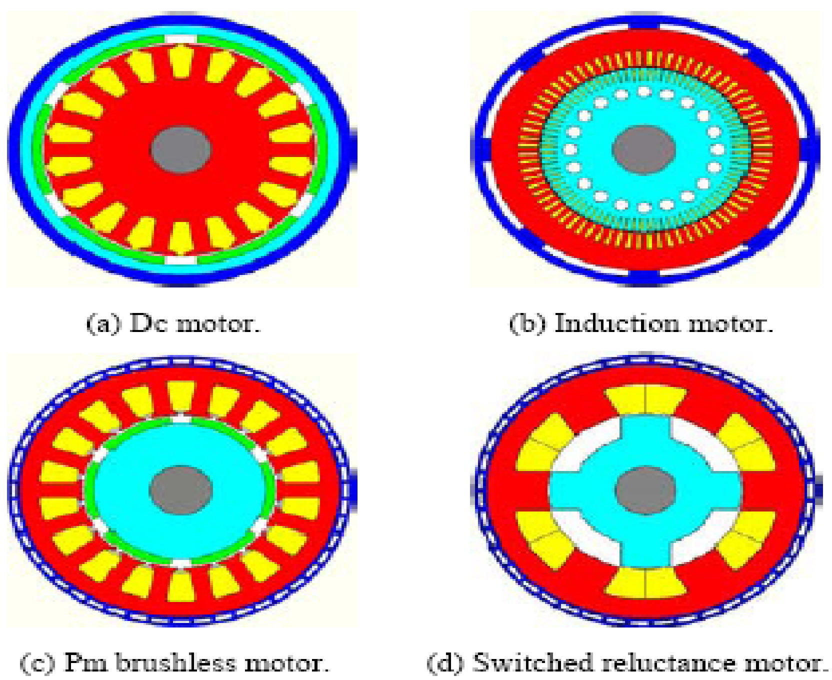


FIGURE 2.2: CROSS SECTION FOR MANY TYPES OF MOTOR IN INDUSTRIES[10]

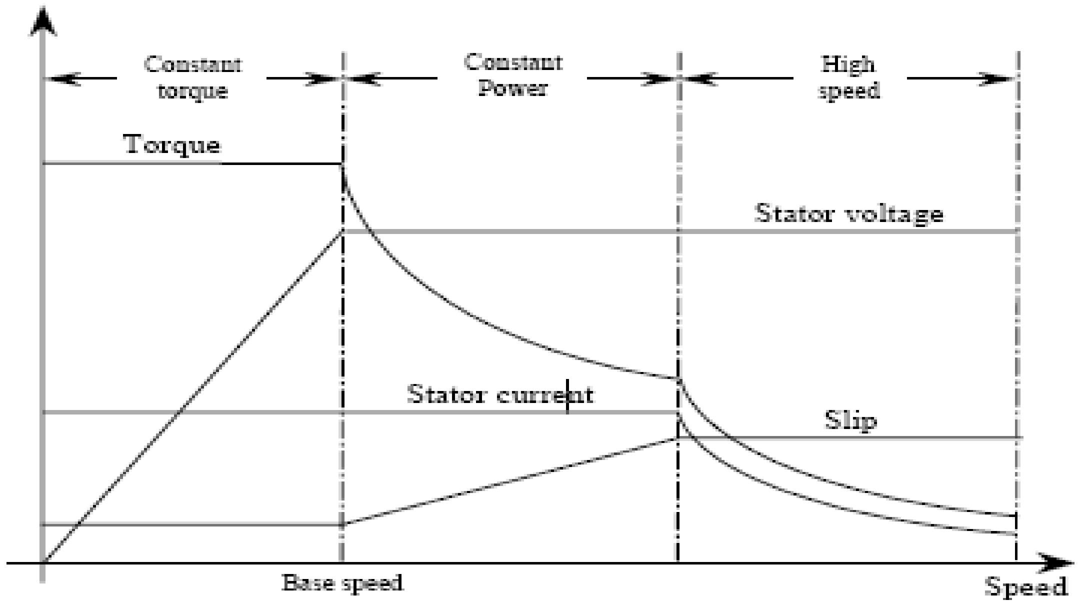


FIGURE 2.3: INDUCTION MOTOR CHARACTERISTICS

2.3.2 BRUSHLESS MOTOR (DC MOTOR)

Other suggestion of motor that been used in this thesis was brushless motor. The characteristics of this DC motor are low weight and high efficiency compare to other DC motor. It was includes of permanent magnet rotor and a set of stator windings.It means for changeably connecting the set of stator windings to operate in a first electrical configuration or a second electrical configuration, wherein the first electrical configuration includes all of the set of stator windings operable connected together for current from the DC source to flow therein, and wherein the second electrical configuration includes connected stator windings and unconnected stator windings, wherein the connected stator windings comprise less than all of the set of stator windings connected together for current from the DC source to flow therein.

Then, in the unconnected stator windings are electrically isolated from the connected stator windings in the second electrical configuration such that a voltage generated across the unconnected stator windings from a back electromotive force as a magnetic field of the rotor interacts with the unconnected stator windings does not add in series with a voltage applied across the connected stator windings, and a commutation circuit commutating the stator windings when connected in the first electrical configuration or the second electrical configuration. Windings are wound around the teeth (Tm) where energization of the windings with electrical currents at respective phases will produce a torque that will rotate the rotor[6]

2.4 DRIVETRAIN OF EV

There are two types of drivetrain of vehicles in this century, first front-wheel drive and another one is rear-wheel drive. Show in below the schematics of these two types of vehicles drivetrain.

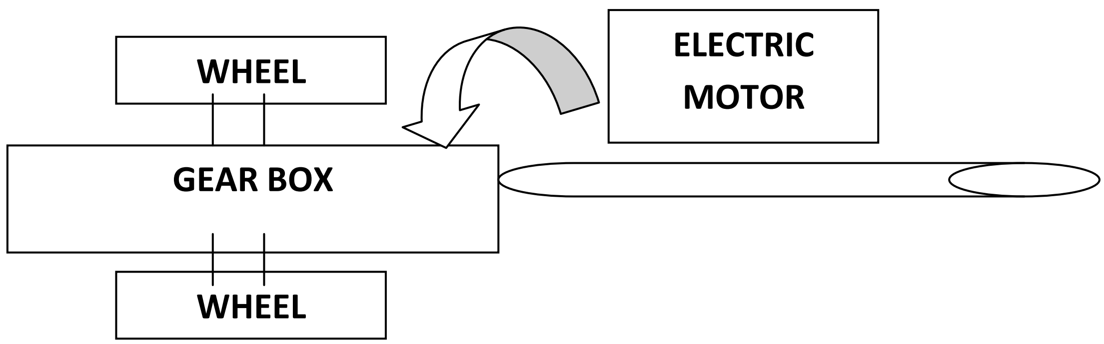


FIGURE 2.4: TYPICAL FRONT-WHEEL DRIVE

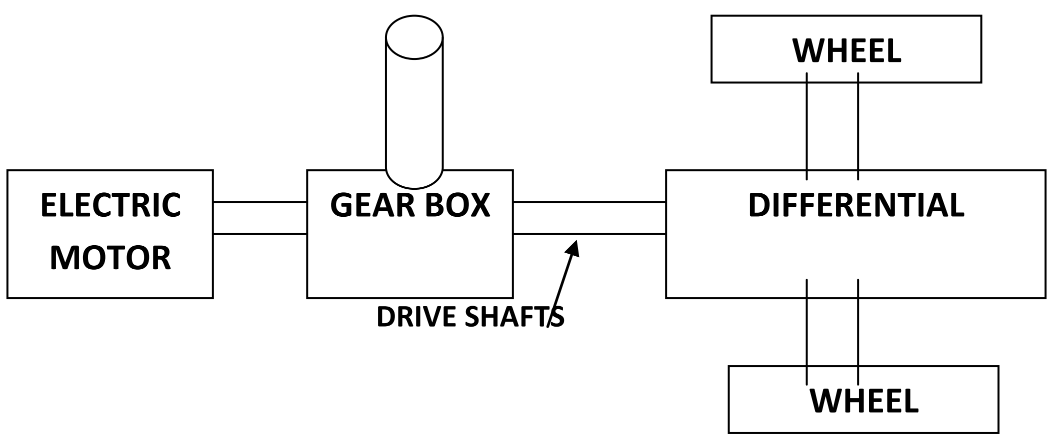


FIGURE 2.5: TYPICAL REAR-WHEEL DRIVE

2.5 TRANSMISSION COMPONENTS

2.5.1 GEARS

Simple mechanical power transmission machine used to gain a mechanical advantage through an increase in torque or reduction in speed or in other words its define as element that transform the mechanical power provided by a power source at a certain speed $\boldsymbol{\omega_1}$ and torque $\boldsymbol{T_1}$ to different speed $\boldsymbol{\omega_2}$ and torque $\boldsymbol{T_2}$ level. Function of gears is be used as torque multiplier or speed reducer and gears used the concept of law of conservation energy. The false concept of gears commonly be used was gears function to increase the shaft speed but the concepts are rejected. It been prove by the application of high torque motor. Size of motor gives a major effect on the amount of torque output. The relationship is size of motor proportional to torque output.

2.5.1.1 Ideal Gearbox

There are many types of gearbox in industries and its describe below;

a) Manual gear boxes : have a finite number of fixed gear ratios and are manually operated by the driver
b) Automatic transmissions : combine a fixed number of gear ratios with gear shift mechanism and a hydrodynamics torque converter or an automated standard clutch.
c) Continuously variable transmission (CVTs) : which are able to realize any desired gear ratio within the limits of this device.

The terms of ideal, its mean by no losses and the efficiency of the element are hundred percent without any internal or external effect. The ideal gearbox algorithm briefly shown below ;

P_{losses} **= 0 then efficiency goes to 100%**

Perfectly rigid gears

No gear backlash (no space between teeth)

IDEAL GEARBOX CHARACTERISTICS

$$\boldsymbol{\omega\, r = v}$$

$$\boldsymbol{r_{in}\omega_{in} = v = r_{out}\omega_{out}}$$

$$\textbf{GR} = \frac{\omega_{in}}{\omega_{out}} = \frac{r_{out}}{r_{in}}$$

$$\boldsymbol{\prod_{gear\ train} = 100\%}$$

$$\boldsymbol{P_{out} = P_{in}}$$

$$\boldsymbol{{}_{out}\omega_{out} = T_{in}\omega_{in}}$$

$$\textbf{GR} = \frac{T_{out}}{T_{in}} = \frac{\omega_{in}}{\omega_{out}}$$

$$\boldsymbol{T_{in} = Fr_{in}}$$

$$\textbf{F} = \frac{T_{in}}{r_{in}} \qquad \textbf{F} = \frac{T_{out}}{r_{out}}$$

$$\textbf{GR} = \frac{T_{out}}{T_{in}} = \frac{r_{out}}{r_{in}}$$

Abbreviations:

$\omega_{in} = input\ angular\ speed$

$\omega_{out} = output\ angular\ speed$

$r = disk\ radius$

$r_{in} = input\ gear\ radius$

$r_{out} = output\ gear\ radius$

GR = gear ratio

$T_{in} = input\ torque$

$T_{out} = output\ torque$

$v = tangential\ velocity$

2.5.2 CLUTCH

Mechanical device used to smoothly engage or disengage the power transmission between a prime mover and the load. Clutch commonly be used in transmission system as the linkage between IC engine with other transmission system components of the vehicle. Technically, its allows the power source to continue running, while the load is freely running due to vehicles inertia or is idle. Major contribution of this component is make the IC engine efficiency increase due to it function on matching the wheel speeds and the narrow range of high-torque operating speed of IC engine. In EVs technology, this transmission system component can be eliminated because EVs motor can start from zero speed and operate all the way to its maximum speed using a single gear ratio.

2.5.3 BRAKES

In automobiles industries, brakes known as friction clutches which use friction to slow a rotational disk. Normally, the driver controls the brake action through a foot-operated linkage. This friction clutch composed of two disks and each disk connected to its own shafts. When these two disks do not engaged each other (driver not push the brakes pedal), its means that one disk can spin freely without affecting the other one. Then when the driver pushes the brakes pedal, then rotating and stationary disks engaged. The friction between these two disks reduces the speed of the rotating disk.

There have two types of friction clutches or brakes- disk brakes and drum brakes. Disk-type brake has a friction pads (brake pads) which controlled by a caliper arrangement. When the operation action (engaged), the caliper clamps to a disk that rotate with the wheel. The friction pads are designed to assist cooling and resist fading. A second type of brake is drum-type brakes. Its have cylindrical surfaces and shoes instead of pads that hold the friction material. The operation starts when the driver gives the brake command input then the shoes press against the drum cylinder, finally reduces the speed of rotating disk.

2.6 VEHICLES SPECIFICATIONS

In order to choosing the motor in completing this thesis, specifications for the fixed vehicles are totally required. What the specifications those have to be known exactly? The specification are dimensions of the vehicles in terms of it maximum height, maximum width, maximum length and wheel base; general characteristics such as weight, structure, body work, steering, brakes, tires, transmission, aerodynamics coefficient, friction coefficient; performance qualities such as demand power, maximum velocity and maximum acceleration; and the extra specification that been considered are occupants load, baggage load, structure and mechanical component weight, batteries load and motorization. The specifications of ISWARA that become the research vehicles of this thesis are shown in figure 2:

2.6.1 SPECIFICATIONS FOR ISWARA

POWERTRAIN

ENGINE	: 4G13P, 12V SOHC
BORE X STROKE	: 71 mm X 82 mm
TOTAL DISPLACEMENT	: 1299
COMPRESSION RATIO : 9.5 : 1	
MAXIMUM OUTPUT	: 62 kN / 6000 rpm
MAXIMUM TORQUE	: 109 Nm / 4000 rpm
FUEL SYSTEM	: Auto choke single barrel ventury downdraft carburetor
FUEL TANK CAPACITY	: 45 Littre
CLUTCH (WIRE CONTROL)	: Single dry plate
TYPE	: F5M21
FINAL GEAR RATIO	: 4.32 2
POWER-ASSISTED STEERING	: Standard

CHASSIS

SUSPENSION-FRONT	: MacPherson Strut, coil and stabilizer bar
SUSPENSION-REAR	: Independent traling arm, coil
BRAKE-FRONT/REAR	: Disc brake / Drum
TYPE AND RIMS	: 185/60R 14” Tyre and 14 X 6.0 J alloy rim

DIMENSION AND WEIGHT

MAXIMUM HEIGHT	: 1360 mm
MAXIMUM WIDTH	: 1655 mm
MAXIMUM LENGTH	: 4110 mm
WHEELBASE	: 2380 mm
TRACK	: 1406 mm (FRONT) 1356 mm (REAR)
CURB WEIGHT	: 970 Kg

GROSS VEHICLE WEIGHT	: 1360 Kg
LUGGAGE SPACE	: 320 Littre
FUEL CONSUMPTION @	
90 km/h / 120km/h / urban cycle	: 5.5 / 7.4 / 10.2 Littre/100km
ACCELERATION 0 to 100km/h	: 13.1 sec

FINISHING (EXTERIOR AND INTERIOR)

UPHOLSTERY	: Dotted grey flat woven
FLOOR CARPET	: Needle punch
FLOOR CONSOLE	: Standard type with utility box
SKIRTING	: Polypropylene
DOOR MIRROR	: Direct remote
CENTRAL DOOR LOCKING	: Standard
INTERIOR TRIMS	: Blend of silver finishing

FIGURE 2.6: SPECIFICATION OF VEHICLES [3]

FIGURE 2.7, 2.8: VEHICLE USED (PROTON ISWARA)

2.7 ENERGY MANAGEMENT

2.7.1 CONTROLLER

Two functions for this controller is supply demand power and maintain the charge of the energy storage system (ESS). It will control the main power unit (HPU) and ESS by using optimal fuel cost strategy. Optimal fuel cost strategy gives the idea of scan all the possible combination of power from HPU and ESS to satisfy the demand power from the vehicles. The other function of this controller is to minimize the power demand by using minimum power threshold strategy. This threshold strategy was the way to determine the optimal comprise of HPU operation and ESS operation to maximize fuel economy by using a MOTIVE POWER THRESHOLD (MPT) which the HPU is not operated except to recharge the ESS.

Other method to control this energy which gets from the electric sources is by using the torque estimation. This strategy been done by diagnose the potential discrepancy in electrical operating characteristics of a three-phase electric motor by using the plurality of current sensor and shaft position sensor. This two sensor will generate two independent torque which be used in EV.

Controls apparatus become a main role of calculate a torque requested for driving the vehicles and control a torque generated by an engine and electric motor. According to this control apparatus, if the responsiveness in changing the transmission ratio of the transmission is poor and the torque generated by the engine becomes lower than the requested torque, electric motor is controlled to generate the deficient (supplementary) torque, and smooth acceleration of the vehicles can be performed.

2.7.2 SUPERCAPACITOR BANKS (SB)

Capacitors are devices that store energy by the separation of equal positive and negative electrostatic charges. The basic structure of a capacitor consists of two conductors, known as plates, separated by dielectric, which is an insulator.[6]

Supercapacitor appears as one of the device to solve the problem in terms of energy management in electric vehicles (EV). Supercapacitor made up of single cells connected in series or parallel in the powertrain system of EV. The main objective added supercapacitor in the EV system was to take it as a suitable peak power unit. Integration of the on-board energy source of an electrically propelled vehicles with supecapacitor can lead to substantial benefits in term of EV performance which major effect on battery life and energy economy[1].

This research activity on SB were previously supported by European Community since the beginning of 1996 and been written in Joule III program and titled on "Development of Supercapacitors for Electric "(contract JOE3-CT95-0001) . SB can featuring appropriates parameters of energy density and power density of EV. With it main characteristics which is high charging- diacharging efficiency and affordable cost, SB become most suitable device to support energy source of an electrically propelled vehicles, then optimized the energy management.

Comparison between supercapacitor and conventional capacitor made in two chategories which is in physical and materials made of. In supercapacitor, dielectric is an electrolyte interposed between two electrodes. Then when the voltage apply, a double layer of charges formed at the interface between the electrodes and electrolyte. The distance appears between the charges respond to the thickness of that double layer is just a few Angstroms. As a results, a capacitance parameters per square centimeters for supercapacitors give the order of magnitude-50 μF/cm^2 compare to conventional capacitor which give nF/cm^2 as a order of magnitude.

The other comparison between the SB and conventional capacitor was the way to increase the energy stored. In conventional capacitor, it operates at high voltage (up to 3000V) which is consistent with the dielectric breaking voltage. Beside that, in SB, it will limited the voltage applied by the solvent or organic electrolyte decomposition voltage (1.23V and 3.5V respectively). Then the way to increase the stored energy was done by raising the capacitance value by adopting electrode materials with very high specific area. Because of that, active carben been used through suitable chemical processes, specific area of 10^3 m^2/g, and leading to a specific capacitance of 10^2 F/g. as a results, it will give a very low value of internal resistance and allows this SB to provide high output power. The general characteristics of the supercapacitor are brieflt explain in Table 2 below:

TABLE 2.3: CHARACTERISTICS OF SUPERCAPACITOR

Electrode material	Carbon	Carbon	Metallic oxides
Electrolyte	Aqueous electrolyte	Organic electrolyte	Aqueous electrolyte
Maximum voltage [V]	1	3	1
Specific power [kW/kg]	0.8–2.6	1.5–5	0.5
Specific energy [W h/kg]	0.2–1.3	3–6	1

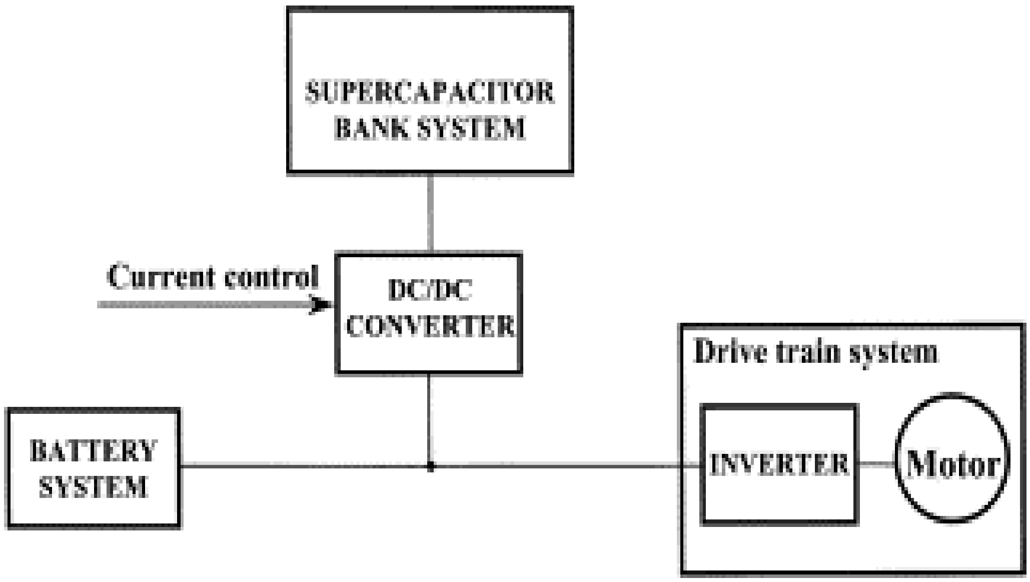


FIGURE 2.9: POWERTRAIN SYSTEM FOR EV[1]

2.7.3 PULSE-WIDTH MODULATION (PWM)

HEV system consisting a continuous stable linear part, therefore pulse element is considered added in. Because of that, pulse-width modulation gives a relation to this thesis occasionally. There are many kinds of pulse-width modulation such as integral pulse-width modulation (IPWM), linear integral pulse width modulation with modulation of a pulse trailing edge (LIPWM-1) and linear pulse-width modulation with modulation of a pulse leading edge (LIPWM-2). Figure 4 show the waveform for several types of PWM.

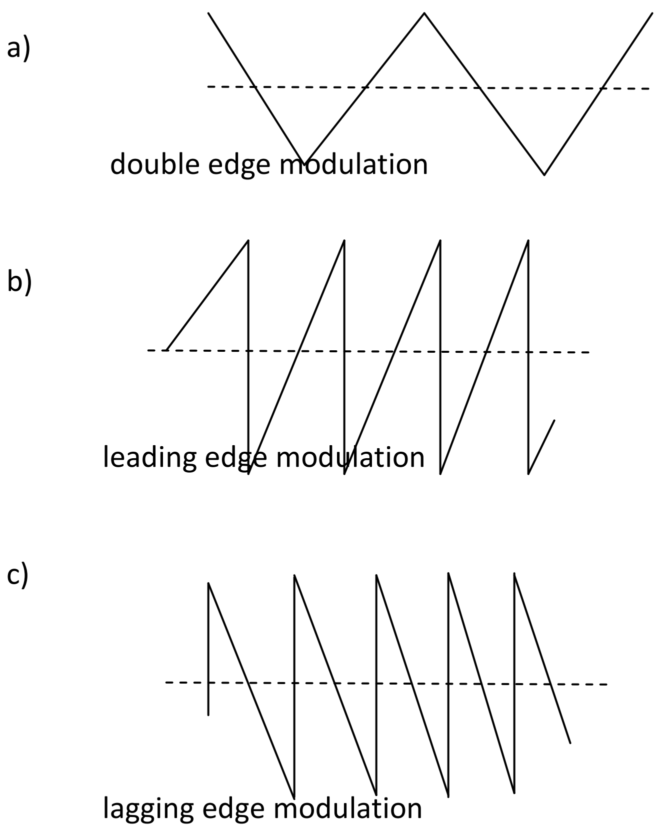


FIGURE 2.10(a ,b ,c): SOME TYPES OF PWM [2]

Due to synthesizing AC motor by PWM, number of pulse per output cycle will only be constant if carrier frequency (fc) is an exact multiple of output frequency (fo) but for normal case, fo will not have same number of pulse in each half cycle, in order word the number of pulse for output will not be the same, then how to make it become constant. Fc= N x Fo, if this going to happen then the process is said to be synchronized subharmonic pulse width modulation. Then, with fixed carrier frequency and variable output frequency, the modulation is said to be asynchronous[2].

Without PWM, motor converter will produce a losses almost pro-rata with carrier frequency. But with PWM, its used to create motor waveform with low harmonic ripple at very low carrier frequencies, in order words, the losses will decrease. The loss of the motor depending on rating and waveform is about 8 to 20 percent. By using PWM, the maximum power factor is presented to supply and minimum energy required make the PWM drive become the most effective and optimal cost solution.

CHAPTER 3

METHODOLOGY

3.0 VEHICLES DYNAMICS CHARACTERISTICS

3.1 PROPULSION SYSTEM ALGORITHM

In order to find the required power and force to move the vehicles, the vehicles performance modeling should be done. In this vehicles performance modeling, many equations been used, developed and finally the questions of finding the required power and force can be answer.

3.2 VEHICLES PERFORMANCE MODELLING

3.2.1 TRACTIVE FORCE

A first step in answering main questions is to find tractive force. The propulsion units of the vehicles used a tractive force, $\boldsymbol{F_{TR}}$ to move the vehicles forwardly with a desired velocity, and as a conjunction to that matter, $\boldsymbol{F_{TR}}$ should overcome all possible opposing forces. $\boldsymbol{F_{TR}}$ has to accomplish the following:

1. Overcome the aerodynamics drag
2. Overcome the rolling resistance of the tires
3. Overcome gravitational force
4. Provide the force required to give linear acceleration
5. Provide the force required to give angular acceleration to the rotating motor.

$$F_{TR} = F_{AD} + F_{roll} + F_{gxT} + F_{la} + F_{\omega a}$$

Abbreviations:

F_{AD} = aerodynamics drag

F_{roll} = rolling resistance force

F_{gxT} = gravitational force

F_{la} = force to give linear accelerations

$F_{\omega a}$ = force to give angular accelerations to rotating motor

3.2.2 AERODYNAMICS DRAG

F_{AD} is a force due to friction of the vehicles body moving trough the air and other words this force describe as a resisting force that opposes the motion of vehicles body as it moves through the atmosphere. Mathematically, this force is a function of frontal are, shape, protrusions (side mirrors), ducts, spoilers and many things. It gives a formula as:

$$F_{AD} = \frac{1}{2} C_D \rho V^2 A$$

Abbreviations:

C_D = drag coefficient

ρ = density of air [$\frac{kg}{m^3}$]

V = speed of vehicles [$\mathrm{m}s^{-1}$]

A = frontal area [m^2]

There are another equation to determine aerodynamics coefficient. The equations form as a results of viscous resistance and pressure distribution over the body of the air working against the motion of the vehicles. The equation stated below:

$$\boldsymbol{F_{AD}} = \boldsymbol{sgn}\,[v_{xt}]\{\boldsymbol{0.5\rho C_D A_F}(\boldsymbol{v_{xT}} + \boldsymbol{v_0})^2\}$$

Abbreviations:

$\boldsymbol{v_0}$ = head-wind velocity

$\boldsymbol{v_{xT}}$ = tangential velocity

3.2.3 ROLLING RESISTANCE FORCE

Rolling resistance is a force due to the friction of the vehicles tyre on the road or in typical words, rolling resistance produced by the hysteresis of the tire at the contact surface with the roadway. When the tire rolls, the centroid of the vertical forces on wheels moves forward from the beneath of axle towards the direction of motion in the vehicles. Weight on the wheel and road normal force are misaligned due to hysteresis of the tire then form a couple that used to retarding torque on the wheel. $\boldsymbol{F_{roll}}$ is a force due to that couple and opposing the motion of the wheel. It is tangential to the road path and because of that $\boldsymbol{F_{roll}}$ contributes in braking or retarding the motion of the vehicles. This rolling resistance can be minimized by reducing the hysteresis which can be done by keep the tire as inflated as possible as well. $\boldsymbol{F_{roll}}$ can be determined using equation below:

$$\boldsymbol{F_{roll}} = \boldsymbol{sgn}\,[v_{xt}]\boldsymbol{mg}(\boldsymbol{C_0} + \boldsymbol{C_1 v_{xT}}^2) \text{ if } \quad \boldsymbol{v_{xT}} \neq \boldsymbol{0}$$

$$\boldsymbol{F_{roll}} = \boldsymbol{F_{TR}} - \boldsymbol{F_{gxT}} \quad \text{if} \quad \boldsymbol{v_{xT}} = \boldsymbol{0} \;\text{ and }\; |\boldsymbol{F_{TR}} - \boldsymbol{F_{gxT}}| \leq \boldsymbol{C_0 mg}$$

$$F_{roll} = sgn\left[F_{TR} - F_{gxT}\ \right](C_0 mg) \quad \text{if} \quad v_{xt} \neq 0 \quad \text{and} \quad |F_{TR} - F_{gxT}| > C_0 mg$$

$$sgn\,[v_{xT}] = 1\ if\ v_{xT} \geq 0 \qquad\qquad sgn\,[v_{xT}] = -1\ if\ v_{xT} < 0$$

Abbreviations:

C_0 = coefficient of rolling resistance

$sgn\,[v_{xT}]$ = signum function

Other researcher said that rolling resistance is approximately constant and hardly depends on vehicles speed. So it just propotional to the vehicles weight and other equation about finding this rolling resistance force appears:

$$\boldsymbol{F_{roll} = \mu_{rr} m g}$$

Abbreviations:

$\boldsymbol{\mu_{rr}}$ = coefficient of rolling resistance

$\boldsymbol{m}$ = due mass of vehicles [kg]

$\boldsymbol{g}$ = due gravitational acceleration constant

3.2.4 GRAVITATIONAL FORCE

$\boldsymbol{F_{gxT}}$ depends on β, angle or slope of the roadway. It will give a positive value to $\boldsymbol{F_{gxT}}$ when vehicles moving upwards and negative value when the vehicles moving downwards of the road. The equation of gravitational force, the force that needed to drive the vehicles upwards or downwards shown below:

$$\boldsymbol{F_{gxT} = mg\ sin\beta}$$

Abbreviation:

$\boldsymbol{\beta}$ = grade angle with respect to horizon

3.2.5 ACCELERATION FORCE

When the velocity of the vehicles changing, then it should be additional force apply to the other forces in finding total tractive force. So this force will provide the linear acceleration of the vehicles and its derived by Newton's Second Law of Motion:

$$F_{la} = ma$$

This force also considers the force needed to make the rotating parts turn faster and because of that, rotational acceleration have been consider too.

$$F_{\omega a} = I\frac{G^2}{r^2}a$$ ⇒ consider the gear system is 100% efficient.

$$F_{\omega a} = I\frac{G^2}{\eta_g r^2}a$$ ⇒ consider the gear system is not 100% efficient

Abbreviations:

G= gear ratio

r = radius of the tyre

I = moment of the inertia of the rotor in the motor

η_g= gear system efficiency

3.2.6 TOTAL COMBINATION

From this primary equation:

$$\boldsymbol{F_{TR} = F_{AD} + F_{roll} + F_{gxT} + F_{la} + F_{\omega a}}$$

Then combine and derived all the forces, so the primary equation goes as below:

$$\boldsymbol{F_{TR} = \frac{1}{2} C_D \rho V^2 A + \mu_{rr} mg + mg\ sin\beta + ma + I\frac{G^2}{\eta_g r^2} a}$$

Or,

$$\boldsymbol{F_{TR} = \frac{1}{2} C_D \rho V^2 A + sgn\ [v_{xt}] mg (C_0 + C_1 {v_{xT}}^2) + mg\ sin\beta + ma + I\frac{G^2}{\eta_g r^2} a}$$

Note that, if the $\boldsymbol{I}$, moment of the inertia of the rotor in the motor is unknown, so by increasing the mass by 5% in the equation $\boldsymbol{F_{la} = ma}$ then term of $\boldsymbol{F_{\omega a}}$ can be ignored. If these situations happen, the equation of total tractive force will be:

$$\boldsymbol{F_{TR} = \frac{1}{2} C_D \rho V^2 A + \mu_{rr} mg + mg\ sin\beta + ma}$$

Finally, the required power to move the vehicles can be determine by using the torque motor equation that can be get from the total tractive force above. The equations that been used until the required power derived, shown below:

$$F_{TR} = \frac{G}{r} T_{max} \qquad T_{max} = \frac{F_{TR}}{G} r \qquad P = F_{TR} . V$$

Abbreviations:

$T_{max} =$ maximum torque of motor

$P =$ power required to move the vehicle

From the power, many specification of the motor can be determined such as angular speed. This parameter is used to choose a suitable motor for that vehicle. Equation below show how to find that specification needed:

$$Power = T_{max} \cdot \omega$$

$$Power(kW) = 0.746 \; X \; Horsepower(HP)$$

Abbreviation:

ω = motor angular speed

3.2.7 CALCULATION

3.2.7.1 Parameter

Parameter that be get from the vehicles specification (ISWARA) are:

1) Mass of vehicle, $\boldsymbol{m}$ = 1360$\boldsymbol{kg}$
2) Gravitational acceleration constant, $\boldsymbol{g}$ = 9.81 $\mathbf{m}\boldsymbol{s}^{-1}$
3) Coefficient of rolling resistance, $\boldsymbol{\mu_{rr}}$ = 0.001
4) Drag coefficient, $\boldsymbol{C_D}$ = 0.3
5) Density of air at 40°$\boldsymbol{C}$, $\boldsymbol{\rho}$ = 1.127 $\frac{\boldsymbol{kg}}{\boldsymbol{m^3}}$
6) Gear ratio is 11:1 , thus $\boldsymbol{G}$=11
7) Radius of the tyre, $\boldsymbol{r}$ = 0.285 $\boldsymbol{m}$
8) Grade angle with respect to horizon, $\boldsymbol{\beta}$ = 0, which vehicles move on a flat road.
9) Frontal area, $\boldsymbol{A}$ = 1.9582 $\boldsymbol{m^2}$

Parameter that been consider due to desired velocity:

1) Speed of vehicles, $\boldsymbol{V}$ = 72 $\mathbf{km/hr}\left(\frac{\mathbf{1000}\boldsymbol{m}}{\mathbf{1}\boldsymbol{km}}\right)\left(\frac{\mathbf{1}\boldsymbol{hr}}{\mathbf{3600}\boldsymbol{sec}}\right)$

   $\boldsymbol{V}$ = 20 $\mathbf{m}\boldsymbol{s}^{-1}$
2) Acceleration of vehicle, $\boldsymbol{a}$ = 2 $\boldsymbol{ms}^{-2}$

3.2.7.2 Total Tractive Force

Total tractive force or force required to move the vehicles are:

$$F_{TR} = \frac{1}{2} C_D \rho V^2 A + \mu_{rr} mg + mg\, sin\beta + ma + I \frac{G^2}{\eta_g r^2} a$$

I, moment of the inertia of the rotor in the motor is unknown, so by increasing the mass by 5% in the equation F=ma then term of F**ω**a can be ignored. The equation of total tractive force will be:

$$F_{TR} = \frac{1}{2} C_D \rho V^2 A + \mu_{rr} mg + mg\, sin\beta + ma$$

5% of mass = (5x1360)/100 = 68kg

$F_{TR} =$ [0.5 x 1.127 x 1.9582 x 0.3 x $(20)^2$] + [0.001 x 1360 x 9.81] + [0] + [(1360 + 68) x 2]

=133.416 + 132.413484 + 2856

= 3121.829484

= **3121.829 N**

3.2.7.3 Power Requirement

Power required in moving the vehicles are:

$$\boldsymbol{Power = F_{TR} \cdot v_{xT}}$$

$\boldsymbol{P} =$ 3121.829N x 20 m/s

$=$ 62436.58968 W

$=$ **62.437Kw**

$$\boldsymbol{Power(kW) = 0.746\ X\ Horsepower(HP)}$$

$\boldsymbol{HP} =$ **62.437 / 0.746**

$=$ **84 HP**

3.2.7.4 Specification of The Motor

There are some specification of the motor that been know after finding the power and force requirement in moving the ISWARA:

$$\boldsymbol{T_{max} = \frac{F_{TR}}{G} r}$$

Maximum Torque, $\boldsymbol{T_{max}} =$(3121.829N x 0.285m) / 11

$=$ **80.884Nm**

$$\boldsymbol{Power = T_{max} \cdot \ \omega}$$

Angular speed, $\boldsymbol{\omega}$ =(62.437Kw) / 80.884Nm

= **771.935 rad/s**

$$\boldsymbol{horsepower = T\ (ft.lb) X\ \omega_e \frac{\left(\frac{rad}{sec}\right)}{550} = \mathbf{T\ (ft.lb) X \frac{RPM}{5252}}}$$

$\boldsymbol{\omega}$ =771.935 rad/s

$\boldsymbol{HP}$ = 84 HP

$\boldsymbol{T\ (ft.lb) = \frac{84}{771.935/\ 550}}$

= 59.8496 $\boldsymbol{ft.lb}$

$\mathbf{RPM = \frac{84}{59.8496\ /5252}}$

= **7371.28 rpm**

3.3 COMPARISON

3.3.1 AERODYNAMICS DRAG

POWER OVERCOME AERODYNAMICS DRAG ALONE, $\boldsymbol{P_{AD}} = \frac{1}{2}\boldsymbol{C_D \rho V^3 A}$

Drag Force, $\boldsymbol{F_{AD}} = \frac{\boldsymbol{P_{AD}}}{\boldsymbol{V}} = \frac{\frac{1}{2}\boldsymbol{C_D \rho V^3 A}}{\boldsymbol{V}}$

3.3.1.1 Constant Parameters

Frontal Area, A = 0.87 X Overall height X Overall Width

= 0.87 X 1.36m X 1.655m

= 1.9582 $\boldsymbol{m^2}$

Density of air at 1atm pressure and 40°$\boldsymbol{C}$, ρ = 1.127 $\frac{\boldsymbol{kg}}{\boldsymbol{m^3}}$

3.3.1.2 Variables Parameters

Drag Coefficient, $\boldsymbol{C_D}$ = 0.2, 0.3, 0.4

Speed, V = 10 m$\boldsymbol{s^{-1}}$, 20 m$\boldsymbol{s^{-1}}$, 30 m$\boldsymbol{s^{-1}}$, $\mathbf{40\ m}\boldsymbol{s^{-1}}$, $\mathbf{50\ m}\boldsymbol{s^{-1}}$, $\mathbf{60\ m}\boldsymbol{s^{-1}}$

3.3.1.3 Results

TABLE 3.1: DRAG COEFFICIENT=0.3

P_{AD}(WATT)	F_{AD}(N)	V (m/s)
331.03	33.1	10
2648.27	132.41	20
8937.91	297.93	30
21186.16	529.65	40
41379.21	827.58	50
71503.28	1191.72	60

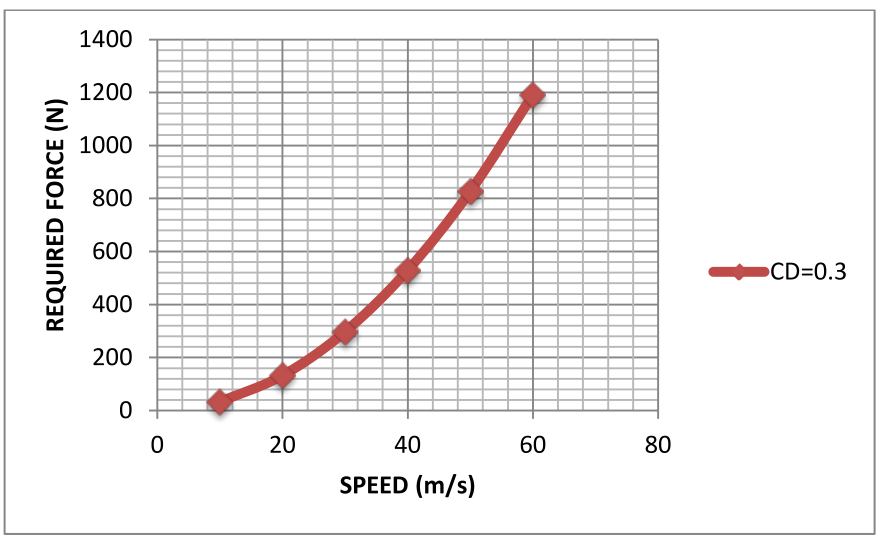


FIGURE 3.1: REQUIRED FORCE VERSUS VELOCITY FOR 0.3 DRAG COEFFICIENTS

TABLE 3.2: DRAG COEFFICIENT=0.2

P_{AD}(WATT)	F_{AD}(N)	V (m/s)
220.69	22.07	10
1765.51	88.28	20
5958.61	198.62	30
14124.1	353.1	40
27586.14	551.72	50
47668.85	794.48	60

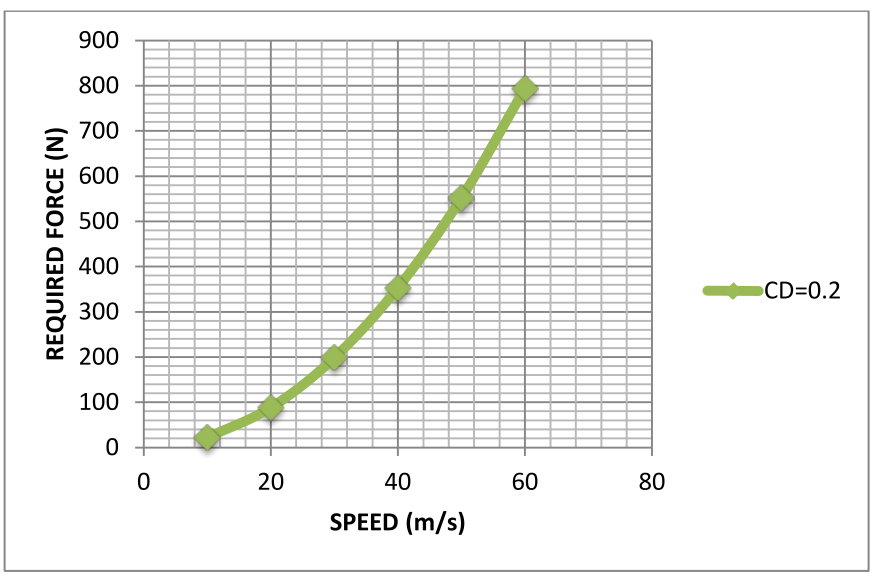


FIGURE 3.2: REQUIRED FORCE VERSUS VELOCITY FOR 0.2 DRAG COEFFICIENTS

TABLE 3.3: DRAG COEFFICIENT = 0.4

P_{AD}(WATT)	F_{AD}(N)	V (m/s)
441.38	44.14	10
3531.03	176.55	20
11917.21	397.24	30
28248.21	706.21	40
55172.29	1103.45	50
95337.71	1588.96	60

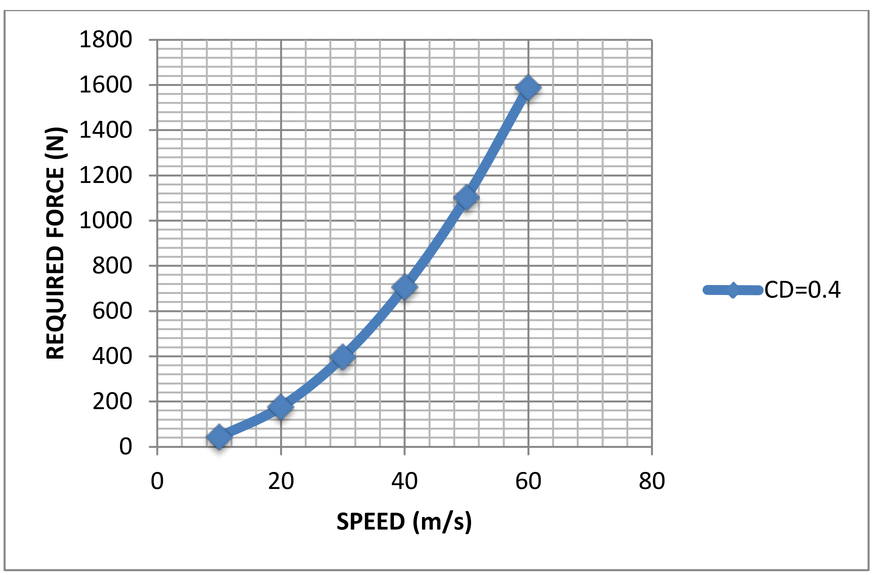


FIGURE 3.3: REQUIRED FORCE VERSUS VELOCITY FOR 0.4 DRAG COEFFICIENTS

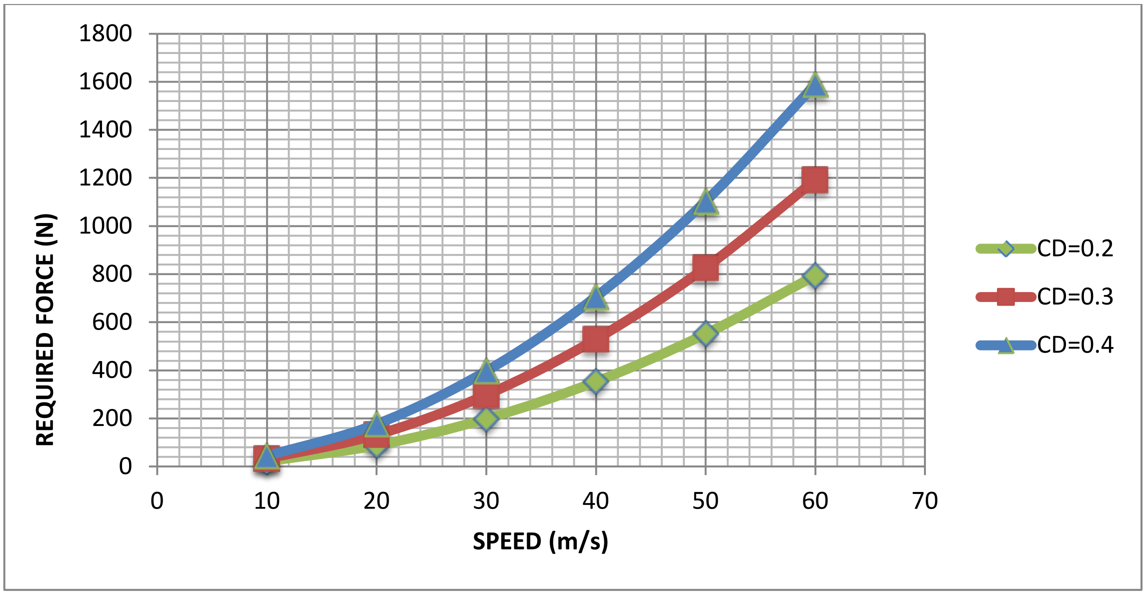


FIGURE 3.4: COMPARISON BETWEEN REQUIRED FORCE TO MOVE VEHICLES FOR 0.2, 0.3, AND 0.4 DRAG COEFFICIENT

Results for this comparison, typically drag coefficient, $\boldsymbol{C_D}$ for sedan car should be between 0.2 to 0.4 and increasing value of $\boldsymbol{C_D}$ will automatically increase the value of requirement force in moving the vehicle. This statement supported by the equation of aerodynamics drag force. Show in the figure 1, the force required to move the vehicle with $\boldsymbol{C_D}$=0.3 in 40m/s is 529.65N, compare to figure 2 and figure 3 which the force are required to move the vehicle with $\boldsymbol{C_D}$=0.2 and $\boldsymbol{C_D}$=0.4 in 40m/s are 353.1N and 706,21N, respectively.

In modeling the vehicles, engineers from automotive industries try to reduce the value of $\boldsymbol{C_D}$ or aerodynamics drag force but in order to reach the comfortable demand of the customer who want to have such a big and comfortable car, then their accomplishment become minor. This will give the impact on increasing the power to move the vehicle so that huge performance electric motor should be chosen.

3.3.2 ROLLING RESISTANCE

Rolling Resistance Force, $\boldsymbol{F_{roll} = sgn\,[v_{xt}]mg(C_0 + C_1 {v_{xT}}^2)}$ if $\boldsymbol{v_{xT} \neq 0}$

3.3.2.1 Constant Parameters

Mass of vehicles = 1360 kg

$\boldsymbol{sgn\,[v_{xT}] = 1}$ because $\boldsymbol{v_{xT} \geq 0}$

Gravitation coefficient, $\boldsymbol{g = 9.81\ ms^{-2}}$

$\boldsymbol{C_1 \ll C_0\ (\frac{s^2}{m^2}\ unit)}$ then assumption made $\boldsymbol{C_1 = 0.004\frac{s^2}{m^2}}$

3.3.2.2 Variables Parameters

Coefficient of rolling resistance, $\mathbf{C_0}$= 0.005, 0.01, 0.015 typically,

0.004$<$ $\mathbf{C_0}$ $<$0.02

Speed, V = 10 ms^{-1}, 20 ms^{-1}, 30 ms^{-1}, $\mathbf{40\ m}s^{-1}$, $\mathbf{50\ m}s^{-1}$, $\mathbf{60\ m}s^{-1}$

3.3.2.3 Results

TABLE 3.4: ROLLING RESISTANCE COEFFICIENT =0.005

$F_{roll}(N)$	V (m/s)
5403.35	10
21413.27	20
48096.47	30
85452.95	40
133482.71	50
192185.75	60

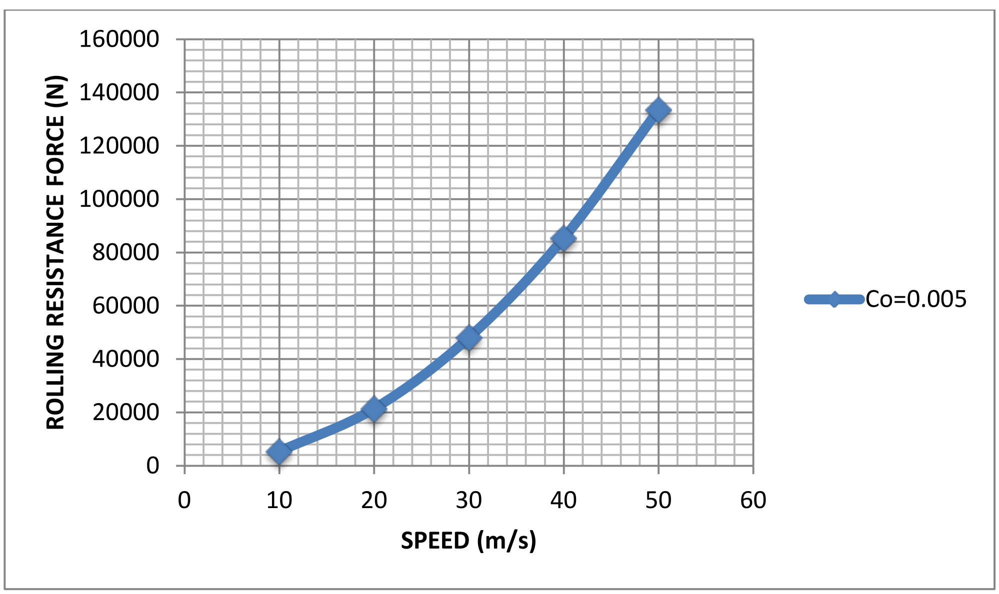


FIGURE 3.5: REQUIRED FORCE VERSUS VELOCITY FOR 0.005 ROLLING RESISTANCE

TABLE 3.5: ROLLING RESISTANCE COEFFICIENT =0.01

$F_{roll}(N)$	V (m/s)
5470.06	10
21479.98	20
48163.18	30
85519.66	40
133549.42	50
192252.46	60

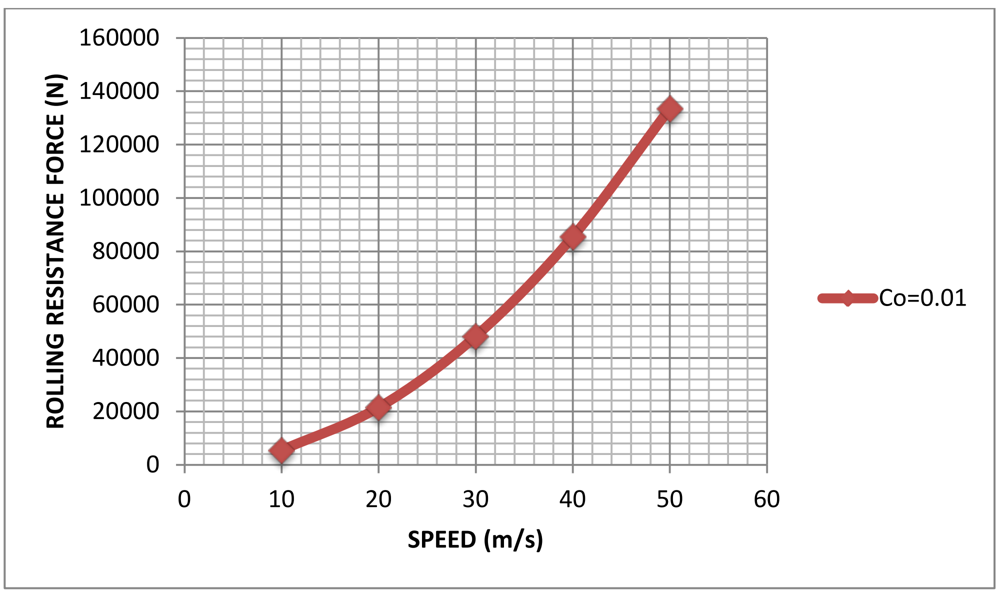


FIGURE 3.6: REQUIRED FORCE VERSUS VELOCITY FOR 0.01 ROLLING RESISTANCE

TABLE 3.6: ROLLING RESISTANCE COEFFICIENT =0.015

$F_{roll}(N)$	V (m/s)
5536.76	10
21546.68	20
48229.88	30
85586.36	40
133616.12	50
192319.16	60

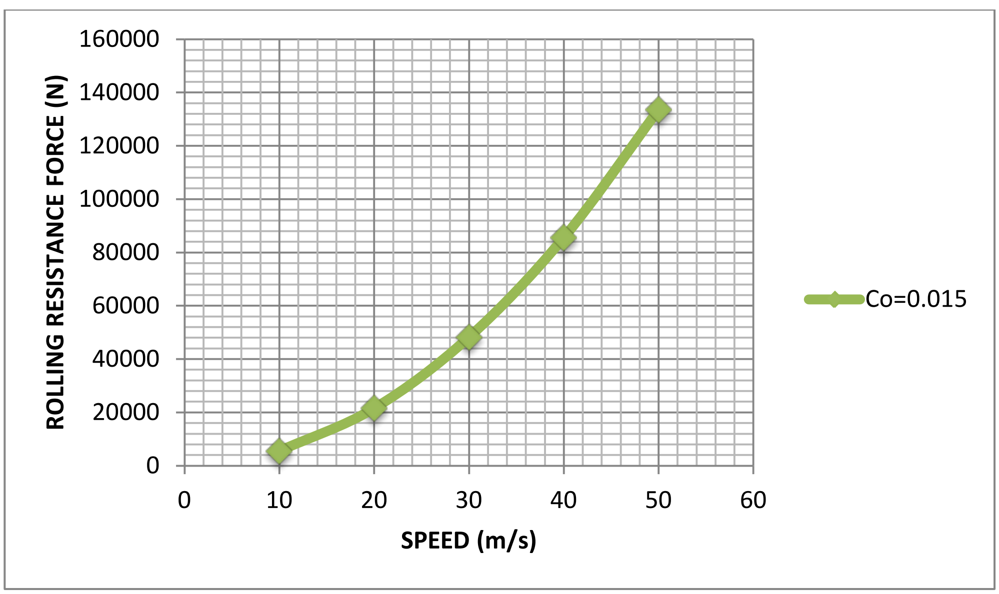


FIGURE 3.7: REQUIRED FORCE VERSUS VELOCITY FOR 0.015 ROLLING RESISTANCE

Results for this comparison, typically rolling resistance coefficient, C_o for sedan car should be between 0.004 to 0.02 and increasing value of C_o will automatically increase the value of requirement force in moving the vehicle. This statement supported by the equation of rolling resistance forces. Show in the figure 5, the force required to move the vehicle with C_o =0.005 in 40m/s is 85452.95N, compare to figure 2 and figure 3 which the force are required to move the vehicle with C_o =0.01 and C_o =0.015 in 40m/s are 85519.66Nand 85586.36N, respectively.

In modeling the vehicles, rolling resistance forces give the minor effect in finding the power required to move the vehicle and actually its can be neglected due to the small value of force. But in this calculation the figure getting error because the are a lot or parameter been consider compare to the other formula for rolling resistance force. Either it getting some error but the sequence still same which is by increasing the value of C_o then rolling resistance force will increase too. In other words, the required force and power to move the ISWARA will get bigger. By proposing on reduction the value of rolling resistance forces, the mass of the vehicle and driving pattern in term of speed the vehicle moving, should be consider.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 ELECTRIC MOTOR CHOOSEN

4.1 CHARACTERISTICS SELECTED

4.1.1 TYPE

Type of motor that been used for moving the ISWARA is three-phase induction motor. It has been chosen because of the required power to move this vehicle is too big and the suitable one is three phase induction motor.

4.1.2 POWER AND TORQUE

Specification of motor:
Maximum output = 15kW / 2950 rpm
Type = three-phase induction motor
Maximum voltage = 415 volt
Maximum frequency = 50 Hz

4.1.3 BUDGET FROM UNIVERSITY

Shown below the tester motor that given from university to analyze the results get from calculation before. To prove the calculation valid or not, simulation must be done using the specification of the tester motor.

FIGURE 4.1: TESTER MOTOR (TOP VIEW)

FIGURE 4.2: TESTER MOTOR (FRONT VIEW)

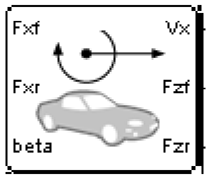
FIGURE 4.3: TESTER MOTOR (SIDE VIEW)

4.2 METHODS TEST THE MOTOR

4.2.1 SIMULATION

Simulation conducted in order to test the tester motor either it can be a suitable motor or not. Comparison made between the characteristics of tester motor and the required power that get from the calculation. Simulation consists of variable components that be consider gives a major impact on moving the vehicles or in vehicle dynamics.

4.2.1.1 Vehicle Dynamics



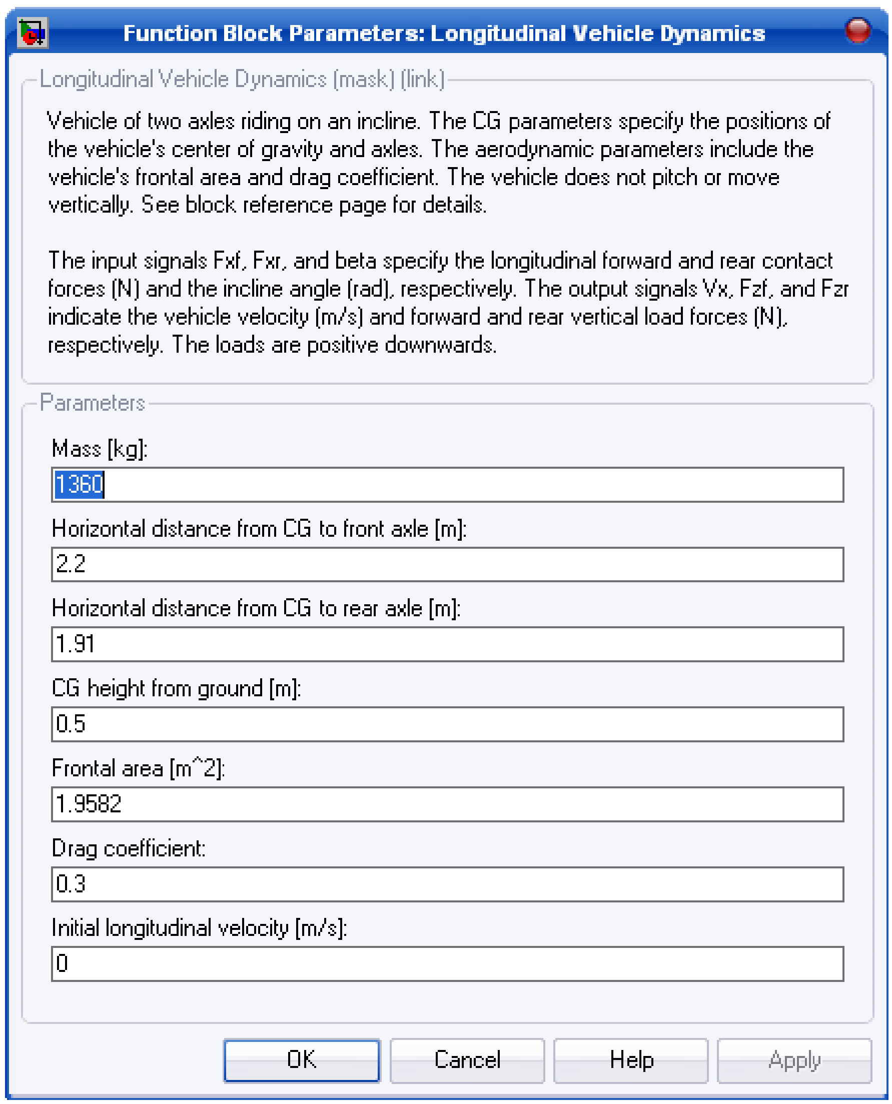
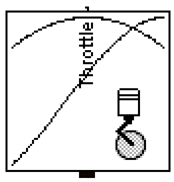


FIGURE 4.4: ISWARA SPECIFICATION PARAMETERS

4.2.1.2 Electric Motor Characteristics



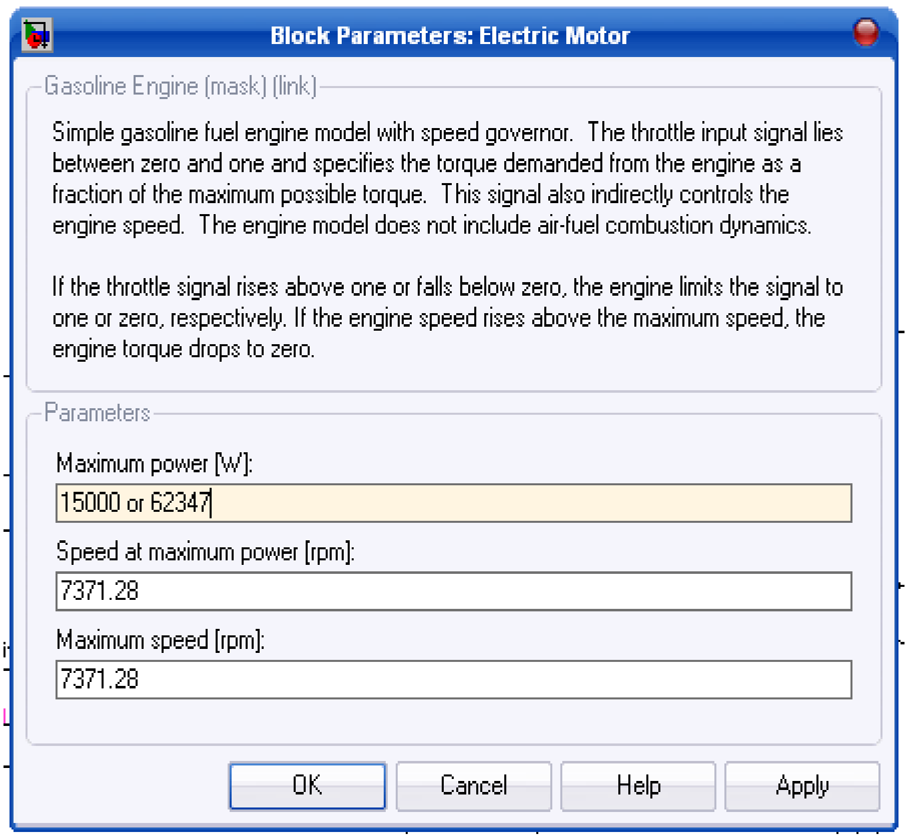
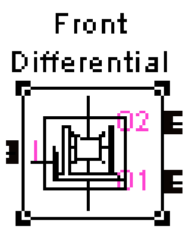


FIGURE 4.5: ELECTRIC MOTOR PARAMETERS

4.2.1.3 Gear Ratio Distribution



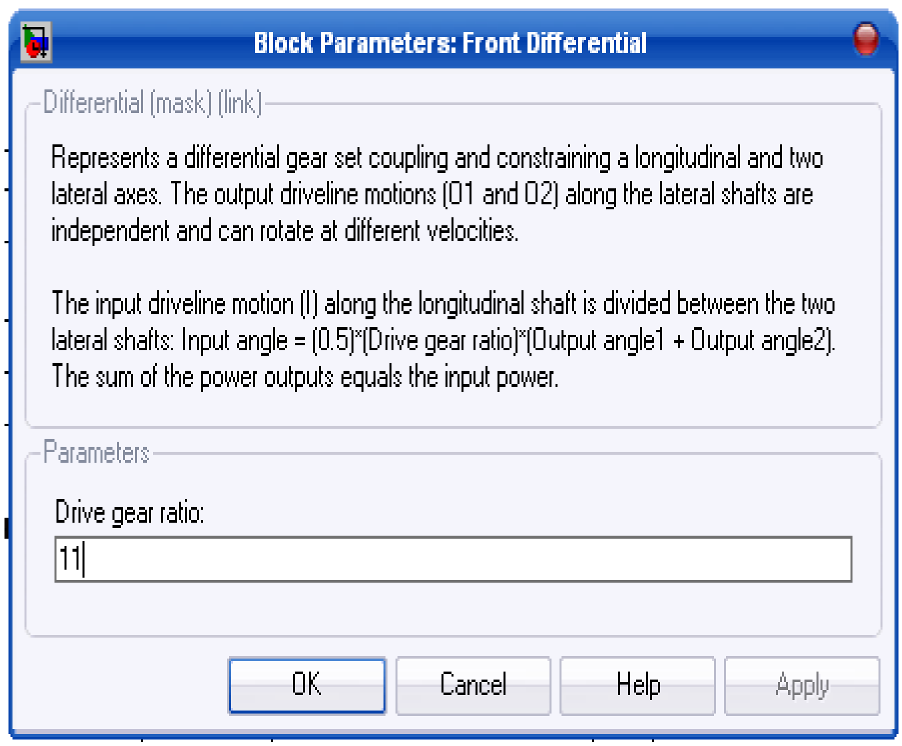
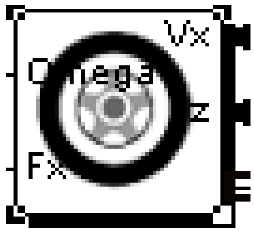


FIGURE 4.6: GEAR RATIO PARAMETER

4.2.1.4 Tyre and Rolling Resistance Contribution



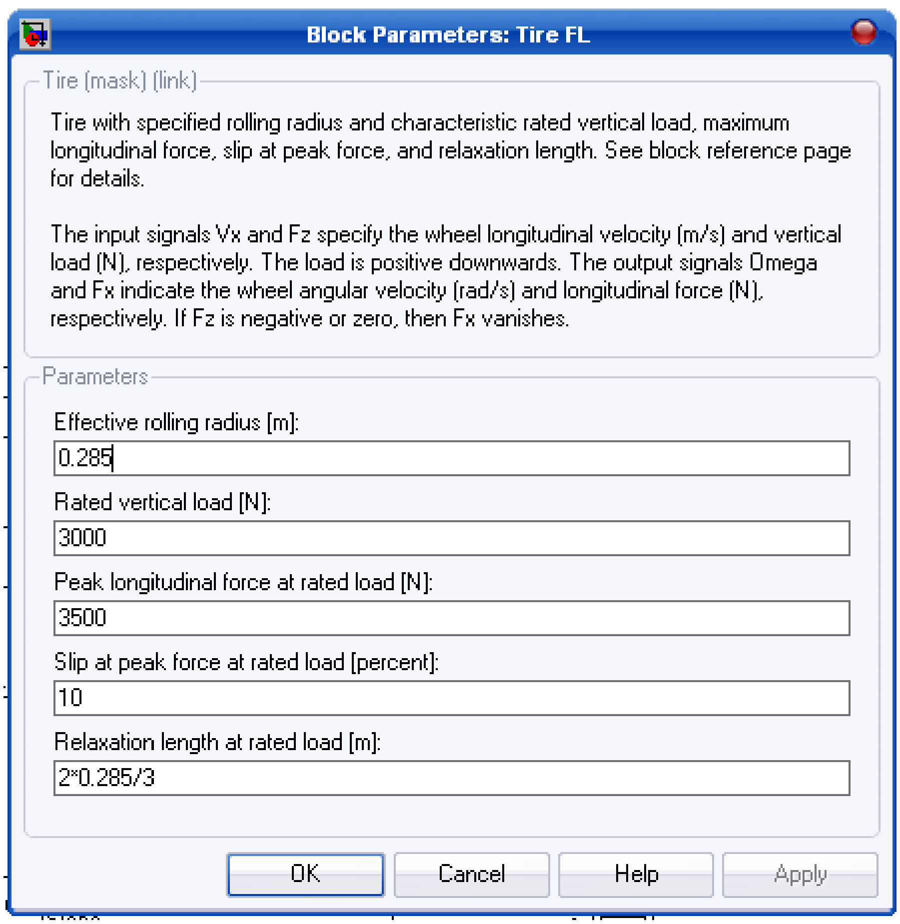


FIGURE 4.7: TYRE PARAMETER

4.2.1.5 Simulation Model for EV ISWARA

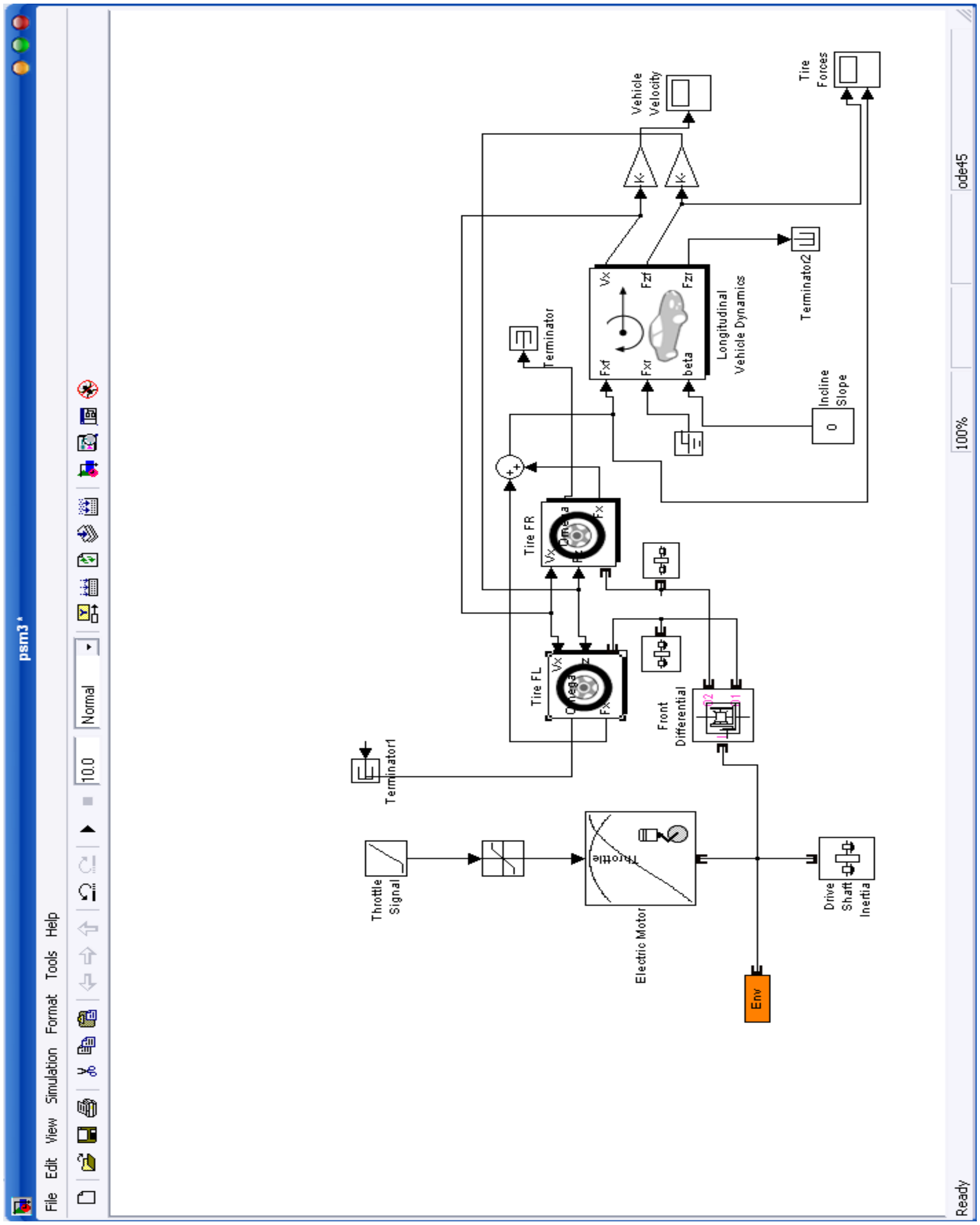


FIGURE 4.8: SIMULATION MODEL FOR ISWARA

4.2.2 SIMULATION RESULTS

4.2.2.1 Results for Vehicle Velocity When Using 15kW Electric Motor

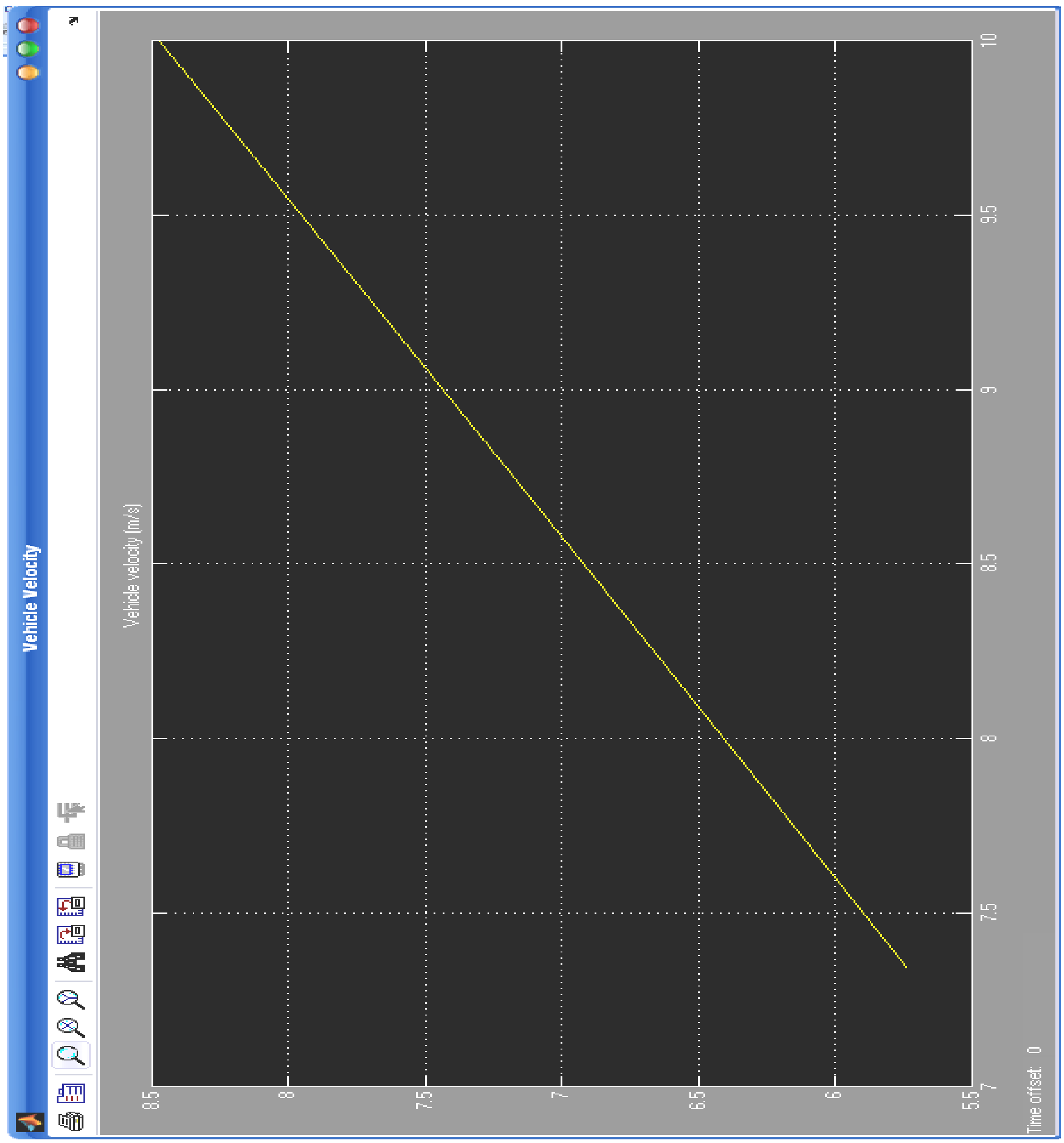


FIGURE 4.9: VEHICLE VELOCITY WHEN USING 15kW ELECTRIC MOTOR

4.2.2.2 Results for Vehicle Velocity When Using 62.437kW Electric Motor

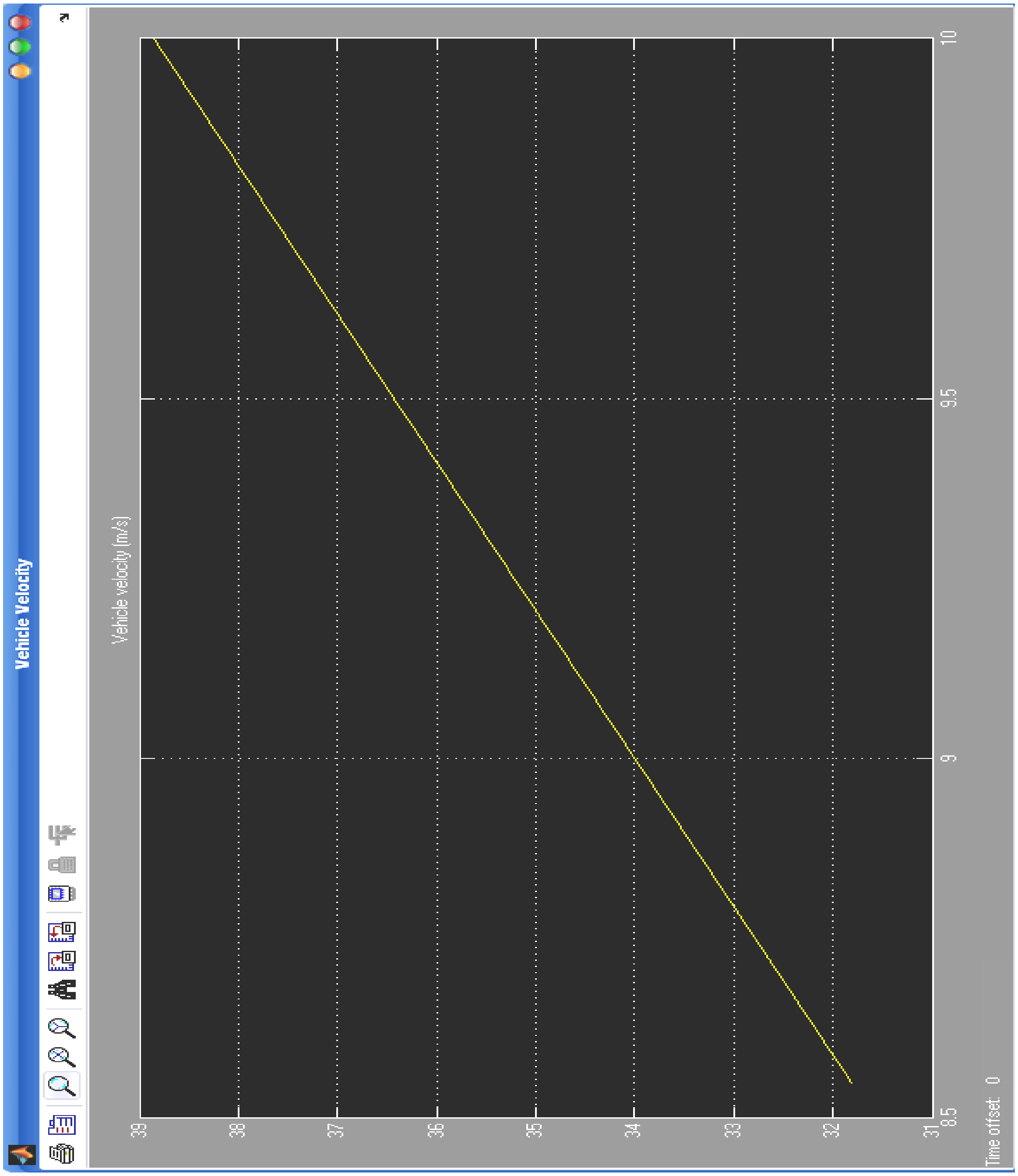


FIGURE 4.10: VEHICLE VELOCITY WHEN USING 62.437kW ELECTRIC MOTOR

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

5.1.1 VEHICLES CONTRIBUTION

From the vehicle dynamics point of view, this thesis conclude the characteristics that been consider in finding the required power for moving the ISWARA which is gear ratio, rolling resistance, aerodynamics drag and driving patterns consisting of desired velocity and speed. Conclude that required power to move the ISWARA is 62.437kW or in other words its requirement is 84 HP.

5.1.2 ELECTRIC MOTOR

In terms of electric motor that been chosen, this thesis analyze that from the power and force get from the calculation, the torque of electric motor must be bigger than 80.884Nm and the angular speed for the motor should be 771.935 rad/s. From the studies in variety type of motor in industries, three-phase induction motor has been considered as a suitable one. But the electric motor (15kW) that is use in this thesis can not fulfill the requirement to move the vehicle (ISWARA) in the desired velocity which is 20m/s. The motor just achieve the moving speed to 8.5m/s. By changing the maximum power of electric motor to 62.437kW, the electric motor gives the vehicle a 39m/s as a velocity. Conclude that either the type of the electric motor is true, but the maximum outputs from the motor have been considered too before choosing it.

5.2 RECOMMENDATION

5.2.1 ERROR ON THE FINAL RESULTS

After changing the electric motor that have the suitable power requirement (62.437kW), the simulation results give some error in terms of desired vehicle velocity.

5.2.1.1 Causes

Many possible causes can be find out such as:

1) The inertia of the vehicle are not well calculate due to the vehicle situation which is not suitable to move. The specifications of vehicle that get from the Proton supplier are not enough to find the inertia in using mathematical solution and calculation.
2) The tester motor been used cannot be test by experimental method due to insufficient budget from university and insincere deal by the supplier to send the manual and inverter apparatus for AC induction motor.
3) The desired velocity that been used are too big and not suitable for the electric vehicles usage which is just build for city transportation.
4) Many parameters from the vehicles dynamics or vehicles performance modeling need to be neglected.

5.2.1.2 Solution

This thesis recommended a continuous study in vehicles dynamics and doing the experimental methods to make the results more valid. The simulation must be done in fully structure of vehicle and consider all the parameter that been apply in finding the suitable electric motor.

5.2.2 EFFICIENCY OF THE MOTOR

5.2.2.1 Apparatus or Methods

This thesis recommended to use the tester motor but improving the efficiency of the motor in order to serve it for many usage. The efficiency of the motor should be analyze in terms of calculation and experimental. The usage of controller device are also been recommended such as motor controller, the supercapacitor banks, and pulse-width modulation.

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APPENDICES A-1

Appendix A
AC Induction Motor Data Sheet

Plant: ______________________________ **Contact:** ______________________________

Industry: ____

Type of equipment: ____

Application: ____

Site Data

Location: City ______________________ State ____________________________

Elevation	_ less than 3300 ft / 1000 m		Other – Specify _____________	
Ambient temperature	Min _______	°C	Max _______°C	
Humidity	Min _______	%	Max _______%	
Motor location	_ Indoor	_ Outdoor	_Heated	_Unheated
	_Roof over motor		_No roof over motor	

Special conditions: ____

Motor Performance Requirements:

HP ______________________________ kW ____________________________________

Poles: ___________________________ RPM ___________________________________

Speed ___________________________ _ Fixed speed _ Adjustable speed

_ Variable torque _ Constant torque

Min Speed ___________ Max speed ___________

Volts ____________________________ 3-phase _ 60Hz _ 50Hz

NEMA Design:	_ Design B (IEC N)	_ Design C (IEC H)	_ Design D
Efficiency level	_ Premium	_ High Efficiency (EPAct)	
Rotor design:	_ Standard	_ Fabricated copper bar	
Service Factor:	_ 1.0	_ 1.15	
Insulation Class:	_ F	_ H	

Temperature rise:
_ Class B (80°C) at F.L.
_ Class F at F.L.
_ Class B (80°C) at F.L.; Class F at S.F.

Torque (Full Load) ______________ Torque (Pull-up % Flt) _________________

Torque (Breakdown % Flt) _________ Torque (Locked Rotor % Flt) ______________

Page 1 of 4

APPENDICES A-2

Enclosure: _ TEFC _ TEBC
_ ODP _ WPI _ WPII _ No filter
_ Galvanized steel filter
_ Aluminum mesh filter
_ Stainless mesh
_ Differential pressure switch
_ Explosion Proof - Class _______Group _________ Zone _______
_ Division 2 – Temperature code ________

Mounting: _ NEMA _ IEC
_ Horizontal _ Vertical
_ F1 _ F2 _ Top _ Other ________________
_ C-face _ D-flange
_ P-base - specify flange diameter ____________________________

Shaft: Drive end shaft
Diameter ________ Length __________ Key ___________________

Opposite drive end shaft
Diameter ________ Length __________ Key ___________________

Special shaft machining – specify or supply drawing _______________________________

____

Shaft Material: _ Standard (not specified) _ 1045 _ 4140
_ Other – type ______________ _ Stainless – type ___________ _ Step-forged shaft

Special Standards: _ NEMA MG1 _ IEEE 841
_ API 541 – data sheets attached
_ CSA approval _ IEC
_ Other ____

Bearings _ Anti-friction: _ Ball Roller
_ Coupled _ Belted (data sheet attached)
_ Sleeve – Renk insert-type (horizontal - coupled only)

Thrust: Horizontal: _ Towards motor ________ _ lbs or _ kg
_ Away from motor ________ _ lbs or _ kg

Vertical: _ Down Continuous ________ _ lbs or _ kg
Maximum ________ _ lbs or _ kg
_ Up Continuous ________ _ lbs or _ kg
Maximum ________ _ lbs or _ kg

Lubrication: _ Self lubricated _ Oil Mist _ Force lubricated
Special grease or oil ____

Bearing protection: _ None
_ Forsheda® type _ Both ends
_ Inpro/Seal® VBX _ Both ends
_ Contact seal _ Both ends

Bearing electrical protection: _ Shaft grounding brush
_ Electrically isolated bearings

Page 2 of 4

APPENDICES A-3

Bearing temperature monitoring: _ RTDs - Qty. 2 – 1 per bearing
_ 100 ohm platinum
_ 10 ohm copper
_ 120 ohm nickel
_ Thermistor - Brand ____________________

Bearing vibration monitoring: _ Robertshaw 365 Vibraswitch® _ Both ends
_ Bentley-Nevada
_ 2 probes each bearing
_ 1 probe each bearing
_ 2 probes one bearing
_ 1 probe one bearing
_ Provisions for 2 probes/bearing

Vibration level _ < 0.15 in/sec _ <0.10 in/sec _ ______ in/sec velocity

Sound level Max sound pressure level ______dBA at _____ ft or ______ m, NL.

Motor Starting / Drive
_ Full voltage
_ Reduced voltage specify _______________
_ Electronic soft start specify _______________
_ Loaded _ Unloaded

Load WK_ at Shaft: _ ≤ NEMA MG1-1998-20.11
_ Specify reflected load inertia __________________

Number of starts: _ NEMA MG1-1998 –20.12.1
_ Additional ______ Cold _______ Hot

Drive Requirements _ Inverter _ Vector _ Vector – open loop
_ Brand / model ________________________

Feedback: PPR _______ Voltage ________
_ Optical Encoder
_ Magnetic pulse generator – # of pickups ________
_ Specific brand / model ______________________

Special Options and Accessories

Winding Temp. Device: _ Thermostats – normally closed
_ RTDs - Qty. 6 – 2 per phase
_ 100 ohm platinum
_ 10 ohm copper
_ 120 ohm nickel
_ Thermistor - Brand ________________________
_ Separate conduit box (required for medium voltage)

Space Heaters: _ 120 volt _ 230 volt
_ Separate conduit box (required for medium voltage)

Surge Protection:
(in self-standing enclosure)
_ Lightning arrestors
_ Surge capacitors
_ Differential current transformers
_ 3 Current balanced current transformers
_ 1 Current balanced transformer

APPENDICES A-4

Special items: _ Deferred warranty / long term storage provision
_ Export crating

Special Testing

_ Standard Production Test _ Unwitnessed _ Witnessed
Each motor will be tested per NEMA MG1-12 or MG1-20.47 as required.
Tests include:

1. Measure winding resistance.
2. Measure no load current, power and speed at rated voltage and frequency.
3. Insulation resistance.
4. High potential test per NEMA MG1-20.48.
5. Mechanical balance and vibration.
6. Measure motor starting current.

_ Complete IEEE 112 _ Unwitnessed _ Witnessed

1. Routine tests above.
2. Measure efficiency at 100%, 75%, 50% and 25% of full load.
3. Measure power factor at 100%, 75%, 50% and 25% of full load.
4. Temperature rise test.
5. Measure locked rotor current.
6. Measure breakdown and starting torques.

_ Sound test (per IEEE 85) _ Unwitnessed _ Witnessed

_ Speed torque test _ Unwitnessed _ Witnessed
Provide curves of motor speed-torque and speed-current at specified input voltage and frequency

_ Bearing temperature _ Unwitnessed _ Witnessed
Determines the stabilized bearing temperature at no load. Specify minimum test duration time on order.

_ Motor/Drive Operating Envelope _ Unwitnessed _ Witnessed
Temperature rise test using drive. Operate motor to Class F rise to establish operating envelope for the motor.

_ Other ____________________ _ Unwitnessed _ Witnessed