College of Engineering Department of Mechanical Engineering

Spring 2020

Senior Design Project Report

Design of a motor differential for solar electric car

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Team 2

Team Members

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Chapter 1 INTRODUCTION

1.1 Project Definition

This report mainly intended to design and fabrication of electric motor and differential system for electric car. Electric motor is the heart of electric car which gets its power from controller and the controller gets its power from the battery. Electric motor drives the car with low voltages. Electric motor replaced with combustion engine which is emission free automotive. There are various types of electric motor used for electric vehicle given below [1]:

1. DC Series Motor
2. Brushless DC Motor
3. Permanent Magnet Synchronous Motor (PMSM)
4. Three Phase AC Induction Motors
5. Switched Reluctance Motors (SRM)#]’

On the other hand, next objective of this project is to design and fabricate the electronic differential system for electric car. The working of electronic differential is working based on the input and output parameters to control the right-left speed of the vehicle. Electronic differential system gets inputs from the throttle speed and steering sensors and the output in the form of vehicle wheel right and left movement [2].

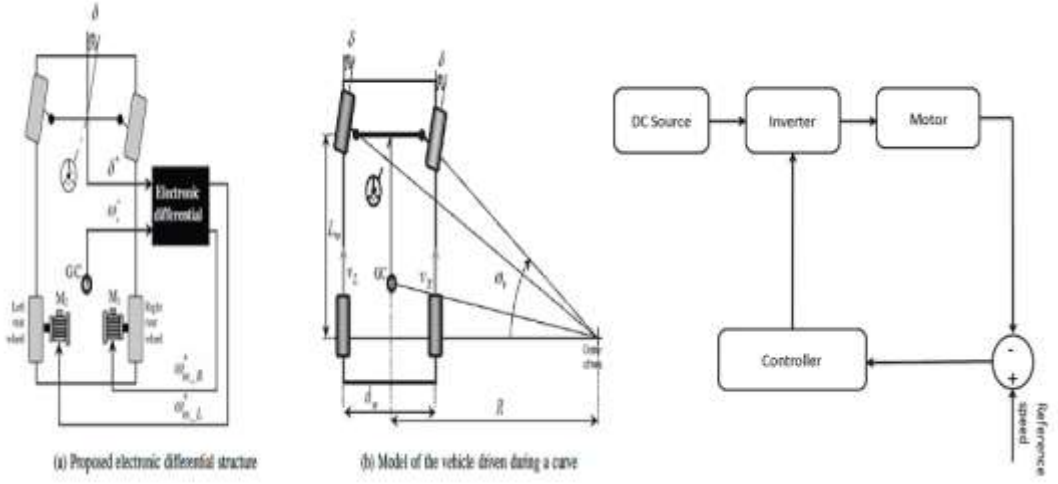


Figure 1: Electronic differential system

1.2 Project Objectives

i. To study the electric vehicle components like electric motor and differential system of electric vehicle.

ii. Design and fabrication of electric motor for electric vehicle

iii. To design Electronic Differential System (EDS) for electric vehicle directly driven by dual induction motors wheel in the rear wheel.

iv. To construct the electronic differential system for electric vehicle with low cost.

1.3 Project specification

There are various types of electric motor and electronic differential system used for electric vehicle but the schematic diagram and design specifications of electric motor and electronic differential system used in this project shown in figure 2 &3 and table 1 & 2.

Figure 2: AC induction motor for electric vehicle

Table 1: Design and specifications of electronic differential system

Sr. No.	Components	Ratings
1	Motor with hall sensor	6000rpm ,24V/8A ,180W
2	RT Simulator	Opal RT
3	Power electronics and drivers	Mosfet P55NF06(nMos 60V,30A) Drivers TLP250

Table 2: Design Specification of induction motor for electric vehicle

Parameters	Values
Induction motor	2kw, 380V, p = 2, 20Nm, 50Hz
Rotor resistance	1.8 Ω
Rotor inductance	0.1568H
Stator resistance	1.2 Ω
Stator inductance	0.1558H
Mutual inductance	0.15H
Moment of inertial	0.07kgm^2

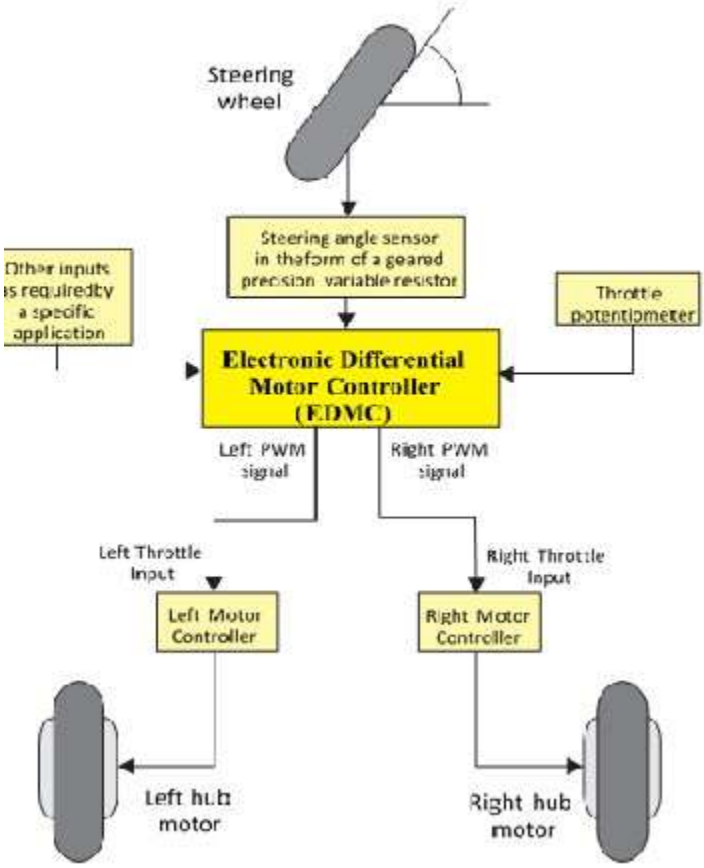


Figure 3: Electronic differential system for electric vehicle

1.4 Application of electric motor and electronic differential system

i. Electric vehicles are widely used worldwide due to its emission free and low cost vehicle.

ii. AC induction motor mainly used in automobile due to its high efficiency, good speed regulator and absence of commutators.

iii. Electronic differential system used in automobile system in place of mechanical differential system. EDS provide required torque to each vehicle wheel and allows various vehicle wheel speeds electronically.

Chapter 2 LITERATURE REVIEW

2.1 Project Background

One of the most challenges in the worldwide is to reduce the negative impact of transports on the road in the form of environmental effect. The carbon emission is harmful for human beings which are produced by automobile vehicles running based on internal combustion engine. In order to reduce carbon emission produced by conventional automobile vehicles, several vehicle manufacturers are trying to move electrification type vehicles such as electric vehicle and hybrid type vehicles and bundles of automobile manufacturers have developed their own BEM models [3]. Electrical motor drive is the heart used to drive the electrical vehicles and other various hybrid vehicles. Electrical motor drive works in a very harsh environment with temperature 40 to 135^{o}C humidity level near about 80% [4].

On the other hand, electronic differential system is widely used in the electric vehicles instead of mechanical differential system. Electronic differential system generally used to provide the torque equally to the driving wheels of the electric vehicles [5]. In the conventional automobile, once the vehicle accelerates due to not using differential gears the slipping of wheel occurs and this cause unsafe driving for the drivers.

2.2 Previous Work

Fakhra Jabeen et al. **[6]** presented the study of preferences and attitude of adoption of electric vehicle in Perth Australia. Author studied the detailed literature about behavior of those drivers who used conventional vehicles and electrics vehicles. It is found from the research that drivers considering the similar feelings to an electric vehicles and conventional vehicles. It means electric vehicles are very friendly in use.

Merve Y ıldırım et al. [7] presented the modeling and simulation of electronic differential system in electric vehicles. Author presented the modeling and simulation of electronic differential system in front two wheels instead of rare wheels which is commonly used in the literature. It is observed from the study that electronic differential system is appropriate within the front wheels of electric vehicles.

Marek Palinski et al. [8] presented the comparative study of electric vehicles and conventional vehicles based of cost and quality perspective. Authors have done detailed literature about awareness of electric vehicles among the public and make a final statement of approved or rejected. Authors also presented the detailed literature about comparative study of electric vehicles with conventional vehicles based on market cost and quality. It is concluded from this study that electric vehicles used in transportation system are more efficient in term of environmental impact, cost and reliability.

Abdelhakim Haddoun et al. [9] presented the study on electronic differential system by using dual induction motor in the rear wheel. Electronic differential system takes signal from controller and provides driving torque to each wheel of the electric vehicles. Authors have preferred the sensor less technique s to a position or speed encoder-based control which is used to reduce the overall cost and enhance the reliability of electric vehicles.

Ann Holms et al. [10] presented the comparative study about the electrical vehicles and gasoline engine vehicles. He is also presented the advantages and disadvantages of electric vehicles as compare to gasoline engine vehicles. Furthermore, authors have also described the future perspective of electric vehicles.

Martino De Carlo et al. [11] proposed the use of two motor combined by using planetary of gear train system. It was concluded that use of combination of two electrical motors is more efficient and reliable as compare to single motor to control the driving torque and speed of electric vehicle. Single use of electrical motor is less efficient and not more than reliable as compare to combination of two electrical vehicles.

C. Pomponi et al. [12] presented a generalization of the aforementioned outcomes to electric vehicles that make use of two in-wheel motors and are required to perform a bend manoeuvre is provided. A lateral control and new cruise were also presented in this research. Experimental and CarSim simulations were also included to investigate the practical effectiveness of the proposed techniques.

2.3 Comparative Study

There is rich literature present in the field of automotive world presented by several researchers but there is few literatures have been presented about electric vehicle and their various

components modification. In this project, design and fabrication of electric motor drive and electronic differential system is presented for electric vehicles. The appropriate design model and fabrication technique is presented in the study which is best for electric vehicles as well as economical and reliable.

Chapter 3 SYSTEM DESIGN

3.1 Design Constraints and Design Methodology

3.1.1: Geometrical Constraints

For electric motor and differential system of electric car to be effective and efficient there are some constraints which are to taken under consideration. First of all the major constraint is the weight. For electric car to be functional and to consume less power it is required to have lesser in weight. We are using electronic differential in replacement of mechanical engine because it was very heavy and electric will be requiring a lot of power to start and move the car. So we will be using brushless DC motor and differential of containing two AC motors attached to rear wheels. As motor itself is quite heavy so differential will help as it will be helping the motion of the rear wheels.

3.1.2: Sustainability

As a whole system design should be able to hold it self physically and functionally and the electronic motor and differential system is not that complicated but still needs to be fixed properly and all attachments of wiring and controller are to be fixed accurately. The system is quite sustainable as we have designed this particular system keeping in view the supportive climate and surroundings. We had made sure in the designing stage that car may achieve 80km/hr speed and without any disturbance and turbulence. There is huge market of electric car in all of the Saudi Arabia and they are increasing day by day as many brands are taking up this opportunity to be more ecofriendly.

3.1.3: Environmental concern

Environmentally this project is very supportive as electric car in terms of fossil fuel consumption can act 100% eco-friendly. It leaves no air pollution behind and neither damages any scarce fossil fuels. As we have replaced the combustion engine with electric motor and differential it will be completely operative on the battery or electric power. This projects promotes to use the abundant source of energy particularly in Saudi Arabia which is going

wasted unused. In the shadow of this project we would like to participate in the Saudi2030 goals to be completely eco-friendly and use less fossil fuel

3.1.4: Social impact

Electric cars are not a new innovation they have been introduced here and there in past in form of hybrid cars as well. Although pure electric cars have also been introduced in the mid nineteenth century but it could never achieve the same preference as that of combustion engine due its low range and being expensive until now. It has been realized that electric may be expensive or provide less range than combustion engine car but it does provide a clean and pure environment as it leave or release no pollution in the air neither it produces noise pollution.

3.1.5: Economic

The financial considerations attached with this project are largest concern and constraint. As electric car usage is not that commonly used neither commercially nor no commercially which makes the mass production of electric cars an issue and bit difficult and more expensive. If electric cars are also manufactured in bulk it will definitely reduce the cost resulting in the lesser expensive electric car. The initial cost of this project is very high as compared to a regular combustion engine car but after the initial installation of setup and investment of money there will be less or no cost in terms of power source for lifetime which is big relief as no fuel will be used for the car. Apart from some repairs and a battery change in 10-15 years it will cost you nothing but one needs a foresightedness to understand the maintenance and timely of the electric car.

3.1.6: Safety

This purposed system is planned such to make it more safer for the driver for this purpose we are using differential system to get better grip of the tire on the road and on the speed of the car especially on the turns and curves of the road. Car will be efficient and functional during all seasons even in rain or humidity as very good insulation is provided. Electric car is made safe from any short circuit as controller is being used to keep check on the power introduced in the system and generated by the system.

3.1.7: Ethics

Electric car is not a new or unique idea as this is in practice already in many countries especially and many brands are promoting the idea of electric cars and more innovation are being in the limelight regarding pure electric car as it is the future car keeping in view the condition of the scarce natural resources like diesel, patrol or gas. It is the need of hour and our ethical responsibility being engineering student that we should be promoting the use of pure electric cars.

3.2 Engineering Design standards

For any system to have a strong foundation in the engineering it must have followed and applied the engineering standards. The engineering standards followed are given in the table below:

Table#3.2: Engineering Standards

Components	Engineering standards
Brushless DC motor	ASTM: F236
Electronic differential	ASTM: F2070
Lithium ion Battery	ASTM: F3353

3.3 Subsystems and Components

.3.1: Components and Dimension

Following table shows the dimensions of the some of the components of the electric car electronic differential system:

Table # 3.3.1: Components and Dimensions

Components	Dimensions
Brushless Dc Motor	13mm – 40mm
Differential	Customized
Lithium Ion Battery	192x274x301mm

3.3.2: Brushless DC Motor BLDC:

A brushless DC motor also known as a BLDC motor is an electronically commuted DC motor which does not have brushes. The controller provides pulses of current to the motor windings which control the speed and torque of the synchronous motor

Table#3.3.2: Specifications of Brushless DC Motor

Place of origin	Zhejiang, China
Certification	CCC, CE, ROHS, UL
Type	brushless DC motor
Torque	2.38Nm
Voltage	220V
Output power	750W
Speed(RPM)	3000rpm
Commutation	Brushless
Protect Feature	Drip-proof

Construction	Permanent Magnet
Continuous Current(A)	2.19A
Efficiency	IE 4
Housing	Aluminium Frame
Speed Range	3000rpm
Material	Permanent Magnets
Controller	Customized, Optional
Braker	Optional
Insulation Class	Class F
Enclosure	IP54
Poles	2P
Wire	100% copper

3.3.3: Electronic differential

In electric car differential is used along with a single motor to take up the motion responsibility of the rear wheels as there is no mechanical combustion engine in electric car. Electronic differential is advancement in electric vehicles technology as it is the mechanical operative of the electric car connected to electric controller. Its task is to provide the required torque for each driving wheel and allows different wheel speeds electronically. It is used in place of the mechanical differential in multi-drive system.

Table#3.3.3: Specification of Differential

Characteristics	**Details**
Application	Electric vehicle
Speed ratio	6:1/8:1/10:1/12:1/11.76:1/12.76:1
Brake (mm)	Φ220/Φ180
Placement method of rear axle	Horizontal/ vertical
Rated load	1.3T
Adaptable Motor	Below 5kw

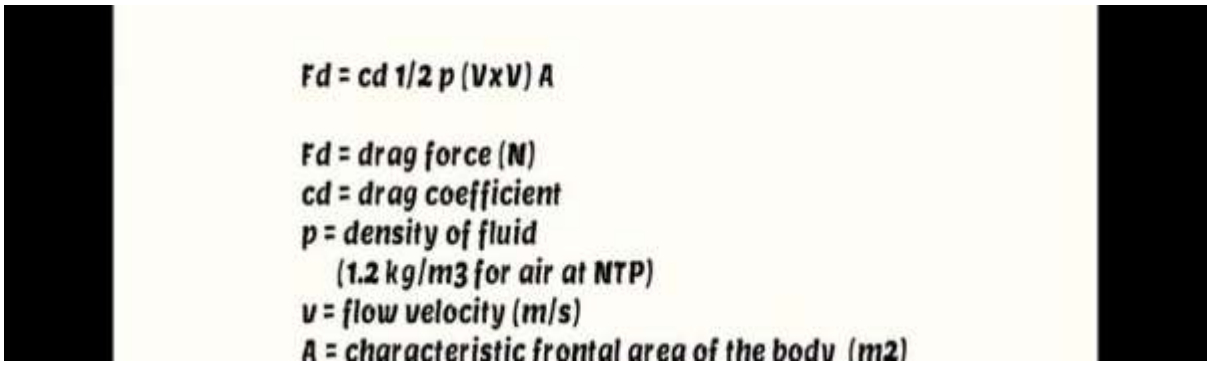
3.3.4: Lithium ion battery

Table#3.3.4: Specification of lithium ion battery

Characteristics	Details
Battery type	12V- 100Ah lithium ion Battery
NOMINAL CAPACITY	100Ah
Nominal battery voltage	12 VDC
OPERATION VOLTAGE CHARGE	15VDC
OPERATING TEMPERATURE	-40°C~+50°C
WATT HOURS	1320Wh

3.4 **Theory and Theoretical Calculations**

These are the equation for calculating the power:



cd (drag coefficient) = 0.2

P (density of fluid) = 1.2 kg/m^3 for air

V (flow velocity) = 80 km/h= 22.22 m/s

A (frontal area of the body) = 10m^2

Fd (Drag force) = (0.2) (0.5) (1.2) (22.22X22.22) (10) = 592.5 N

Ft (total force) = friction force + drag force

= μmg + 592.5

= (0.1X600X9.81) + 592.5

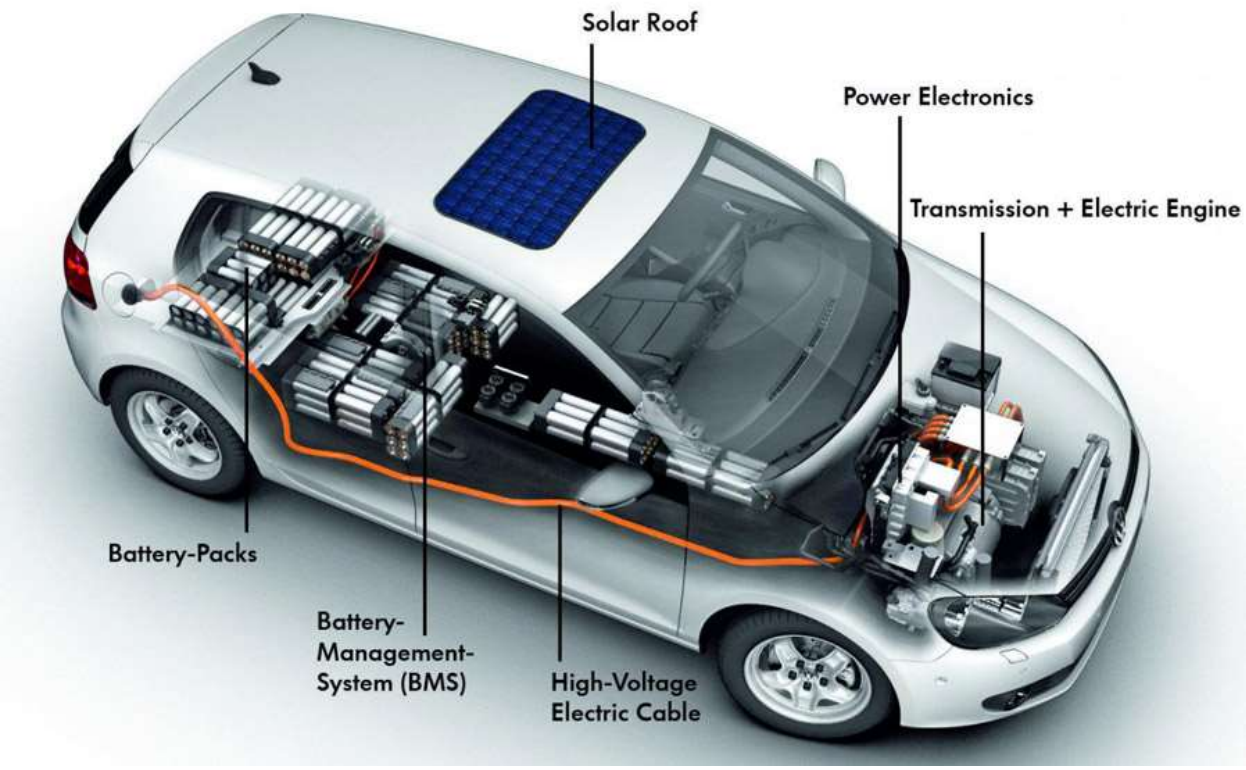
= 1181.1 N

power = (1181.1) (22.22/0.95)

Power = 27.63KW

3.5 Manufacturing and Assembling

The said project is working on the brushless DC motor which takes up the load of the car and another important component of the electric car is the replacement of the regular combustion engine which is differential. Differential's task is to perform the mechanical gear action as it is attached on the axle of the rear wheels. When cornering, the inner and outer wheels rotate at different speeds, because the inner wheels describe a smaller turning radius. The electronic differential uses the steering wheel command signal and the motor speed signals to control the power to each wheel so that all wheels are supplied with the torque they need. This keeps the speed of the car in control and provides with good grip of tires on the road. Battery is very essential part of the electric car as it supposed to be taking the load of the whole car not just starting the engine. It continuously provides the electric power to the DC Motor of the car to keep it running. So there are number of lithium batteries will be used in the electric car.



Figure#3.5: Idea of engine of solar-electric car

Chapter 4 Conclusions and future recommendations

4.1 Conclusion

The purpose of this project is selecting differential motor and create a placement system for the differential motor for an electric car that works on solar energy. First, we had to calculate the needed power of the motor to move the car. The desired speed of the car is 80km/h and the estimated weight of the car is 600 Kg. Based on these data and the data we got from measuring the chassis dimensions, we calculated the needed power of the motor which is approximately 30 Kw. We found that the most suitable motor would be a brushless DC motor. A brushless DC motor also known as a BLDC motor is an electronically commuted DC motor which does not have brushes. The controller provides pulses of current to the motor windings which control the speed and torque of the synchronous motor. An electric car differential is used along with a single motor to take up the motion responsibility of the rear wheels as there is no mechanical combustion engine in electric car.

4.2 Future recommendation

- Cooling system for the motor. The system we suggested is similar to computer CPU water cooling, the system is work by two radiators connecting with water lines around the motor to absorb the heat from motor.
- Reducing the weight from and part that have rotational inertia.
  If we reduce rotational part 0.5 KG it is equal 1 KG on non-rotational part, rotating part example: wheels, shaft and pulleys.
- Using dual connected motors to increase the performance
- Using steel chain to connect the motor with differential instead of pulley and belt because it is less service and hard to cut

Reference

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Appendix A: Progress Reports

March

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2020**
PROJECT TITLE	**Solar electric car**		
SUPERVISORS	**Dr. Mohamed Saleh**		

ID Number	**Member Name**
201501686	**Mohammad Abualsaud**
201402546	**Mohammed Albadeen**
201701257	**Ali Alzahrani**
201403365	**Ali Alkhars**

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**Calculating the motor power**	Mohammad Abualsaud	100%	
2	**Placement of the motor and gear calculations**	Mohammed Albadeen	80%	
3	**Solidworks modeling**	Ali Alkhars	0%	
4	**Design of the motor and differentials**	Ali alzahrani	20%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Calculating the motor power**	Mohammad Abualsaud
2	**Placement of the motor and gear calculations**	Mohammed Albadeen
3	**Solidworks modeling**	Ali Alkhars
4	**Design of the motor and differentials**	Ali alzahrani

April

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2020**
PROJECT TITLE	**Solar electric car**		
SUPERVISORS	**Dr. Mohamed Saleh**		

ID Number	**Member Name**
201501686	**Mohammad Abualsaud**
201402546	**Mohammed Albadeen**
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2	**Placement of the motor and gear calculations**	Mohammed Albadeen	100%	
3	**Solidworks modeling**	Ali Alkhars	100%	
4	**Design of the motor and differentials**	Ali alzahrani	100%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Calculating the motor power**	Mohammad Abualsaud
2	**Placement of the motor and gear calculations**	Mohammed Albadeen
3	**Solidworks modeling**	Ali Alkhars
4	**Design of the motor and differentials**	Ali alzahrani

Appendix B: CAD drawings and Bill of Materials