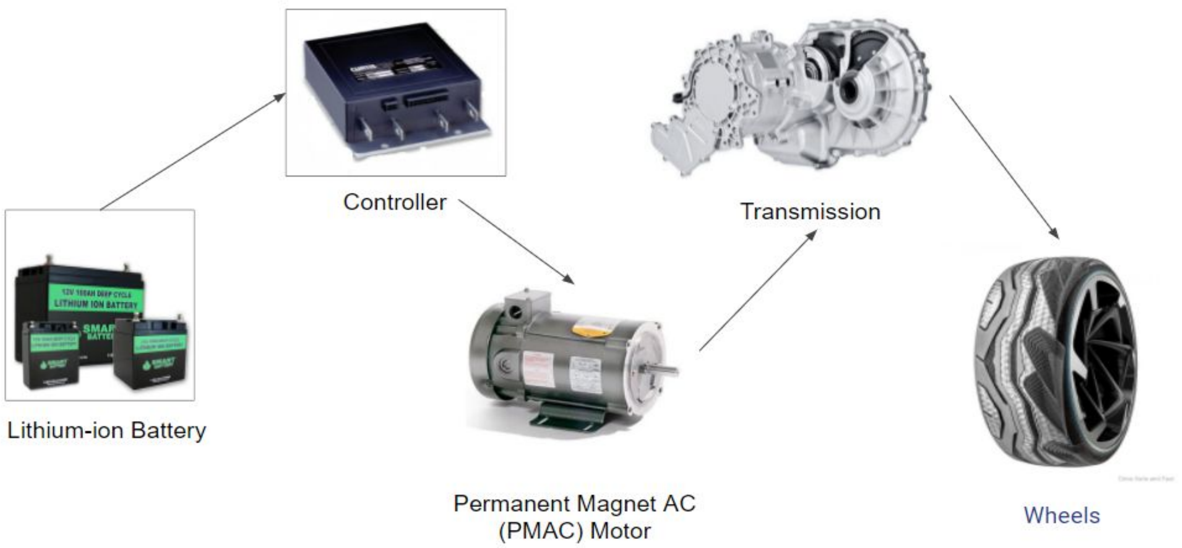
EV 2.0 DESIGN SOLUTION

In coming up with a top design solution for our electric propulsion system, each team member did individual research and came up with the following design ideas. Owing to the complexity of the electric propulsion system, we decided to focus on the most important components:

1. The motor
2. The motor controller and
3. The battery pack

These components come in different types and ratings The choice of motor, motor controller or battery pack to used has to be made based on the design requirements. For example, the maximum torque generated, the cost and efficiency are factors that must be considered when choosing a motor.

Olaniyi Nafiu's Individual Design Idea

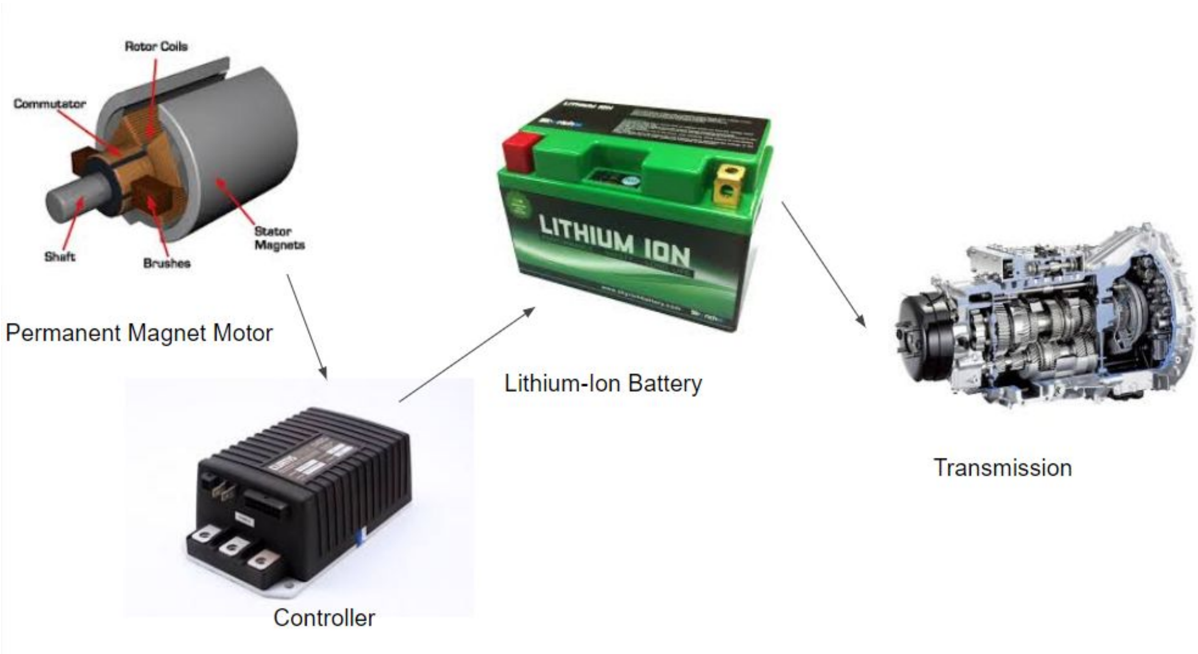


The Motor: Most electric vehicles (EV) today use AC induction motors. However, some EV manufacturers have opted for Permanent Magnet Alternating Current (PMAC) motors in the production of their latest EVs. PMACs offer higher efficiency and smaller frame size. These qualities are very important for the advancement of the EV industry because there is a great demand for lighter and more efficient vehicles.

The Controller: Since the PMAC motor uses alternating current for its operation, the motor controller is a DC - AC converter which converts the DC supplied by the batteries to the AC needed by the motor. It also regulates the amount of current delivered to the motor.

The Battery: Lithium - ion batteries are the most durable batteries because they are not affected by the Peukert's law like other batteries such as Lead acid batteries, i.e. the battery's available capacity does not decrease with increasing rate of discharge.

Ikenna Onyenze's Individual Design Idea

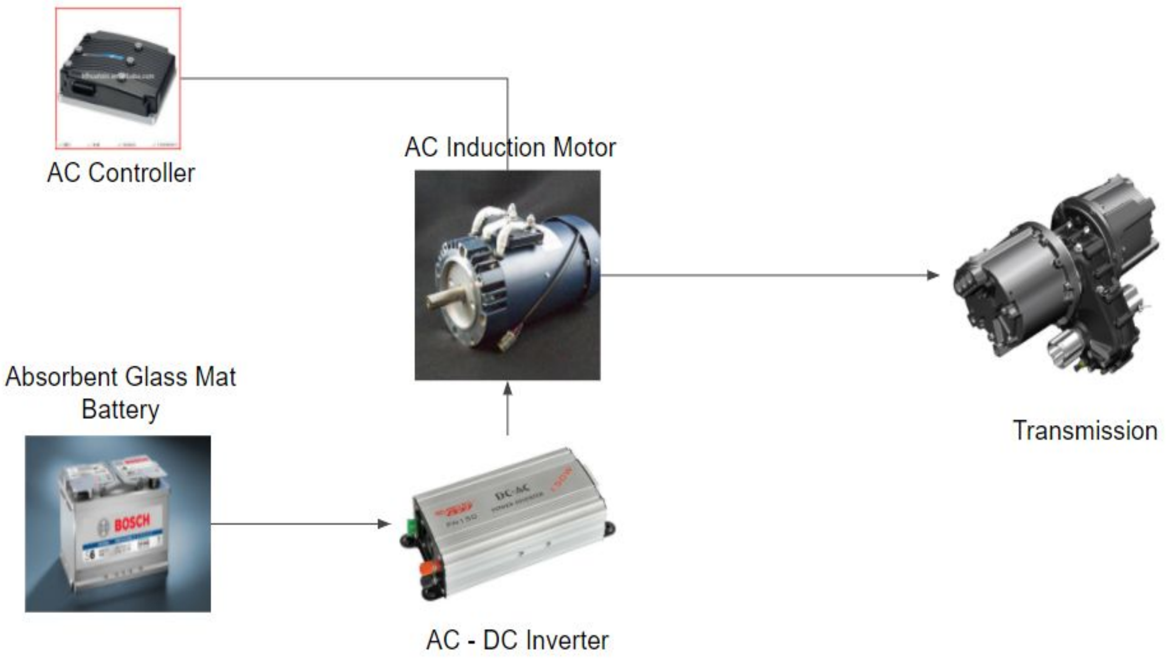


The Battery: I used the Lithium Ion in this design mainly because of the speed at which it reaches full charge. Li ion batteries charge fast because lithium ions can be set in motion more easily during charge when compared to other batteries.It is also inherently lighter in weight than most other batteries.

The Controller: A controller controls the amount of power going to the electric motor. It takes the power from the battery and breaks it into pulses that power the electric engine. The Permanent Magnet motor operates in AC, therefore controller converts the battery's DC to AC for the Motor.

The Motor: Permanent Magnet motors have a high starting torque which is very important in vehicles because most cars only have high torque at high speeds.PM motors are also very efficient.

Goodness Fowora's Individual Design Idea

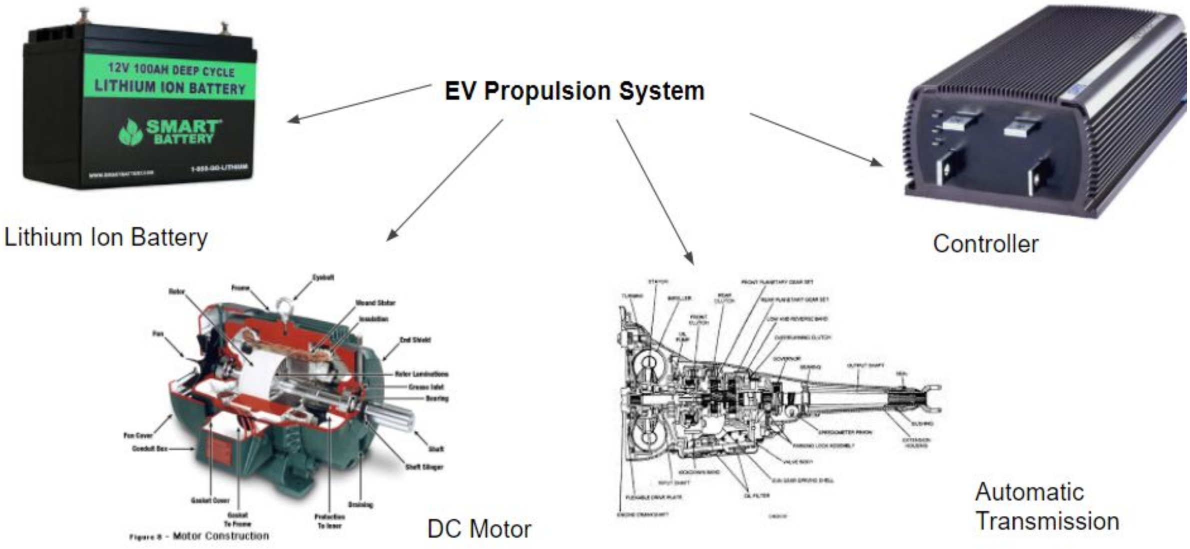


The Motor: The motor in this design is an AC induction motor. This is the type of motor used in one of the most popular EVs on the market, the Tesla Model S. It uses an inverter to convert the DC power of the battery to AC power. It is highly efficient over wide ranges of rpms and loads, moderately priced and aids with regenerative braking.

The Controller: The AC induction motor uses an AC controller to help manage the power going to the motor. It works hand in hand with the inverter to make sure the battery can supply adequate power when necessary.

The Battery: The Absorbent Glass Mat (AGM) battery is a lead acid based battery that provides a lighter and more reliable battery than regular lead acid batteries. It uses a very fine fiberglass mat to absorb the sulfuric acid, essentially making it spill proof. They are reliably safe, last longer than average lead based batteries and recharge quickly.

Arinze Udeh's Individual Design Idea



The Motor: The motor used is a DC motor because they have low inertia so are useful where high accelerations are required. They are also very cheap and require low maintenance.

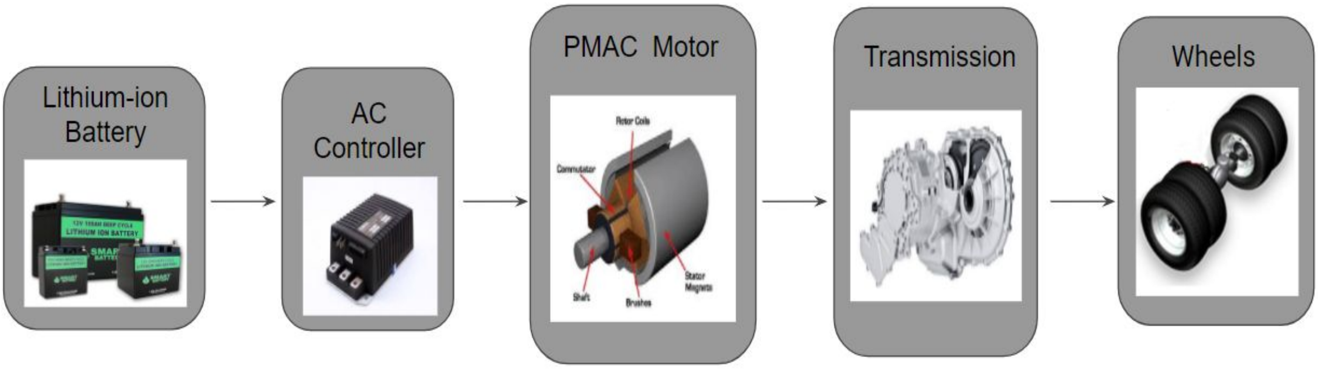
The Controller: A DC controller is used which works by switching the battery connection to the motor on and off around 20,000 times a second. If the battery is only connected for half the total time, then the motor sees half the voltage of the battery. Also, because the switching is so fast, the motor's inductance keeps the current in the motor flowing constantly.

The Battery: A lithium-ion battery is used in this design because they have a high energy density which will allow the the car to operate longer between charges while still consuming more power. They also have a low self discharge rate and require low maintenance.

Conceptual Designs

Based on the individual ideas, we came up with two conceptual ideas that highlighted the most important parts of the electric propulsion system; the battery, the controller, the motor, the transmission and the wheels.

Conceptual Design 1

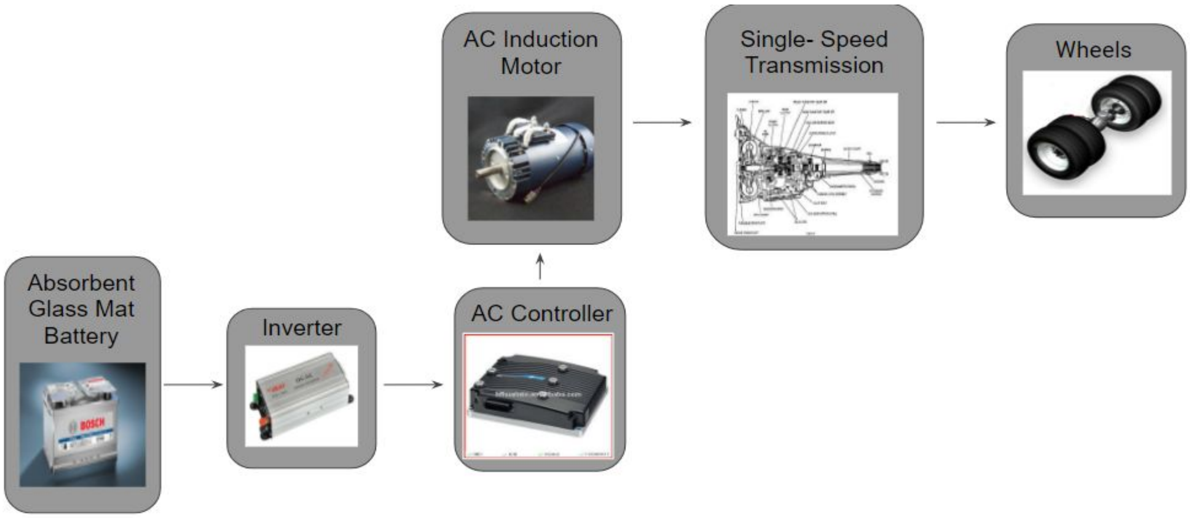


In this conceptual design, the Lithium Ion battery supplies DC power using electrochemical processes. This DC is first converted into AC by the controller, since the Permanent Magnet operates in AC. The controller also regulates the amount of current delivered to the PMAC motor (battery management). It avoids too much power pull when the batteries are hot, cold, or close to empty). This allows the PMAC to operate at a very high efficiency.

Components:

1. Hyper 9 IS - It is capable of producing 173 ft-lbs of torque at 0 rpm. Designed for use in light to mid weight automotive application with a curb weight of 4000 lbs or less
    a. Motor
        i. Permanent Magnet AC motor
    b. Controller
        i. 100V 750A HyPer-Drive X1 Controller
        ii. Main contactor
        iii. Display
2. LiFePO4 lithium 96v battery pack
    a. Weight- 96kg
    b. Price - $2000
    c. Capacity - 100 Ah
    d. Charging time - 4 hours
    e. Cycle Life - Over 3000 times

Conceptual Design 2



In this conceptual design, the AGM battery supplies DC power using electrochemical processes. This DC power is first converted into AC power by the inverter then managed by the AC controller to meet the user's demands in terms of speed and acceleration. Based on the user's demand, the AC power is used to generate torque which is then transmitted to the car's original transmission which then propels the wheels. To ensure efficient transmission of energy, a coupler and an adapter plate is used to ensure the motor does not move around in the previous engine compartment and ensure the axle of the motor fits into the transmission respectively.

Components

1. AC 51 kit - It is capable of producing 88 horsepower and 108 ft-lbs. of torque. It us designed for use in an automotive application with a curb weight of 4000 lbs or less
    a. Motor
        i. Ac induction motor
    b. Controller
        i. 72 - 96V 650A Curtis 1238E-7621
        ii. Tyco Contactor
        iii. Display

2. 96V AGM Battery Pack
    a. Weight- 259kg
    b. Price - $1560
    c. Capacity - 100 Ah
    d. Charging time - 6.67 hours
    e. Cycle Life- 700 cycles

Design Analysis

Motor Selection

1. Permanent Magnet AC Motor

PROS	CONS
High power density and high efficiency	Uses rare earth metals
High starting torque	Noisy
High cruising speed and precise speed control	High initial cost
Cooler operating temperatures	
Small size	
Easier installation and maintenance	

2. AC Induction Motor

PROS	CONS
Light weight	Expensive motor/controller combination
Single - speed transmission	Requires an inverter
Averagely Priced	Difficult speed control
95 % efficiency at full load	
Aids regenerative braking	

MOTOR SELECTION DESIGN MATRIX

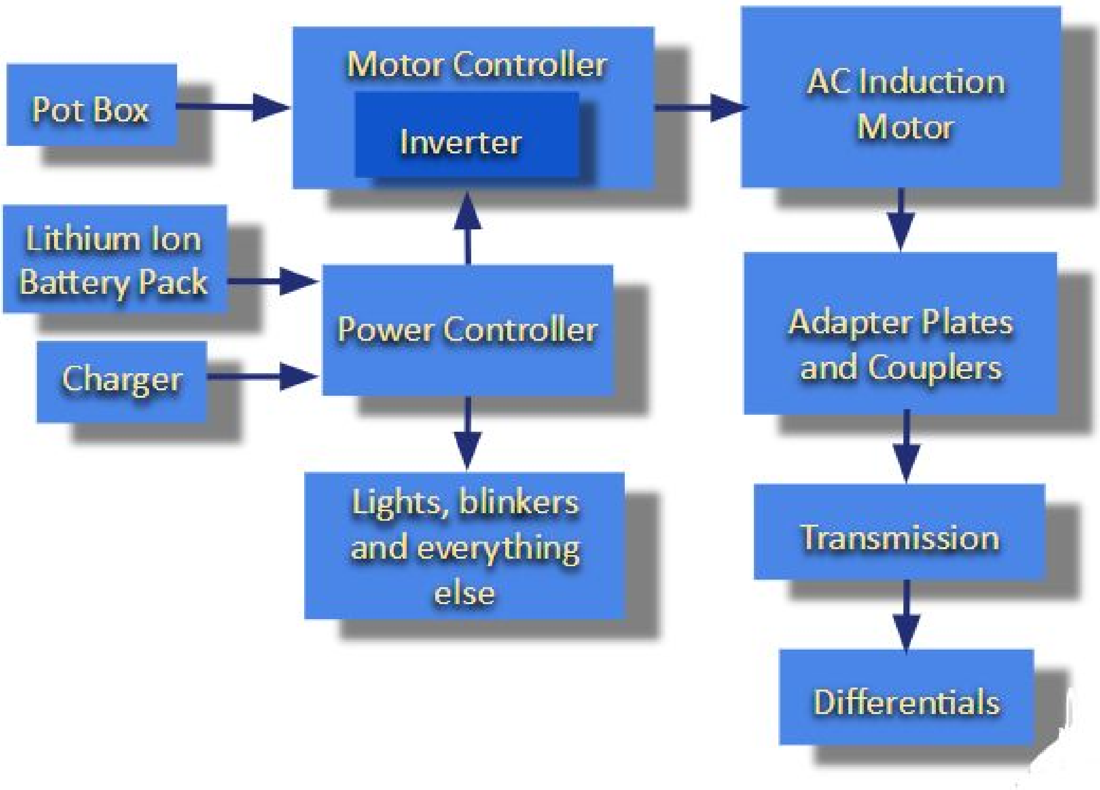
	Weight	Permanent Magnet	Score	Aggregate Score	AC Induction Motor	Score	Aggregate Score
Peak Efficiency	5	93% at 1100 RPM	5	25	87% at 1100 RPM	4	20
Max RPM	3	10,000	4	12	15,000	5	15
Cost per shaft	4	$130	3	12	$75	5	20
Efficiency at 10% Load	2	82%	3	6	94%	4	8
Longevity/ Maintenance	1	10 years or more	4	4	15 years or more	5	5
Total				59			68

Battery Selection - Based on the design requirements, we determined that a battery with a 96V and 100Ah power rating would meet the demands of the electric vehicle.

BATTERY SELECTION DESIGN MATRIX

	Weight	Lithium Ion Battery	Score (1 - 5)	Aggregate Score	AGM Battery	Score (1 - 5)	Aggregate Score
Weight	5	212 lbs	5	25	572 lbs	2.5	12.5
Charging Time	4	4 hours	4	16	6.67 hours	3	12
Price	3	$2000	3	9	$1560	4.5	13.5
Peukert’s constant	1	1.00-1.09	5	5	1.05-1.15	4	4
Cycle Life	3	Over 3000 cycles	5	15	700 cycles	2.5	7.5
Total				70			49.5

TOP DESIGN



In coming up with our conceptual designs, we focused on the primary components that are needed for the design analysis. The LiFePO4 lithium 96v battery pack and the AC 51 kit which consists of Ac induction motor and the 72 - 96V 650A Curtis 1238E-7621 were selected based on the result of the design matrix. Other relevant components in the drivetrain are included in the top design to give a better understanding of the connection between the several components in the proposed electric propulsion system. The function of each component in the top design is explained below.

1. **Battery Pack -** a lithium-ion battery pack is used and is arranged in parallel and in series to produce a maximum voltage of 96. This battery is used as the main power supply of the electric vehicle.
2. **Charger -** charges the battery pack by connecting it to an external power source. The type of charger used influences the charging time of the battery pack. Sophisticated chargers can automatically disconnect the battery pack from the power source to prevent overcharging the battery.

3. **Power Controller -** the power controller is used to distribute the power supplied by the battery to the motor controller and other necessary components like blinkers that need power.
4. **Pot Box -** hooked to the accelerator pedal via the accelerator pedal cable. It tells the motor controller how much power to deliver to the AC induction motor. varies power delivered to the motor.
5. **Motor Controller -** varies the electric current input to the motor based on the information provided by the pot box. It also contains an inverter which converts the DC supplied by the battery pack to AC needed by the AC induction motor. The controller is rated based on the maximum current it can deliver which determines the acceleration of the vehicle..
6. **AC Induction Motor -** the main component that turns the wheels which in turn moves the car. When power is supplied to the winding, flux is generated and current is induced in the coil of the rotor. Another flux will get generated in the rotor and legs with respect to the stator flux. So the speed of the rotor depends upon the ac supply from the battery.
7. **Adapter Plates and Couplers -** the adapters and couplers are used to hold the different components together. The couplers are car specific because the different components are from different manufacturers.
8. **Transmission -** the transmission transfers engine power to the driveshaft and rear wheels. Gears inside the transmission change the vehicle's drive-wheel speed and torque in relation to engine speed and torque.
9. **Differentials -** a differential is a gear train with three shafts where one shaft is the average of the angular velocities of the others. It is designed to drive a pair of wheels while allowing them to rotate at different speeds. In vehicles without a differential, both driving wheels are forced to rotate at the same speed, usually on a common axle driven by a simple chain-drive mechanism.

CONCLUSION

We had four individual designs for our electric propulsion system and in those designs, we focused on the motor, the motor controller and the battery pack. Based on the individual ideas, we came up with two conceptual designs to make a selection. The components come in different types and ratings. For the battery, we used the constraints of a 96V, 100 Ah. After using the design selection matrix for the battery selection, we selected the Lithium Ion Battery over the Absorbent Glass Mat Battery. For the motor, we selected the AC Induction Motor which comes with 72 - 96V 650A Curtis 1238E-7621 controller. Our top design includes other components that are not included in the conceptual designs. The inclusion of these components makes the top design a more comprehensive schematic diagram of the electric propulsion system.