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Original Research Article

Electric Car Conversion

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Abstract

One of the directions for making cleaner and more economic vehicles is to adopt electric vehicle concept. Therefore, an internal combustion powered engine Nissan Micra Vehicle was converted into battery powered electric vehicle. The power train of the car was redesigned to use DC electric motor in replacement of the existing internal combustion engine and to give the gear ratios possibility of a normal car. The power rating of the motor was determined by considering the rolling, gradient and aerodynamic resistances which gave a total tractive effort of 12190.84 N. The designed power rating was then determined to be 8 kW and this value was used to select the number of batteries that gave the required current to reach an adequate range of operation. To balance the weight of the car, the battery rack was located behind the center of gravity to give the developed vehicle a neutral steer characteristic. After installation of electric motor, inverter and the batteries, then the batteries were connected in series and parallel to the inverter with cable wire via variable frequency drive to ac motor and potentiometer. The vehicle was then evaluated and the voltage produced was able to move the vehicle at 6.24 m/s and the maximum frequency obtained was fifty megahertz (50 MHz).

Keywords: Electric vehicle, batteries, inverter, gear ratio, rolling resistance, gradient resistance, aerodynamic resistance.

1. INTRODUCTION

One of the major challenges in the global society today is how to mitigate the negative impacts of road transportation on the environment due to toxic and green-house-gas emissions (IPCC, 2020). The automobile industry is the largest producer of greenhouse gases in addition to other environmental pollutants accounting for as much as 41% of global warming sources (Nordelöf *et al.*, 2014). As a consequence, these environmental pollutants from vehicles are legally regulated on national and sometimes regional levels. In order to comply with these regulations, vehicle manufacturers are now investing in various fuel saving technologies and this has led to increased interest in vehicle electrification, foremost hybrid electric vehicles (HEVs) which can reduce fuel consumption compared to conventional vehicles, and also electric vehicles (Möller *et al.*, 2019).

Electric vehicles (EV) differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power and wind power or any combination of those (Hawkins *et al.*, 2013). EV also refers to a vehicle powered by an electric motor instead of internal combustion engine (ICE), and the motor is run using the energy stored in the batteries and the batteries have to be charged frequently by plugging into the main (240 V) supply which could be within or outside the vehicle (Massimo, 2011). The batteries used in electric cars vary in design, and include the lead-acid type familiar to all conventional car owners (albeit, much larger than in a normal car), lithium ion (similar to those used in laptops and mobile phones, but once again much larger), molten salt, zinc-air, and various nickel-based designs (Massimo, 2011). EVs are known as zero emissions vehicles (ZEVs) while neglecting the battery charging source and are more environment friendly than gasoline powered vehicles. As EVs have fewer moving parts, maintenance is also minimal; with no engine, there are no oil changes, tune-ups, or timing and there is no harmful exhaust emission (Ruan, 2016).

Recently, several researches have been conducted on Electric vehicle, for example, Jardel and Jair (2019) converted an ICE-powered Mercedes-Benz Class A 190 into an EV. The results of several tests indicated that the conversion is feasible, as the car reached an average travelling cost of 0.16 R$/km, assuming a price for the energy of 0.63 R$/kWh. Moreover, this cost could be as low as zero if solar radiation is utilized to generate electricity through photovoltaic panels, which is an even more environmentally sustainable solution. Fabian (2021) investigated ICE to EV retrofitting, a potential solution to improve the transition to widespread adoption of EVs, using the case of Germany. The research developed a business model that highlighted how a company can set up and integrate ICE to EV conversion into existing market structures. Xiaoli *et al.*, (2020) provided a comprehensive review of the technical development of EVs and emerging technologies for their future application. Key technologies regarding batteries, charging technology, electric motors and control, and charging infrastructure of EVs were summarized. The paper also highlighted the technical challenges and emerging technologies for the improvement of efficiency, reliability, and safety of EVs in the coming stages as another contribution. Holms and Rony (2010) explained in their report the working of electric vehicle and compared it with the conventional internal combustion engine and hybrid electric vehicle. The report provided the details of advantages and disadvantages of Electric Vehicles along with the future views of technology.

In Nigeria, there is a long-time tendency within automotive industry to build vehicles with as low CO_2 emission as possible. Large vehicle manufacturers make enormous investments in the development of hybrid drive vehicles, fuel cell powered vehicles and electric vehicles. This paper therefore describes a modification procedure for a Nissan Micra vehicle and a comparative calculation of tractive and dynamic characteristics. The importance of analyses is emphasized from the aspect of optimising vehicle parameters when converting ICE powered vehicle into an electric vehicle.

2. MATERIALS AND METHODS

2.1 Materials

A Micra Nissan car was used to give light weight and more rooms for batteries; lithium ion batteries were used to provide high energy storage potential for the car; a 60 kW dc electric motor was selected to provide enough power and fed through an inverter. The current flow to the motor was varied using a potentiometer and frequency variable drive system.

2.2. Design Parameters

The design parameters include:
Overall length of the car l_c is 3719 mm
Overall width of the car w_c is 1659 mm
Overall height of the car h_c is 1539 mm
Cross sectional area of the Car is $2.5532\ m^2$
Front track is 1359 mm
Rear track is 3121 mm
Ground clearance is 150 mm
Weight specification unload is 835 kg
Gross weight limit is 1340 kg
Design weight of the vehicle is 2000 kg
Top speed is 154 km/h
Weight of the battery is 84 kg
Tyres size is 155/70R13
Aerodynamics drag coefficient (C_d) is 0.33
Acceleration of the car is 3.568 m/s^2

2.3 Deign Analysis

The equations used for the design of electric motor conversion are as shown in equations 1 to 17 respectively as extracted from the studies of Gari (2012), Eydgahi (2015), Ali (2011), Mark and Sanath (2017), and Buddhi (2016)

The following equations were used in the design:

$$F_{rolling} = C_r\, M\, g \quad (1)$$

$$F_{gradient} = M\, g \sin \alpha \quad (2)$$

$$F_a = \frac{1}{2}\rho_a\ C_d\ A_f\ (v_{car})^2 \quad (3)$$

$$F_{\rm I} = a \times Weight_{car} \quad (4)$$

$$F_{total} = F_{rolling} + F_{gradient} + F_a + F_{\rm I} \quad (5)$$

$$F_{\rm start} = F_{\rm I} + F_{\rm rolling} \quad (6)$$

$$P_t = (F_{total}\ X\ v) n_g \quad (7)$$

$$\text{cap} = \text{N V A} \quad (8)$$

$$\text{R} = \frac{\text{Cap}}{F_{\text{top}}} \quad (9)$$

$$T = \frac{\text{R}}{v_{car}} \quad (10)$$

$$A_b = 2(l_b\, w_b + l_b\, h_b + h_b\, w_b) + A_l \quad (11)$$

$$f = \frac{1}{T} \quad (12)$$

$$P = VAcos\theta \quad (13)$$

$$MOSFETs = \frac{actual\ power\ of\ the\ design}{power\ rating\ of\ the\ MOSFETs} \quad (14)$$

$$drain\ current = \frac{output\ power}{battery\ voltage} \quad (15)$$

$$load\ output\ current = \frac{output\ power}{output\ voltage} \quad (16)$$

$$A_i = 2(l_i\, w_i + l_i\, h_i + h_i\, w_i) \quad (17)$$

where: C_r is coefficient of rolling resistance, g is acceleration due to gravity (m/ s^2), α is road gradient (rad), a is acceleration of the car (m/s^2), C_d is aerodynamic drag coefficient, F_a is aerodynamic drag (N), ρ_a **is** air density (kg/m^3), A_b is area of the battery compartment (m^2), A_i is area of inverter compartment (m^2), R is battery range (m), Cap is battery pack capacity (kW.h), w_b is breadth of the battery box (m), w_i is breadth of the inverter compartment (m), C is capacitance (μF), M is designed weight (kg), n_g is drivetrain efficiency (%), A_f is effective cross sectional area (m^2), F_g is gradient resistance (N), h_b is height of the battery box (m), h_i is height of the inverter compartment (m), $F_{\rm I}$ is internal resistance force (N), L_b is length of the battery box (m), L_i is length of the inverter compartment (m), N is number of battery, f is oscillating frequency (Hz), h_c is overall height of the car (N), l_c is overall Length of the car (N), W_c is overall width of the car (N), P_t is power (kW), P_f is power factor, F_r is rolling resistance (N), T is time (s), F_s is total force at starting (N), F_t is total force at top (N), F_p is total tractive power (N), v_c is vehicle speed (m/s), V is voltage (v)

2.4 Selection of Power Train, Variable Frequency Drive (VFD) and Batteries

The raw power calculation helps to select appropriate electric motor and the number of batteries required. The selection was also made in such a way as to result in the lowest possible difference in the weight of uninstalled and newly installed elements, while retaining (as much as possible) the original weight distribution between the axles. This could not be done entirely, due to the fact that the weight of the batteries is substantially higher than the weight of the full fuel tank. Lithium ion batteries were chosen for storing the energy needed because it does not emit fluids or gases during normal operation, high energy density, good performance at high temperature, recyclable and low memory effect. 8 kVA electric motor with frequency regulation is chosen to propel the vehicle. The variable frequency drive is a device that helps in converting the fixed voltage and frequency of the input power provided to the motor, into variable voltage and frequency, and this conversion regulates the functioning of the electric motor used. 500 W load three-phase variable frequency drive was selected for the developed vehicle as shown in Figure 2.

2.5 Conversion Process

The internal combustion engine (ICE) parts and equipment were removed from the vehicle. These include: engine and its auxiliary units, engine electric wiring, exhaust system, fuel tank and supply system. In order to place the batteries and change the vehicle category, the rear bench, the back seats with its accompanying equipment were also removed. The electric motor (EM) was then mounted into the vehicle and then connected to the gearbox, with mounting bracket built to ensure that suspension points of installed electric motor correspond to the suspension points of ICE. The accelerator pedal was hooked to a potentiometer that provides the frequency variable drive with the signal that indicates the amount of power to be delivered. The installation of electric vehicle and potentiometer are shown in Plate 1.

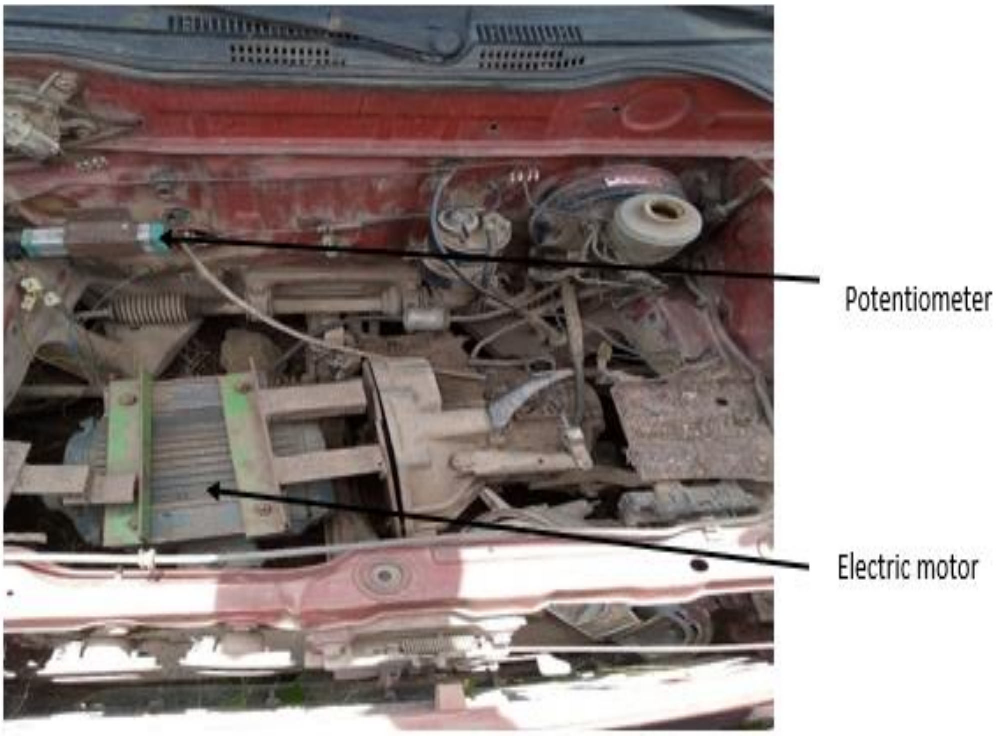


Plate 1: Installation of EM and potentiometer

At the rear part of the vehicle, two sheet steel boxes were fitted to the vehicle boot to accommodate batteries. The cells were placed in two serially / parallel connected groups, with the output voltage of 4 x 12 V as shown in Plate 2. The batteries were connected to the electric motor and looped with control unit and variable frequencies drives. An inverter was also installed at the back of the batteries to convert the DC power from the battery to AC power used in the electric vehicle. The connections are shown in Plates 3.

Plate 2: Installation and connection of batteries

Plate 3: Installation of inverter

The petrol filling point was modified to accommodate the charging point. A battery charger was added so that the batteries could be recharged from any 110-volt or 220-volt wall outlet. The gas gauge was replaced with voltmeter for the reading of current and battery voltage respectively. The circuit diagrams, the power train, the exploded and the wireframe views of the developed EV are shown in Figures 1,2,3,4 and 5 respectively.

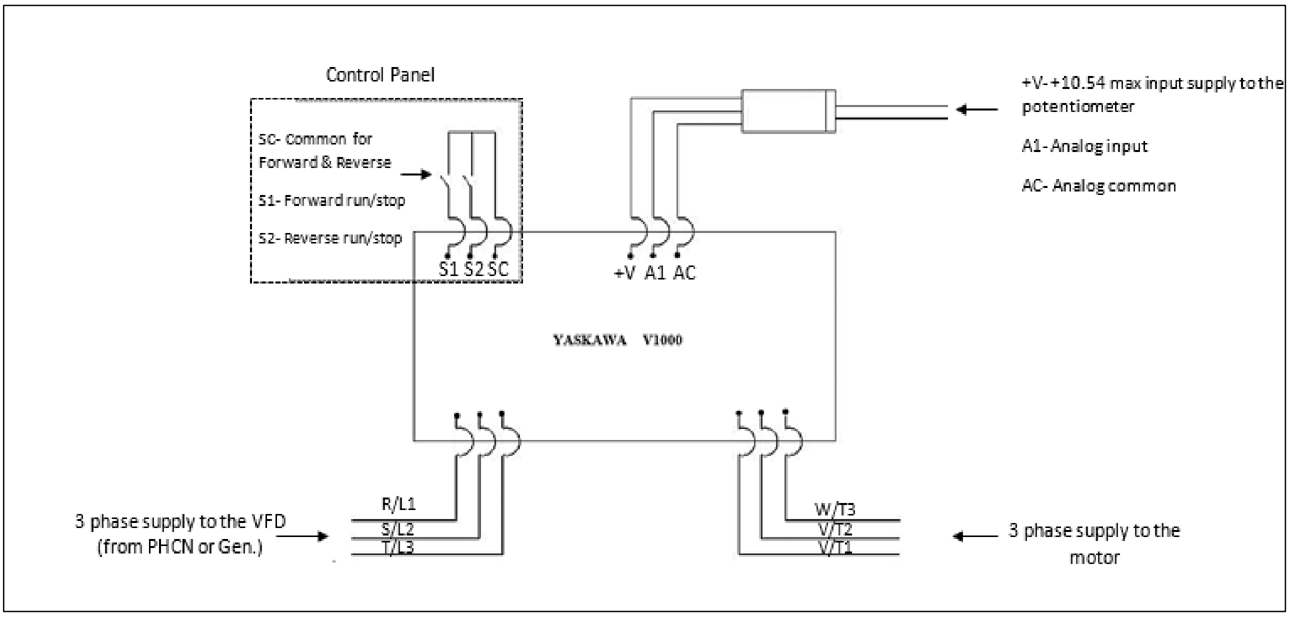


Figure 1: Developed control circuit of the EV

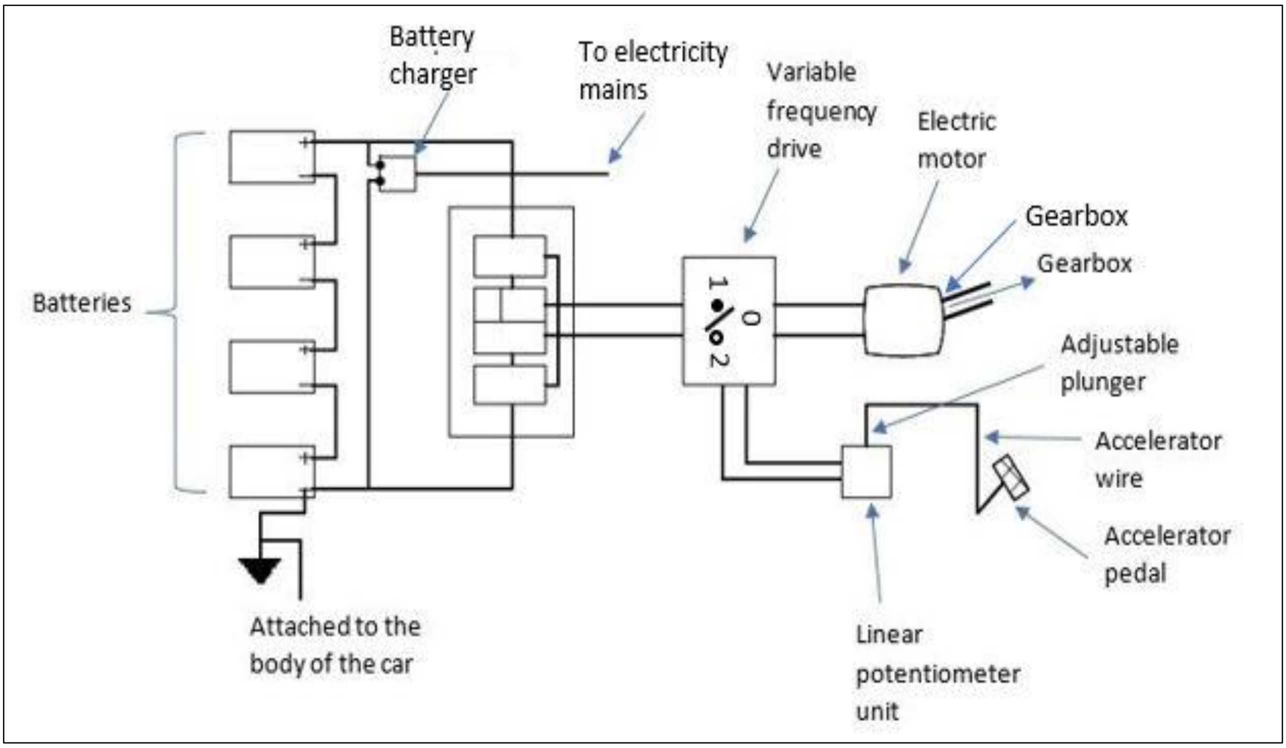


Figure 2: Circuit diagram of the developed EV

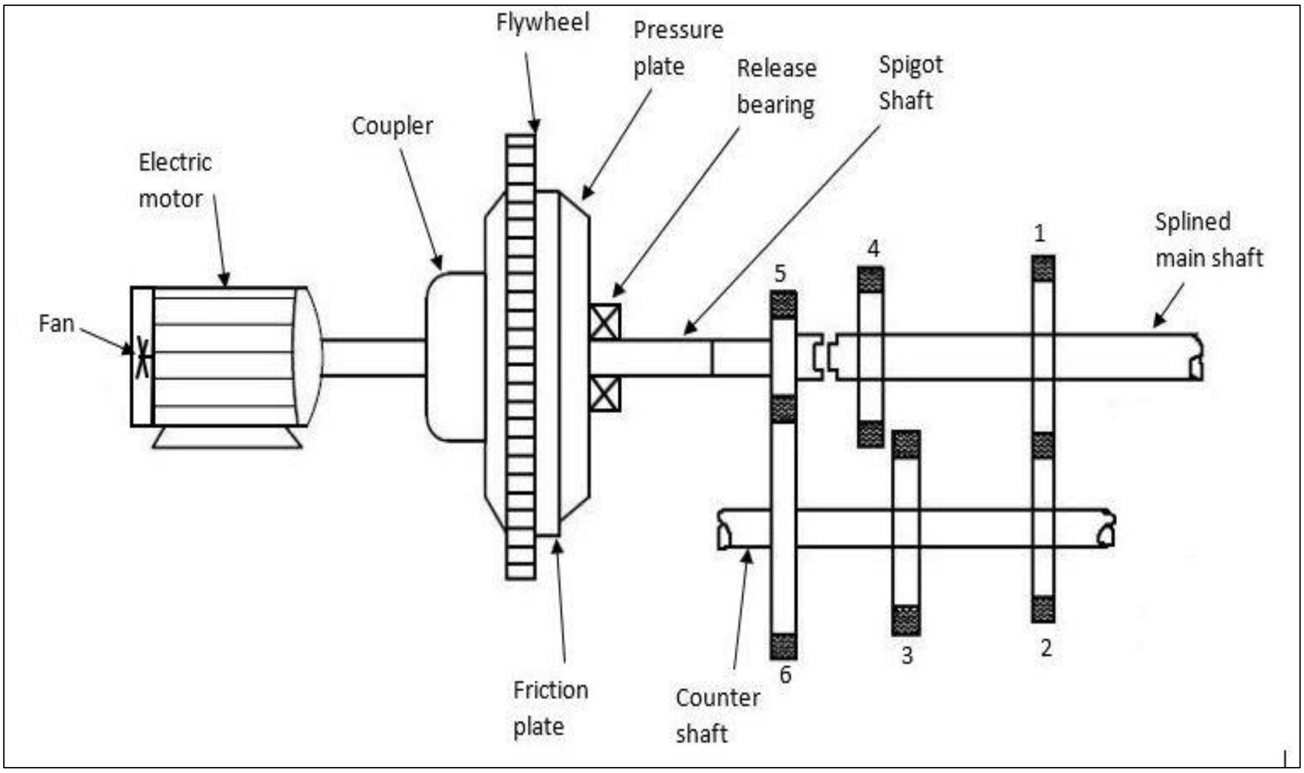
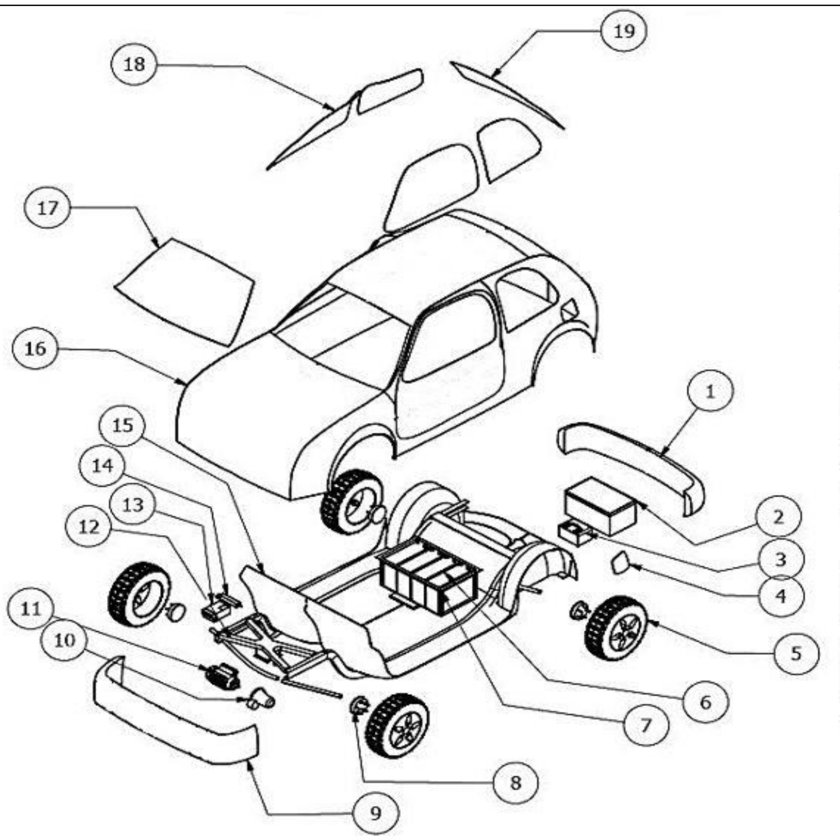


Figure 3: Power train of the developed EV



S/N	Part Name	QTY
1	back bumper	1
2	inverter box	1
3	battery charger	1
4	charging port	1
5	tyre	4
6	lithium batteries	4
7	battery tray	1
8	wheel hub	4
9	front bumper	1
10	couplings and gearbox	1
11	AC electric motor	1
12	motor mount frame	1
13	variable frequency drive unit	1
14	potentiometer unit	1
15	chassis	1
16	body	1
17	front windscreen	1
18	door glass	4
19	rear windscreen	1

Figure 4: Exploded view of the developed electric car

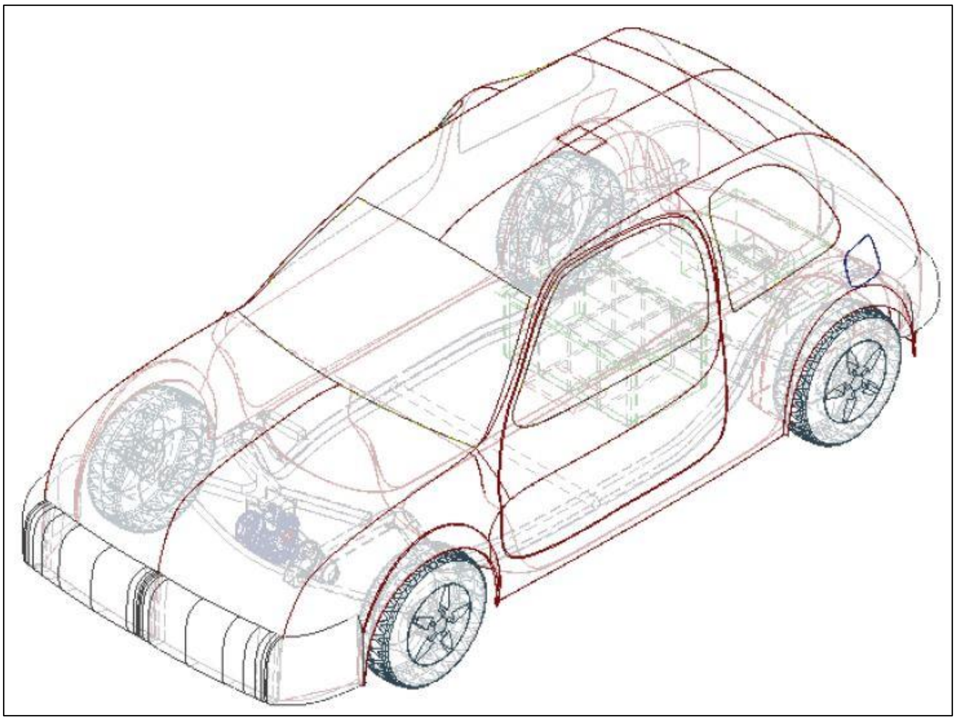


Figure 5: The wireframe of the converted car

3. PERFORMANCE EVALUATION

A Nissan Micra car was selected for conversion taking into consideration its light weight and compact shape. The existing internal combustion engine was removed and AC electric motor attached to the gearbox to give the gear ratios possibility of a normal car. After installation of the electric motor, variable frequency drive, batteries and inverter with its driver board configured with fast arithmetic function and floating point operator to process the control using proteus design suite, the vehicle was then tested and the voltage produced was able to turn the AC motor and move the car. The transmission worked perfectly and the revised gear was successfully engaged. The control system also works perfectly in supplying the correct voltage to the AC motor. During road testing of the developed EV, acceleration time of 0 to 60 mph was achieved in 30 seconds at speed of 6.24 m/s and the maximum frequency recorded was 50 megahertz (50 MHz).

4. CONCLUSION

A Nissan Micra vehicle was modified and converted to battery powered electric vehicle by removing the existing internal combustion engine and installing the AC electric motor. The power rating of the motor was determined by considering the rolling, gradient and aerodynamic resistances. The power rating and range of car per charge obtained were used to determine the number of batteries that produced the required current. The electric vehicle developed was tested and the voltage produced was able to move the car. Acceleration time of 0 to 60 mph was achieved in 30 seconds at speed of 6.24 m/s and the maximum frequency recorded was 50 megahertz (50 MHz). All necessary factors have been taken into consideration to ensure the reliability of the developed vehicle and ease of maintenance.

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