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Modelling and Simulation of Composite Material Used in Electric Vehicles for Power Consumption

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Abstract
Composite materials have become increasingly prevalent in several industries such as aerospace, automotive, and marine. Worldwide car transportation and industry have been increasing at the quick rate in last few decades notably in metropolitan region. The present internal combustion (IC) cars are generating a significant level of pollution as a result of their reduced efficiency and substantial weight within the road transport industry. Hence, the worldwide automotive industry is increasingly transitioning towards the utilisation of lightweight composite materials in the manufacturing of automobiles. Composite materials have gained significant popularity within the vehicle industry due to its advantageous characteristics such as lightweight nature, extended lifespan, improved physical and mechanical properties, and their ability to be easily moulded into various shapes, surpassing the capabilities of traditional metals. This study encompasses a survey focused on the architectural aspects of electric car components manufactured utilising composite materials. Additionally, the study employs modelling and simulation techniques to forecast energy usage in all-electric automobiles. This study employs the term "electric vehicles" to encompass a range of electrified vehicle models. The technological aspects pertaining to these electric vehicles were also deliberated upon. A hybrid electric vehicle was developed with the ADVISOR software tool, and subsequently subjected to a comparative analysis with another automobile referred to as the targeted car. The fuel efficiency of the car that was designed showed a lower consumption rate in comparison to the car that was targeted.

Keywords: Composite Material, Simulation, Modelling, Electric Vehicle

1. Introduction

The progression of technology over time has facilitated the development of electric vehicles, thereby catering to the demands of the populace. Electrified vehicles have been observed to yield advantages in terms of reducing fuel usage and mitigating the release of greenhouse gases (GHGs). The primary purpose behind the invention of hybrid electric vehicles was to enhance the driving capabilities of petrol vehicles powered by internal combustion engine (ICE) technology. During this particular phase of advancement, the use of electric motors played a crucial role in enhancing the propulsive capabilities of ICE technologies. The primary aim of the hybrid car was not centred on the reduction of fuel consumption, but rather on the enhancement of driving power. The initial development in the field of enhanced propulsive power was the creation of a parallel hybrid vehicle [1]. In contemporary times, there has been a significant surge in the production of electric vehicles, primarily driven by the imperative imposed by governmental entities to mitigate greenhouse gas emissions. The demand for electric vehicles is experiencing exponential growth [2]. The discourse surrounding the mitigation of climate change has become a well-established and widely discussed subject in the contemporary day. The phenomena under discussion holds significant importance at both the worldwide and local levels of governance, particularly in prominent nations such as the United States of America, China, Canada, the United Kingdom, and others. Prior studies have indicated that the primary contributors to greenhouse gas (GHG) emissions are human activities, specifically the utilisation of fossil fuels in various sectors including transportation (such as automobiles and aircraft), household heating and cooling, and electricity generation [5]. The impact of carbon

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emissions has manifested in several consequences, including the escalation of global warming, the evaporation of soil moisture, alterations in climate patterns, the thawing of polar ice, instances of flooding, and a rise in sea levels [6]. Hence, it is crucial to adopt technology that facilitate decarbonization. Electric vehicle technology has been identified as one of the aforementioned technologies.

Electric vehicles play a key role in contemporary society, serving as indispensable means of transportation in our daily lives. Various modes of transportation, such as electric automobiles, electric buses, and electric trucks, have been readily accessible in the contemporary era. The adoption of electric vehicle technology has gained significant traction in the 21st century, mostly driven by the imperative to reduce carbon emissions. This study encompasses a comprehensive review of several electric vehicle models, accompanied by the presentation of a design simulation for a hybrid electric vehicle (HEV).

In the past, it has been customary to construct automobiles using a range of materials including glass, plastic composites, and metals. In the field of automation, the utilisation of aluminium and magnesium alloys has emerged as a viable alternative to steel in order to achieve weight reduction. The utilisation of novel composite materials in the pursuit of reducing the weight of modern cars has been made possible through recent breakthroughs in this field. The aerospace and automotive sectors are employing recently developed composite materials in order to achieve enhanced levels of strength and rigidity. Composite materials have superior safety characteristics when compared to traditionally utilised materials. One of the key advantages associated with the utilisation of composite materials in the automation industry is their ability to effectively lower the weight of vehicles by up to 10%. Composite materials exhibit a weight reduction of 61% compared to steel and 36% compared to aluminium. In the production process of automobiles, the utilisation of composite materials in components has the potential to significantly decrease tooling costs by approximately 50 to 70%.

Artificial neural networks (ANNs) have been extensively utilised in engineering applications [7,8] and various other domains owing to their exceptional accuracy capabilities. Numerous research have employed artificial neural networks (ANNs) as a means to forecast specific metrics pertaining to electric vehicles. Batteries have been utilised for the purpose of predicting the state of charge [9], estimating range [10], conducting design simulations [11,12], and determining velocity, among other applications. According to Balci et al. [13], the utilisation of an artificial neural network was employed in the development of an engine fuel consumption map using datasets obtained from a conventional passenger vehicle. A comparison was conducted between the fuel consumption of a conventional vehicle and a parallel hybrid vehicle, which was simulated using MATLAB/Simulink. The findings indicate a decrease in both fuel consumption and carbon dioxide emissions when comparing the parallel hybrid vehicle to a conventional vehicle in terms of engine calibration on the map. Artificial Neural Networks (ANN) were employed to conduct design simulations on the characteristics of pure electric vehicles [11]. The findings indicate that a singular model can be employed to routinely forecast many parameters with a notable level of precision.

1.1 Factors contributing to the increase in demand of electric vehicles

Numerous variables are contributing to the upward trend in the utilisation of electrified vehicles. Several factors contribute to the phenomenon, including governmental regulations, the enactment of legislation aimed at mitigating greenhouse gas (GHG) emissions, the rise in conventional vehicle fuel costs, heightened global awareness, and the provision of tax credits for both electric car makers and consumers [2]. Figure 1 depicts the various elements that contribute to the rise in demand for electric vehicles. The utilisation of electric vehicles in certain nations has been facilitated by government policies, which are recognised as a significant contributing element. In both Canada and the United States, there are legislation at both the provincial and federal levels that impose restrictions on greenhouse gas (GHG) emissions [4]. Moreover, it is noteworthy that the government has enacted a resolution with the aim of implementing carbon taxes on various organisations as a means to regulate and mitigate the release of greenhouse gas emissions [14]. Regulations or standards pertaining to greenhouse gas (GHG) emissions are enforced by the government on automotive manufacturers in various nations, including the United States and Canada [15, 16]. The implementation of government rules has prompted some provincial governments in Canada to gradually discontinue the usage of conventional buses and instead adopt electric buses.

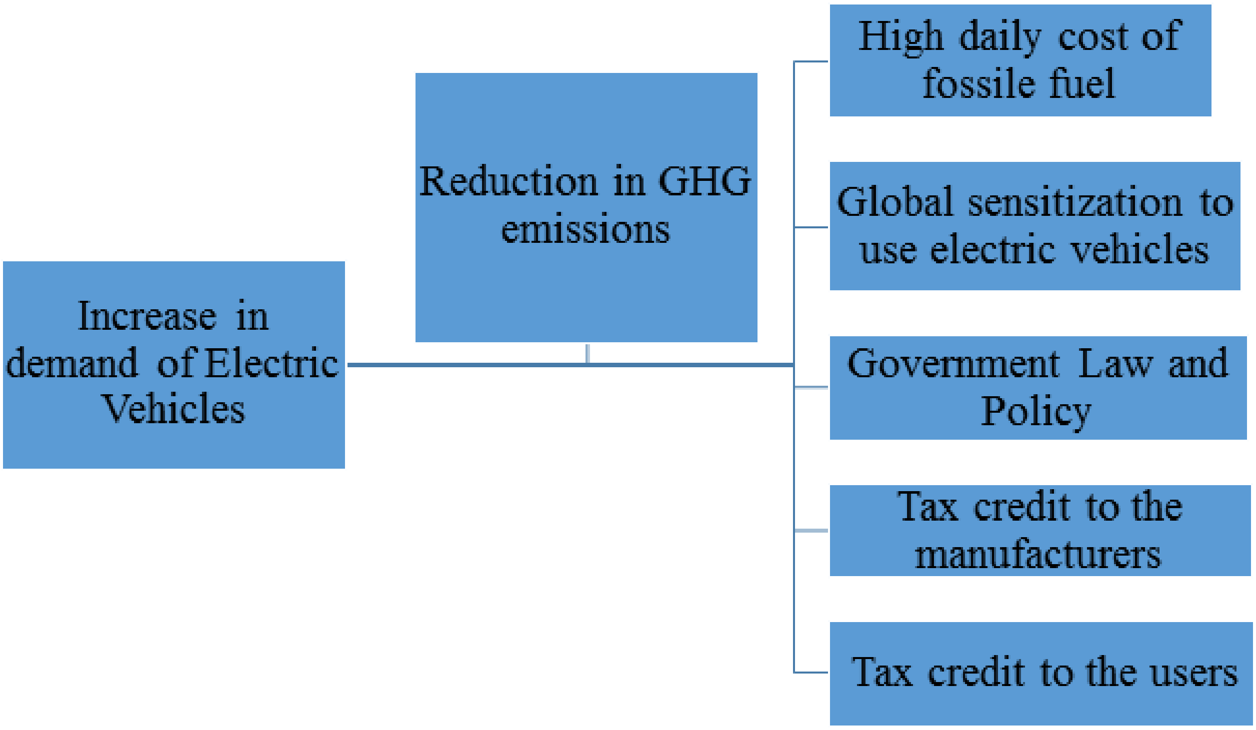


Figure 1 Factors contributing demand of electric vehicles

2. Vehicle technologies

Electric cars (EVs), The battery is key to this fundamental advancement and the technology that enables it. Throughout history, the significance of batteries in electric cars has been shown. Electric vehicle batteries are not the same as those used in consumer electronics such as laptop computers and mobile phones. They must be capable of handling high power in kW and high energy capacities (tens of kWh), all while fitting into a small space and weighing little. Electric cars may be designed into the power grid system in the facility. They can be used in concert to offer grid support for renewable energy, frequency management, voltage framework streamlining and governance, among other things. They may also be broadcast and utilized to control local load to reached demand side. The battery in EVs is a critical component in the grid integration problems as described in the literature. This paper goes through the basics of EV battery technology. Common EV battery technologies are Li-ion and NiMH, will be highlighted. Understanding the various batteries' initial chemistry, as well as specific EV battery demands like as cost, energy density, durability, power density, and specific energy, is crucial for power engineers. The electric car battery modelling will be given in such a way that power engineers will be able to comprehend and apply it in the design of power electronic interface converters.

The functionality of battery varies as the operational parameters (temp, charge or discharge current, or charging time) & maintenance time change. This chapter will also go through battery characterization, including how to derive battery model parameters, and state of health's (SOH). We'll discuss about battery power management and reusing used Electric Vehicle battery is stable smart grid application at the last of this chapter.

2.1. Electric Propulsion's Power and Energy

Depending on the requirements of the vehicle, the battery within an electric vehicle delivers part or all of the vehicle's propelling force and energy. This subsection's theme is for a proper battery electric vehicle without losing generality. The power train of an electric car, like those in traditional cars, must applied power for the vehicle in a range of driving modes or road conditions. Moreover, an Electric Vehicle must be capable of regenerative braking, this permits the driver's angular momentum to be captured and converted into electricity for future use.

2.2. Capacity-rate

The rated Ah capacity is indicated by the letter . C is equivalent to charging or discharging a 1.6 Ah battery at 1.6 A. While charging or draining the battery, 2C is equivalent to 3.2 A

2.3. Specified Energy

The values of energy that the battery can charge pu mass is known as its "specific energy," which is also known as its "gravimetric energy density." The most important factor in calculating the entire battery weight for an electric vehicle's reported mile range is the specific energy of the battery. The specific energy of a battery, expressed in Watt-hours per kilogramme (Wh/kg). 1.5.4 Specific Strength-Specific power is the highest power of a battery pu mass. The battery is known as gravimetric power density a. In W/kg, it's written formula:-

Specific Power one by four Rated Maximum Power = Battery weight in kg

2.4. Energy Density

The quantity of energy that can be stored (Wh/l) in a battery is measured by energy density, often called as cubic energy density.

2.5. Power Density

Power densitys are calculated as the battery density of highest power per unit volume (W/l).

2.6. Internal Resistance

The total value of the resistor of a battery is its internal resistance. It fluctuates depending on the charging / discharging circumstances, and it may alter as the working environment changes.

3. Modelling & designing of electric vehicle

The electric vehicle utilised in this research is a compact automobile specifically designed for urban transportation in Indonesian cities. Figure 2 illustrates an electric vehicle featuring an induction motor serving as the primary driving mechanism, an inverter serving as an intermediary connection between direct current supply and the induction motors, and batteries serving as the primary power source. The model was created using the Simulink/Matlab tool.

In a significant milestone, electric vehicles have been produced on a large scale, prompting a call for increased incorporation of educational opportunities related to this subject matter. The time period spanning from 2010 to 2020 has been designated as the anticipated "tipping point" wherein there will be a transition from internal combustion engines (ICE) to electric propulsion systems as the predominant means of transportation. Currently, there is a lack of ABET-accredited degree programmes in Automotive Engineering or Technology that offer coursework specifically focused on electric vehicles. A comprehensive examination of the existing literature on electric vehicle training courses revealed a limited number of courses that are either offered as standalone programmes or focused on certain themes, as indicated by references [17-22]. The academic years of tenth and eleventh grades. In contrast, the industrial sector primarily relies on internal training programmes to educate engineers, highlighting the pressing need for educational initiatives in this domain. Such initiatives are crucial for cultivating a skilled and knowledgeable workforce capable of effectively supporting the growing Power Grid and Electric Vehicle sectors. In that addition is the advancement of latest technologies, the design process in industry’s have changed dramatically in recent years. For sophisticated embedded systems, Model-Based Design is now widely employed in the automobile, aerospace, and other sectors. The traditional design workflow includes the following steps:- Requirements, Design, Implementation and Testing.

3.1. Validation

- Needs must be read and understood by various engineers on distinct teams, problems with traditional design may arise.

- Design programmers' techniques must be rewritten by application engineers.
- The issue isn't discovered until the testing stage.

Model-Based Design starts with modeling to build executable specifications that engineers can examine and check against requirements right away. Engineers then exchange models that show the performance of subsystems and components, as well as employ Simulink/Real Time and Embedded Coder's automated programming capabilities to ease HIL testing. Simulation is a useful tool for speeding up design and lowering product development costs. Engineers can use SIL, MIL, and HIL developing modelling models as the design process progresses.Engineers may save design costs and time by incorporating simulation into the design process, allowing organisations to produce and test developed things faster.

3.2. Drive Cycle

Vehicle travel testing and simulations are used to aid in the design phase and assess whether the design is suitable for the intended use. During the simulation, the simulated vehicle must accomplish a set of vehicle velocity figures second by second. The goal of a drive cycle is to minimise the amount of time-consuming on-road tests while simultaneously reducing test time and fatigue for the test engineer. There are a number of standard driving cycles that are used to assess the fuel economy and other characteristics of road vehicles. Several driving cycles are theoretical, while others are based on real-world observations of a typical driving pattern. During a driving cycle, you may experience rapid speed fluctuations or long periods of continuous speed.

3.3. Torque and Speed Values

The simulation shown assumes that the speed and torque parameters are known. Torque values may be calculated using the vehicle's wheel diameters and road load data if speed values are acceptable. The sum of the rolled, air, and gradient resistances, that are either known or can be estimated, is the total road load.

3.4. Electric Vehicle Drive Car Operation

The engine consumes gasoline but does not return it to the gas tank. The idea that an electric vehicle's battery is part of stationary the drive car symbolises a paradigm transition from gasoline engines to electric autos. Car with an electric drive train. The battery in the schematic is compared of Lithium Ion batteries and delivers 230+ volts and a large current to the power electronic devices. The battery pack is controlled by a battery controller, which monitors and regulates important battery characteristics. For both directions of rotation, these motors may provide accelerating or braking torque. When you apply the brakes on your automobile, the motor goes into regeneration mode or rectification mode, reversing both the current and torque directions. The torque is reversed to give vehicle braking torque while also assisting in battery recharging. The Vehicle Interface connects to the Battery Controller and Motor Controller, as well as providing a connection to the vehicle's controls and sensors. A Controller Area Network (CAN) communications technology is used to communicate amongst the various devices.

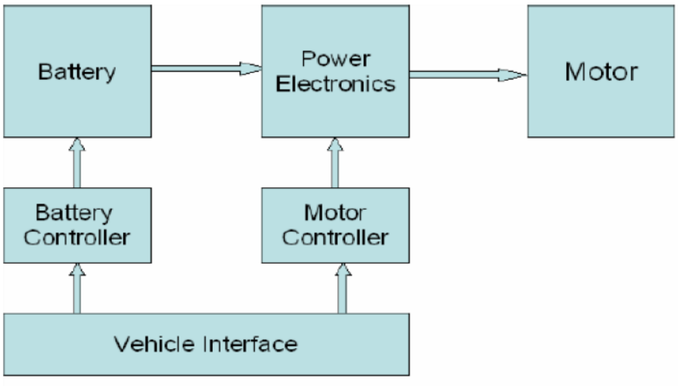


Figure 2 Electric Vehicle Drive Car.

3.5. Circuit Diagram

Asynchronous Machine are employed as drivers because they are reliable, have a high inertia, and do not require frequent maintenance. They are commonly used for electric driving with constant velocity and have a big inertia. QDN coordinates have been used to depict the driving of an induction motor. This design is more malleable than others. Because this model can operate with a non-sinusoidal voltages, it can still be analysed in non-symmetrical source conditions. Lead acid batteries are the type of battery that uses an energy source, and they are commonly found on the market at a reasonable price. This is one of the main reasons why this sort of battery should be chosen. Furthermore, this form of battery may be employed for engine starting, which necessitates strong currents. Because the battery's output is dc voltage and current and the motor in an electric car is an asynchronous motor, a power converter is requirement of IGBT to power the induction motor. This model's PWM converter technique is the power converter. Figure 3 shows the electric vehicle model of in this study.

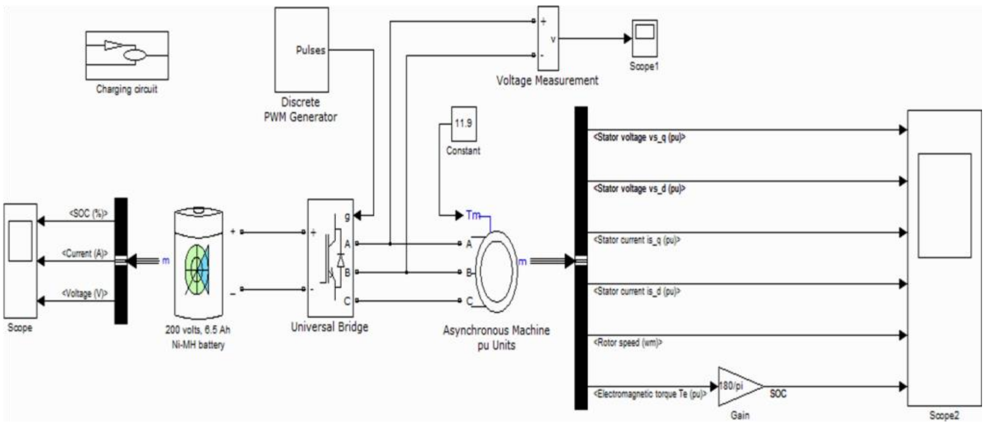


Fig 3 The electric vehicle model of in this study.

4. Model Description

4.1. Universal Bridge

Functional approach power converters with fully customizable topologies and power digital evices Library.

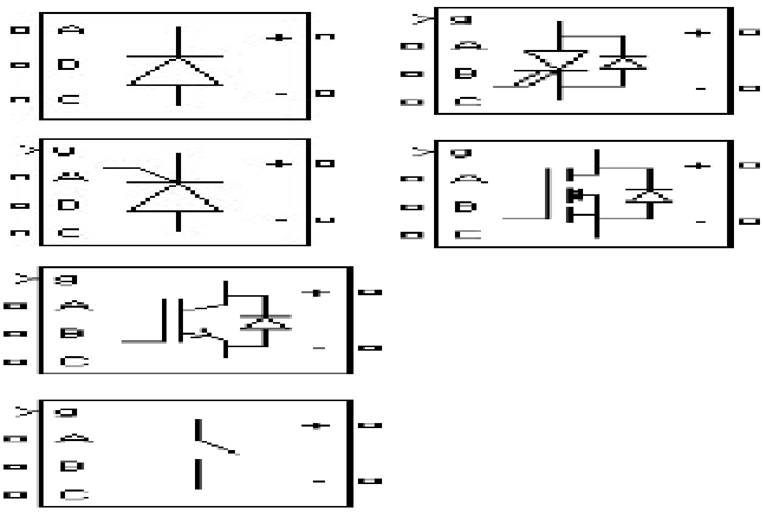
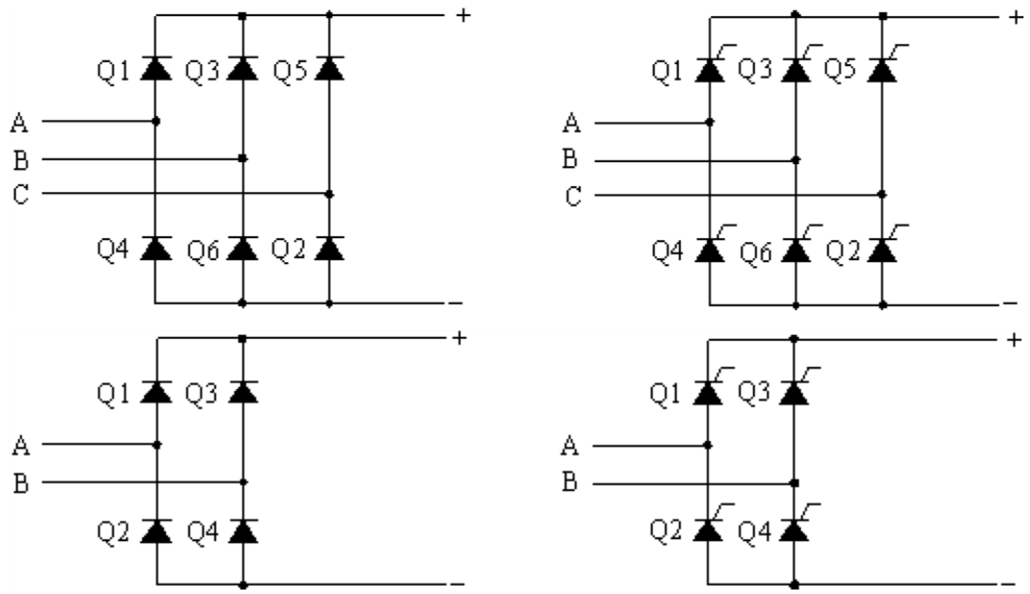


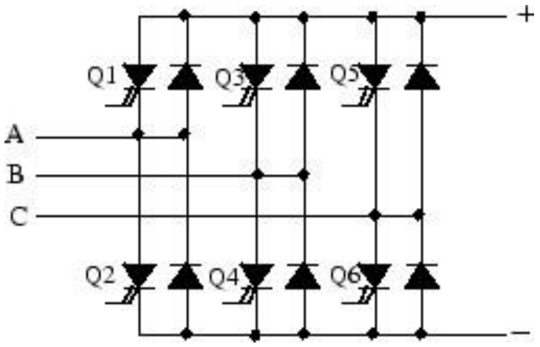
Figure 4 Symbol of universal bridge

The By connecting up to six power switches in a series arrangement, the Universal Bridge block provides a universal 3-phase converter. You may select the type of power button and converters configuration in the settings dialogue box. By combining naturally commutated (or line-commutated) and forced-commutated power electronic components (thyristor and diode), the Universal Bridge block imitates converters (IGBT,GTO, MOSFET). The Universal Bridge is an essential element in the design of multiple voltage- sourced converters (VSC).

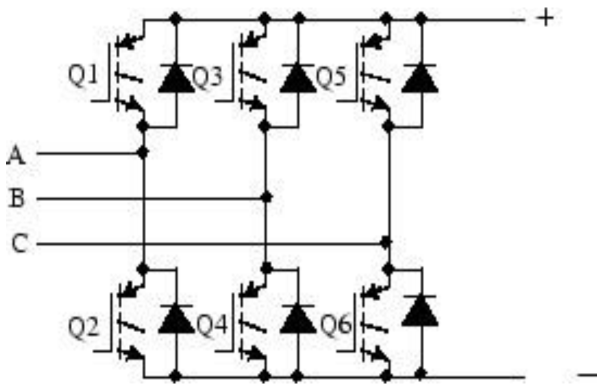
According as to whether the power electronic devices either naturally or forced- commutated, the product identification changes. The identification of a spontaneously permanent magnet synchronous 3-phase converter (thyristor and diode) follows a logical sequence of commutation:



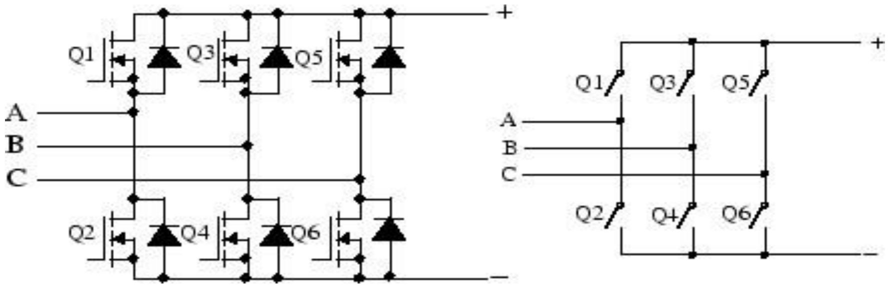
4.1.1 GTO-Diode Bridge:

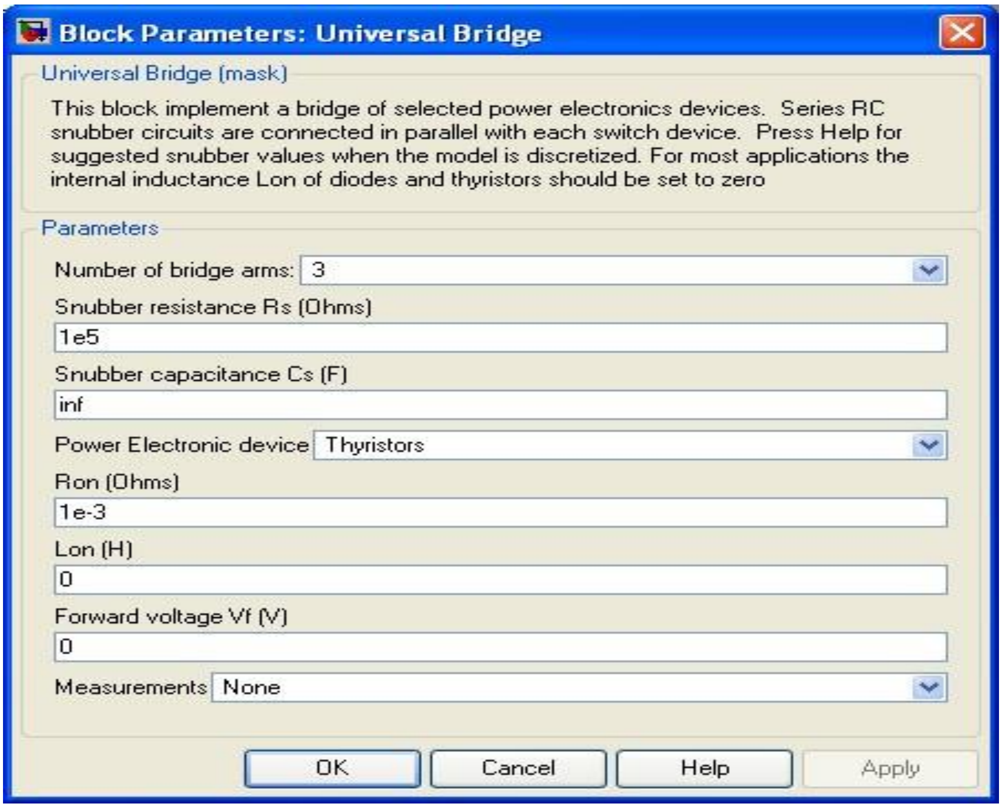


4.1.2 IGBT-Diode Bridge:



4.1.3 MOSFET-Diode and Ideal Switch Bridges:





Assigned a value 1or 2 to even get a 1-phase converter. (either 2 or 4 diode having switched devices) Set to three to use a three-phase adaptor to produce a Viscous dissipation bridge setup (six switching devices). The snubber impedance in ohm (). Set the Decoupling capacitor resistance Rs attribute to zero to remove all snubbers from the model. The farad bypass capacitor capacitance (F). To deactivate snubbers, set the Zener diode circuit capacitance Cs value to 0, and to inf to enabling sensitive snubbers. When your system are discredited, you must give Rs and Cs switching regulator constants for diode and switched regulator bridges to minimise numerical oscillations. The bridge can work successfully with only resistive snubbers for imposed devices provided long even though firing pulses are provided to power switches (IGBT, GTO or MOSFET). Just antiparallel transistors work when discharge pulses to forcible electronics are blocked, and the bridge functions as a half - wave rectifier. Appropriate Rs & Cs values should also be used in this situation.

After the network has indeed been fuzzified, the following equation may be applied to obtain an approximation of Rs and Cs:

$$Rs > 2\frac{Ts}{Cs}$$

$$Cs < \frac{Pn}{1000(2\pi f)Vn^2}$$

where

P_n = Nominal power of single or three phase converter (VA)

Vn = Nominal line-to-line AC voltage (Vrms)

f = Fundamental frequency (Hz)

T_s = Sample Time (s)

4.2. Modelling of electrical vehicle

The transportation sector's negative environmental effect necessitates the search for alternatives to current transport vehicles. The car described in benefit of carry a zero- emission vehicles. The vehicle is construction of depicted in Figure 4

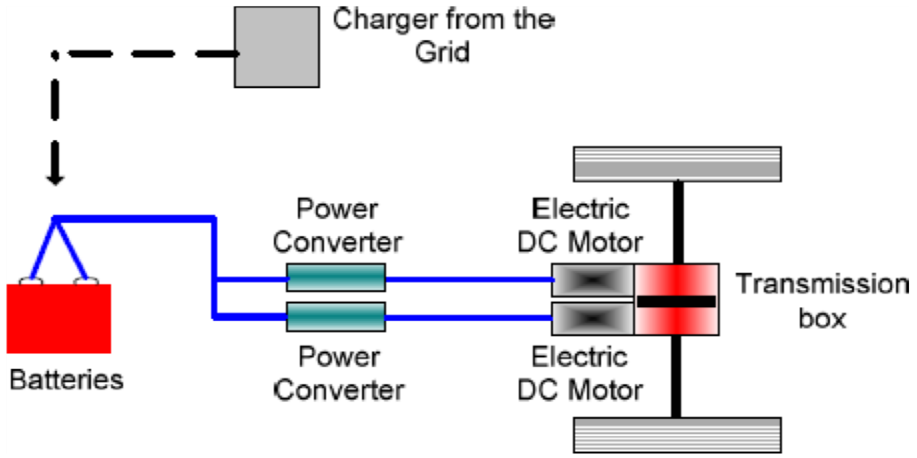


Fig. 4 Structure of a pure battery electric vehicle

Figure 4 depicts the electric car with two motors set, every connected to single wheel, resulting in a system with multiple independent wheel drives. Multiple power converters (DC-DC converters) provide power to the motor, which is powered by three 12V cells linked in series. The power grid may be used to replenish these batteries (grid). The vehicle is powered by two 48V@11kW DC motors. These motors need a high current value (»200A). The basic components of a closed loop DC motor current control system are shown in Fig. 5.

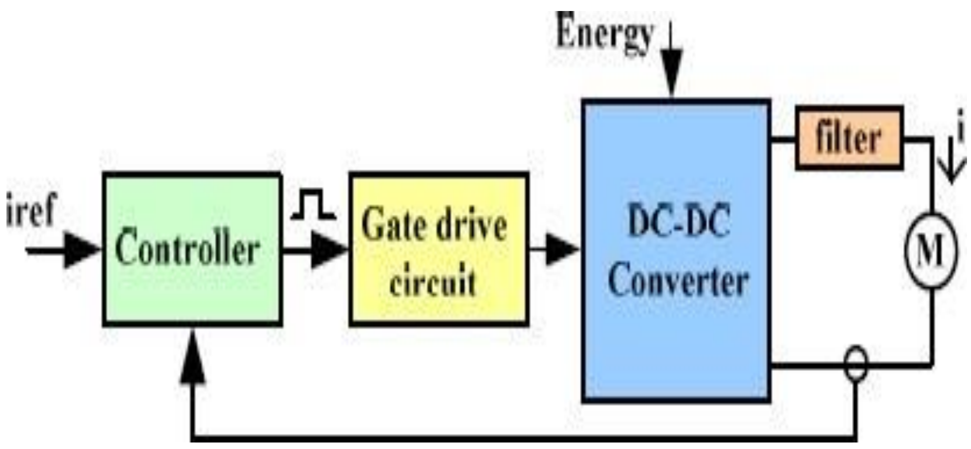


Fig. 5 - Building algorithm of a DC motors current

The many components of Fig.5, as well as their structure, will be described throughout the text. The focus of this research will be on DC-DC converter techniques and construction issues, as well as their control. This theme is about power conservation, safety, and the system's intuitive responsiveness to human engagement.

5. Simulation results

The model is powered by three 375-volt lead acid battery, a Pulse Width Modulation inverter, and a 3-phase induction machine operating at 220 volts and 50 Hz. The modelling of wave form an electric vehicle model is shown in Figure 5.5. This simulations shown above were apply to assess the performance of an electric vehicle under both starting and running conditions.

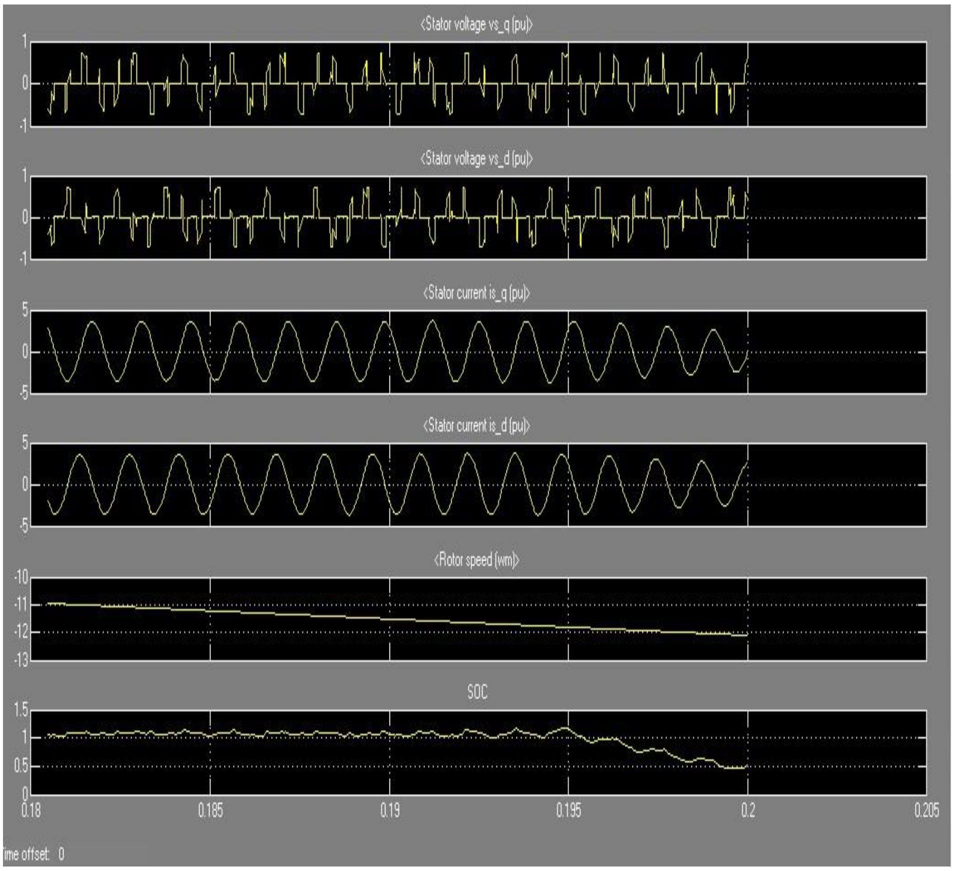


Fig 6 Simulation of electric vehicle system model.

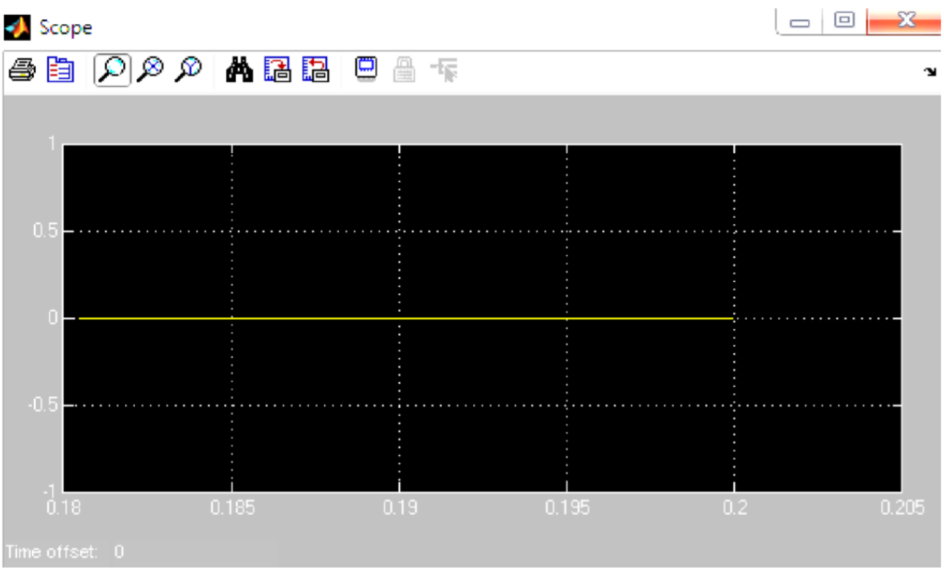


Fig 6 Simulation of electric charging circuit current.

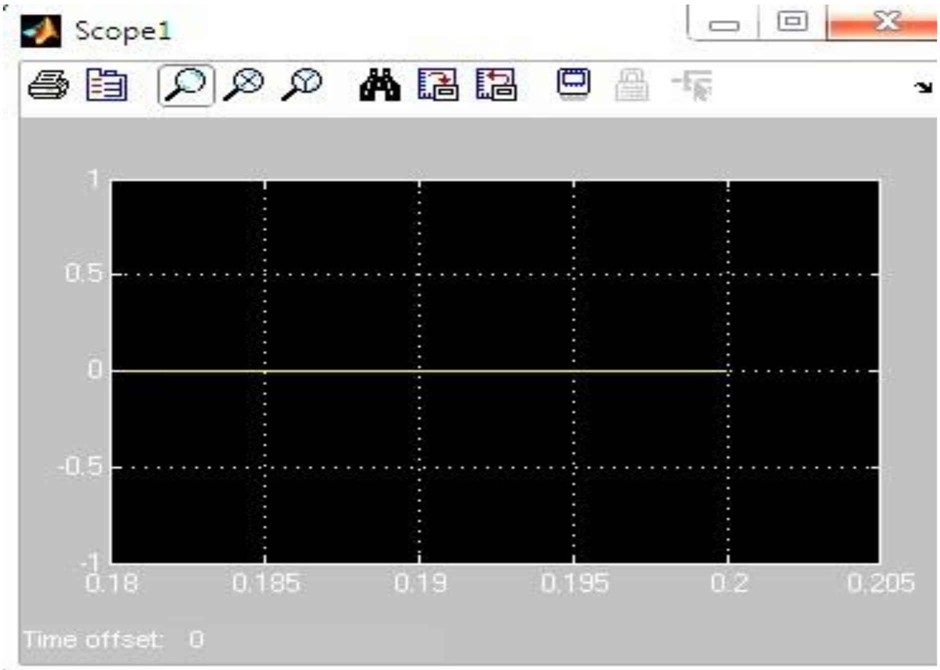


Fig 7 Simulation of electric charging circuit voltage.

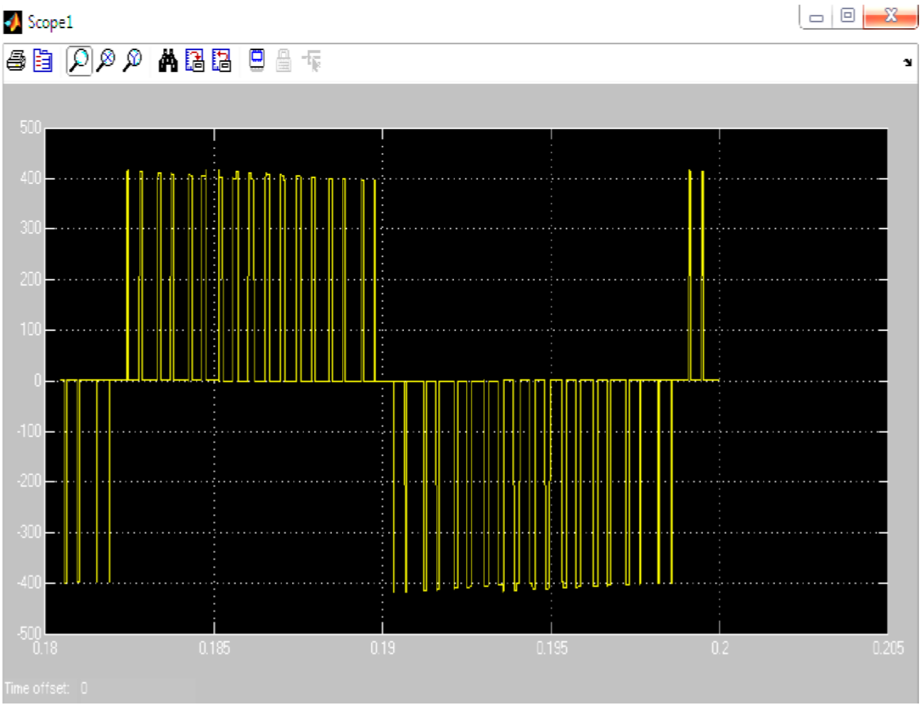


Fig 8 Simulation of electric vehicle system voltage.

6. Conclusions

The process of designing electric vehicle equipment facilitates the efficient determination of the frequency at which a rechargeable battery in an electric automobile has to be recharged in order to meet the precise travel requirements for a given distance. This model has the capability to assess and determine the duration for which an electric vehicle's battery may be effectively employed. The model can also be utilised for the estimation of an electric vehicle's performance attributes, such as its acceleration capabilities or its endurance at a sustained velocity.

6.1. Future scope

To further elaborate on this concept, it is essential to consider several factors. The optimization of regenerative braking energy collection is a key aspect that might be significantly enhanced in this strategy. In order to optimize energy recuperation during the braking process, it may be advantageous to make adjustments to the places at which downshifting occurs. However, it is important to note that these components can also provide additional insights into the behavior of the simulation.

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