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Solar Electric Vehicle with Bidirectional Technology

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ABSTRACT

Due to the increased call for the use of eco-friendly energy sources in the transport industry, there has been progress in the development of technologies used in EVs. In this project, we present the development of solar solar-charged EV equipped with a bi-directional charging system. This system also replenishes the vehicle battery and at the same time, the battery of the vehicle can act as a power source for the other devices as well. The primary devices and system that run through our project are a specially developed inverter and DC-to-DC converter regulating power distribution inside an electric automobile. These components effectively interface the Direct Current DC electricity stored in the solar EV battery to the external Alternating Current AC use or vice versa and they also ensure compatibility with most of the devices and grids.

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1. INTRODUCTION

In this paper, we look into the possibility of integrating solar power with three-wheeler electric vehicles, especially for the geography and conditions of Ladakh, the beautiful region located in the Indian Himalayas. The research paper aims to present the inception of a new invention, a solar power-driven three-wheeling vehicle which can be categorized under the alternative transportation innovation. This is an invention of a vehicle that incorporates a set of photovoltaic (PV) panels installed on the outer part of the vehicle body. They are panels that can transform the sun's energy into electricity and the electricity is regulated through Maximum Power Point Tracking (MPPT). This system makes it possible for the solar panels to draw power optimally depending on the amount of sunlight received thus maximizing the energy received from the sun. Hereby, electrical energy produced at PV panels is further stored in a lithium battery that has a long-life cycle and high energy density. These batteries directly drive an electric motor through a complex motor controller that measures, controls, and delivers the required electricity to the motor to enable the vehicle's speed and torque that it needs to perform optimally. This direct conversion of solar energy means that masts can be powered for longer distances and with less reliance on external charging stations thus making the vehicle more autonomous. A bidirectional charging system is among the advances that enhance the energy management of the SEVs. In this respect, it is a bidirectional technology that also means charging from the grid to the vehicle (G2V) but also from the vehicle back to the grid (V2G or from the vehicle to home, other loads V2H, V2V). The inverter plays the role of converting the Direct Current DC that is sourced from the vehicle's battery into an alternating Current AC that is suitable to drive the electric motor and similarly, during the regenerative process, it converts the AC from the electric motor back into DC to recharge the battery. It also has a central function in bi-directional power exchange. An important feature of the automobile built with the use of a three-wheeler vehicle is that it is equipped with an IoT control system. Some of the new advancements incorporated in this system include; the wireless control of keyless door locks through RFID and RF modules making it convenient for the control and security of vehicles. Based on the IoT the structure also permits appliances' distant control and observation of different characteristics of a vehicle, providing a Cut smart connected driving model. Furthermore, it displays components like indicators, brakes, and speed control systems among others which are constructed with safety and usability parameters in mind. The coordination of these components into a single system offers several difficulties, ranging from right power control to effective vehicle operation in a variety of climate conditions. This paper presents a systematic approach used in the integration and development of each module of the solar-powered three-wheeler vehicle, including the solar energy collection system and the IoT-based control systems. It is with this project that we hope to show that solar energy can be used to power electric cars, which will in one way or another help society to create better solutions for the future.

2. Ease of Use

A. User-Friendly Interface

Bidirectional charging in SEVs is integrated in such a way that end users will be able to understand well. In smart interfaces, drivers are in a position to determine when, as well as the extent to which, power is to be fed back to the grid or stored solar energy. Energy transfers can be automated in line with the demand of systems and concerning time-of-use pricing.

B. Maintenance and Durability

The Inverter and differential technologies have greatly developed and this has helped cut down on maintenance needs of SEVs. The incorporation of solid-state electronics in inverters and the changing over to electrical differentials reduce mechanical usage hence enhancing the useful life of these automobiles.

C. Future Developments

In the future, the efficiency of SEVs is poised to improve with the adoption of wireless charging technology as well as advanced solar cells. Furthermore, it should also be pointed out that, in the further development of bidirectional technology, SEVs could contribute even more actively to renewable energy grids in decentralized energy systems.

3. METHODOLOGY

A. Chassis (Design and Analysis)

Chassis play a crucial role in a vehicle support system that other body parts require as they act as a central frame. It must also be able to withstand several forces such as torsion, vibrations, and shocks resulting from acceleration, deceleration, road surfaces, and contact with other car parts. Furthermore, it has to include provisions for maximum load in all circumstances the vehicle may meet during its use. As these parameters, the design has been created with the help of the SOLIDWORKS tool. Later, the ANSYS 16 was used for more in-depth studies to further fine-tune devices for best performance. These iterations and analyses were useful in the process of finalizing the frame design. Selecting an appropriate chassis model by using SOLIDWORKS software after many rounds of iterations and modifications. Shown in Figure 1.1.

Table 1: Specifications

S. No.	Specification	Values (inches)
1	Wheelbase	40
2	Height	36
3	Track width	33
4	Vehicle weight	150-180kg

a) Wheel Arrangements

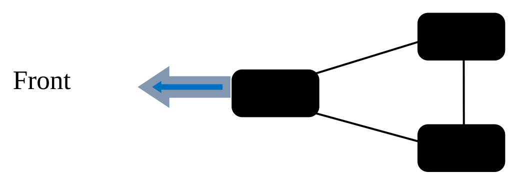


Fig 1: Delta Configuration

Delta Configuration (1 Front, 2 Rear): In this configuration, there is only the front wheel, and two wheels are placed at the rear end. This paper targeted the three-wheeled vehicle design and we chose the delta wheel configuration which pointed to the single front wheel and two rear wheels because of the higher stability and better traction. This contributes to a more stable setup, particularly in high-speed cornering and slow speed or at lower speeds due to the wider base given by the two rear wheels. It offers more grip and the ability to manage the changes in the road surface which are important for vehicles used in different terrains which makes it more suitable for stable application and usage, for example, the urban vehicles or the cargo ones. Further, it thrusts efficient weight distribution, which is critical for the optimum load bearing with the added benefits of a workable center of gravity. It provides a good compromise between the stiffness we need for our vehicle's intended use and general maneuverability which may be required in several driving situations, not to mention load-bearing capacity. In this respect, the proposed delta wheel configuration is consistent with the objectives of our vehicle design since it focuses on the key requirements such as stability, traction, and load-carrying capacity most relevant to practical scenarios.

Fig 2: Chassis in process

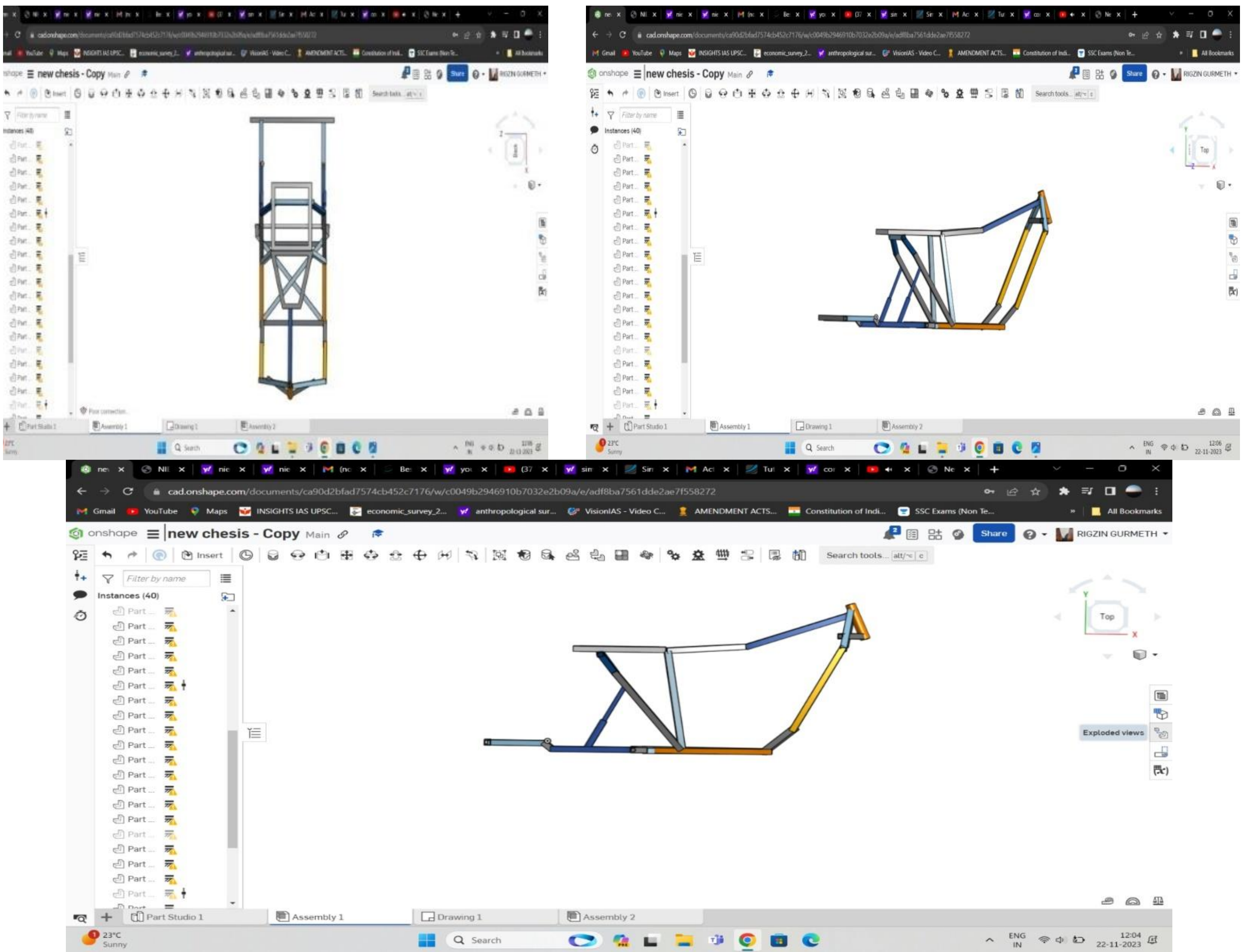


Fig 3: Chassis Design in on shape

Fig 4: Delta Configuration Wheel Arrangement

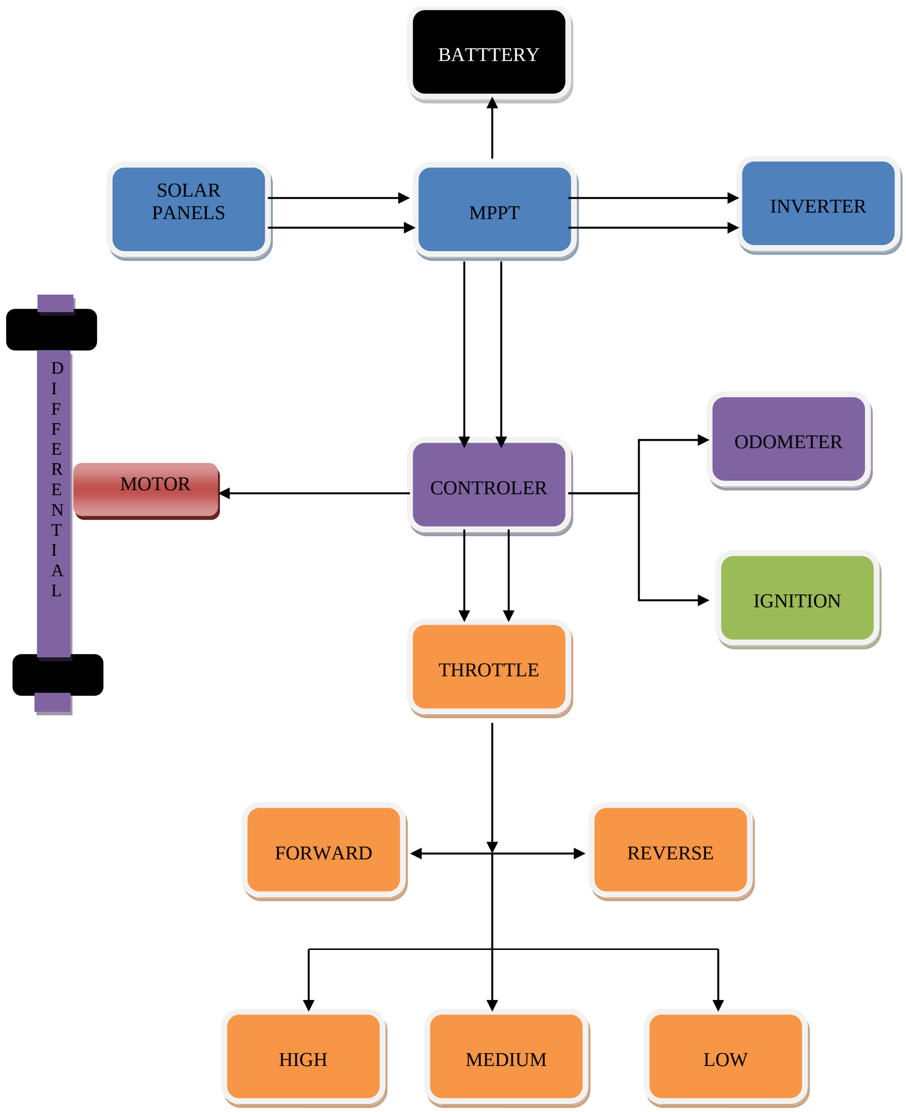


Fig.5 Block diagram

b) Solar panels

Renewable energy technologies such as solar panels are widely used as a reliable source of energy for many applications and uses because they are environmentally friendly. Making use of solar panels in vehicles enables them to tap solar energy to recharge batteries, and enhance their range or power add-on equipment in a sustainable manner thus reducing their dependence on external charging.

Power- 20watt

Voltage-12v

Dimension-

Type - Thin-film solar panel. The name ‘thin film’ clearly implies that in comparison to crystalline silicon, these panels are considerably thinner, and thus flexible, and lighter – ideal for use in curvy surfaces, or areas where larger solar panels cannot be used.

The lightweight nature of thin-film panels makes them easily integrated into a variety of vehicle designs. This flexibility allows for placement in non-traditional areas, achieving the most solar gain without adding excessive weight. Thin-film solar panels can be integrated to match the vehicle's aesthetics and make it look good apart from functional. This is particularly relevant to consumer markets where design is a major parameter for making any purchase decision. Crystalline silicon panels are more expensive to make, and thus purchase, than most thin-film technologies. This can also be reflected in the overall cost of integrating solar solutions into vehicles. Certain thin-film solar panels do quite well under low light or diffuse light conditions, meaning they are better at generating electricity in overcast or foggy conditions. This can be especially advantageous for sites that experience several cloudy days each year.

c) MPPT (Maximum Power Point)

In the context of solar energy, a power tracker is referred to as Maximum Power Point Tracking MPPT in solar photovoltaic systems. MPPT helps maximize the power produced by the photovoltaic arrays by adjusting the various system parameters so that the maximum power point is always obtained. These include the efficiency of the work, response to changing conditions and efficient charging of batteries. Functions of MPPT in SEVs Talking of MPSS technology in solar electric vehicles, this effectively controls the relationship between the solar panel interfaces, battery interfaces, and electric drive interfaces. Here’s how it functions: Persistent Voltage and Current Tracking: MPPT has to keep track of the voltage and current output of the solar panels and thus the load can be adjusted so that the panel is at the MPP irrespective of the changes in entrained parameters such as the intensity of sunlight or the panel’s temperature. Integration with Battery Systems: MPPT enhances the charging process hence giving room for storage of solar energy in the battery of a vehicle. This is especially true if one wants to keep your battery healthy in the best possible state and as long-lasting as possible.

Fig 6: Solar Panel

a) Solar cell efficiency calculations:

Single Solar Panel power = $20W$ (1)
Single Solar Panel voltage = $12V$ (2)
Single Solar Panel current = $1.6A$ (3)
Total Panel Connected in Series = 4 (4)
By multiplying equation (2) and (4) we get
Total Voltage = $12V$*4s
= $48V$ (5)
Total Panel Connected in Parallel = 2 (6)
Multiply equations (4) and (6) we get
Total solar cell = 4s*2p
= 8 cells (7)
Now multiply equation (1) and (7) we get
Total Solar power = 20w*8cell
= $160W$

b) Solar charging time calculation:

DOD (depth of discharge) = 100% (1)
Battery voltage = $48V$ (2)
Battery Ah = $40A$ (3)
Solar panel watt = 160w
Type of charging controller = MPPT
Solar panel current = 3.2 Ah (4)
Multiply equations (3) and (4) we get

$$\text{Charging time} = \frac{battery\ Ah}{panel\ Ah}$$

$$= \frac{40A}{3.2Ah} \quad (5)$$

Total Time Taken for Full Charging = 12.5 *hr (6)*

D) Battery (Lithium-ion)

There is therefore a need to look at the various types of batteries that can be found in EVs with each type having its useful as well as its disadvantages. Two examples of rechargeable batteries are Lithium-ion (Li-ion) and Lead-Acid batteries. However, Li-ion batteries are predominantly used in modern EVs due to several reasons: However, Li-ion batteries are predominantly used in modern EVs due to several reasons: They can hold more energy per unit volume enabling long driving distances with additional energy without considerably increasing bulk. Another advantage of lithium-ion batteries is the longevity or the relative number of charge-discharge cycles it can withstand before their capacity is diminished, thus serving the vehicle for quite some time. These factors include charging times that are normally faster than those used in charging lead-acid batteries, and low maintenance costs which add to the convenience. Besides, their ability to deliver power and efficiency is better, they provide high acceleration and optimum energy consumption. In the early years, they may be costly but present improvements in technology have ensured that their costs are gradually being offset while retaining these benefits. All these characteristics make lithium-ion batteries the most suitable for use in modern electric automobiles because of their efficiency, longevity, and performance as compared to lead-acid batteries. The negative electrode (anode, when the cell is discharging) and the positive electrode (cathode, when is cell is discharging) are prevented from shorting by a separator. The electrodes are connected to the powered circuit through two pieces of metal called current collectors. The negative and positive electrodes swap their Electrochemical roles (anode and cathode) when the cell is charged. Despite this, in discussions of battery design the negative electrode of a rechargeable cell is often just called "the anode" and the positive electrode "the cathode". The design of the battery pack gives an output of 48V and 40A with the cells arranged in 15 in series and 19 in parallel.

E. Battery Management System

The BMS serves as the brain of the battery system in solar vehicles, performing several critical functions:
Cell balancing: keeping every charge and discharge current of the battery pack balanced and prevent to overcharge or discharge any cell.
Voltage Monitoring: Daily checking the voltage of each cell to avoid the condition under which the battery is either overcharged or over-discharged since both conditions will damage the battery irreversibly.
1. **Temperature Monitoring:** Controlling the temperature of the battery pack and usage of measures against overheating of the battery pack or what is known as thermal runaway.
***a*. Optimal Operating Temperature:** Every battery has its own temperature range in which they are most effective and this ranges between 20°C to 40°C. Any deviation from this range of current puts the efficiency and capacity of the cells at a wash and hastens the wear of the cells.
b. Impact on Charging: Further, it is advised to charge the battery at higher temperatures because it leads to unwanted chemical reactions and degradation. As with low AC rates, charging at very low temperatures also results in lithium plating that diminishes the capacity and increases the likelihood of failure.

2. Temperature sensor in BMS

The BMS system employs different temperature sensors in which the most common are the thermostats for sensing the temperature of the battery cells and pack. These sensors feed real-time information to the BMS from where it controls everything to do with battery, its charging, discharging, and cooling.
Sensor Placement: Sensors are generally installed in close vicinity to the cells, the modules, and crucial components of the system to provide close to real-time coverage. In safety-critical applications, redundant or backup sensors may be added to provide an additional layer of safety, ensuring that, even if a primary sensor fails, the system remains protected. This ensures comprehensive coverage, minimizing risks of overheating or thermal runaway.

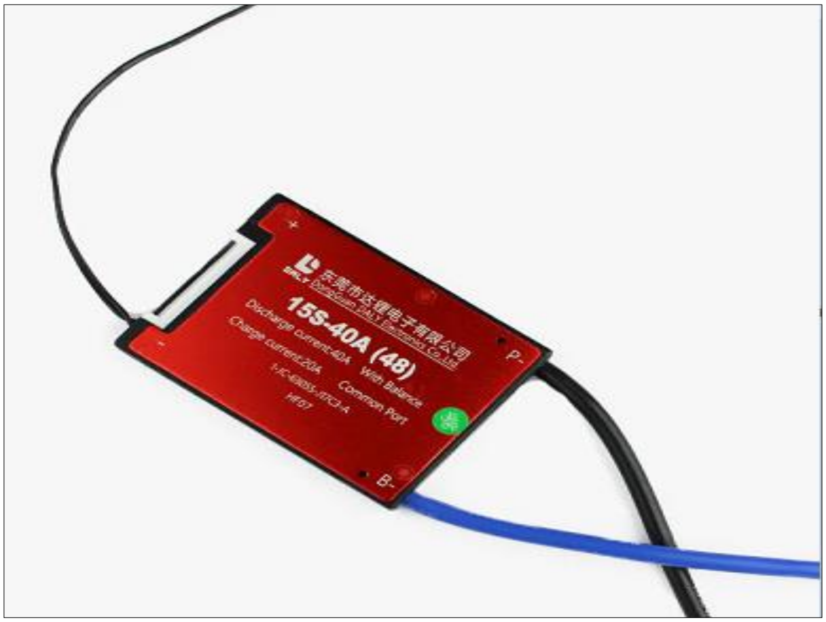


Fig 7: BMS

3. Connections

The BMS connects to various parts of the battery system and other external devices via several key connections:

I. **Positive and Negative Terminals:** The BMS is connected to the overall battery pack's main positive and negative terminals. These connections enable the BMS to monitor the pack's total voltage and provide protection features like over-voltage, under-voltage, and short-circuit protection.

II. **Cell Voltage Connections***:* These are individual connections between the BMS and each battery cell or group of cells (modules) for voltage monitoring. This allows the BMS to track the voltage of each cell to prevent overcharging, deep discharging, or imbalance between cells.

III. **Temperature Sensor Connections:** The thermistors or other temperature sensors connect to the BMS to monitor the temperature of the cells and pack. The BMS uses these connections to prevent overheating and mitigate the risk of thermal runaway.

IV. **Current Sensor Connections:** The BMS connects to a current sensor (often a shunt resistor or Hall effect sensor) to measure the current flowing into and out of the battery pack during charging and discharging.

V. **Balancing Connections:** For cell balancing, the BMS has dedicated connections to each cell or module. These allow the BMS to shunt excess energy away from fully charged cells, ensuring a balanced charge across all cells in the pack.

4. Battery Calculations

BMS = 15s and 40A

Total Battery in Series = 15 (1)

Battery Parallel Connected = 19 (2)

Multiply equation (1) and (2) we get

Total number of cells = 15*19

= 285 cells (3)

Discharge current = 40*A*

Charging current = 20*A*

Table 2: Specification of BMS

Balance current (m A)	30±5
Balance Detect Voltage (V)	3.5
Charge Current (A)	20
Charge Voltage (V)	54.75
Over Discharge Detect (V)	2.2±0.05
Over Discharge Release (V)	Off Load
Overcharge Detect Voltage(V)	3.75±0.05
Working Current (u A)	100
Working Temperature Range (℃)	-20 to 70
Cable size (AWG)	10
Height (mm)	10.6
Length (mm0	81.5
Width(mm)	60.6

Fig 8: Lithium-ion Battery

Table 3: Specification of Lithium-Ion Battery

Nominal Voltage	3.7V
Nominal Capacity	2600mAh (0.52A Discharge)
Internal Impedance	≤ 70mΩ
Discharge Cut-off Voltage	3.0V
Max Charge Voltage	4.20±0.05V
Rapid Charge Current 1	1.3A
Standard Charge Current	0.52A
Standard Discharge Current	0.52A
Max Pulse Discharge Current	2.6A
Weight	46.5±1g
Storage Temperature	During 1 month: -5 ~ 35℃ During 6 months: 0 ~ 35℃
Operating Temperature	Charge: 0 ~ 45℃ Discharge: -20 ~ 60℃

Bidirectional system

A bidirectional system in electric vehicles (EVs) is an advanced energy management system that enables power flow in two directions: Electric from the battery to the motor (to move the car) and from the motor to the battery or a different system, for example, the grid or home. The central focal point within this system would be the inverter as it is in charge of both electrical power categories which are direct current (DC) and alternating current (AC). The bidirectional character of this system makes the system more efficient and saves energy as well as puts the foundation of advanced technologies such as V2G and V2H in front of the people. In an average EV, the battery is used in storing energy in DC format. Engine, for example, propulsion, is mainly electric motor that is AC based. Hence, there is a need for the change of voltage levels, where one uses DC while the other uses AC in power transmission. Having a bidirectional inverter, this flow is two way where the vehicle is being driven, and the system also being able to take energy in, for example during the braking and supply it outside as well when required.

Two Primary Functions in a Bidirectional System:

Forward Energy Flow (DC-to-AC): This is the standard mode in which supply is directly given from the battery to the motor through the inverter. The feature that characterizes the inverter is its ability to convert the stored Direct Current [DC] power in a battery into the Alternating Current [AC] power necessary to energize the motor. This process makes the car to move or to be propelled Forward.

Reverse Energy Flow (AC-to-DC): In regeneration breaking or in other special external energy storage applications, the motor works like a generator and produces AC current. The inverter ch Rooevers this AC power into DC power that would be stored in the battery for the boost of the vehicle's energy efficiency, and its range.

The role of Inverter

The inverter is the central device in bidirectional systems because of its responsibility for the indispensable duty of maintaining the conversion of electrical energy between DC and AC. The more important component lost from the electrical architecture of the vehicle when the inverter is removed is the essential operation of the EV motor as well as the battery power that cannot be tapped for other uses.

DC-to-AC Conversion (Driving Mode): The inverter gets the DC from the EV battery storage and converts it into AC and the uses the AC to charge the electric motor. AC power is always used with motors, especially induction motor and permanent magnet motors require AC supply. The inverter does not only control the kind of the current flowing through the electrical circuits but also the magnitude of current in forms of frequency and voltage which directly influences the motor's speed and torque.

AC-to-DC Conversion (Regenerative Mode): In the regenerative braking mode, one gets the feeling that the entire affair is more like using the motor as a dynamo in the braking process where it generates a little bit of AC current as the car slows down. The inverter is used to transform this AC power back into DC and this is sent into the battery; in this process, electrical energy that would have been wasted during the process of breaking, is regained.

Power Flow and Control

Forward Power Flow (Battery to Motor): Energy from the battery is cleanly converted to AC form for use in powering the motor. This process has to be very accurate since the inverter regulates both voltage and the frequency of current supplied to the motor. From the above factors, it is observable that they can be changed by the inverter and hence, can be used for the regulation of speed and torque of the motor in as much as driving demand is concerned.

Reverse Power Flow (Motor to Battery): While the regenerative braking or energy recovery is taking place the flow is in the opposite direction of what is described above. This AC is then rectified by the inverter back to DC then the DC is either fed back to the battery or to re-charge the battery in the system. Charging in both directions is necessary to provide maximum effectiveness and the greatest possible range of the car.

Uses of Bidirectional inverters in EVs

Bidirectional inverters are not only useful for driving vehicles, but hold great potential in power storage and conversion as well. Two particular technologies under this kind are called vehicle to grid (V2G) and vehicle to home (V2H) whereby the EV can engage with other energy systems.

Vehicle-to-Grid (V2G): A V2G system enables the provision of power by the EVs into the electricity utility in the same way they draw it when required. This bidirectional inverter takes stored Direct Current DC power in the EV battery and transforms it to an alternating current AC for connection to the grid.

Vehicle-to-Home(V2H): In using V2H applications, the EV can power up a home or building in the event of a power failure. It can convert DC power from the battery of the automobile to an AC power in case of a power fail or during a time of high costs of power in order to operate the home appliances, the lights and all the electrical systems in a home.

Vehicle-to-Load (V2L): This means that using the stored energy in their battery, an EV can directly operate other electric devices. This can be helpful if working off grid or outdoors as the bidirectional inverter in the car supplies AC power to run devices or tools.

Energy Recovery Through Regenerative Braking

A key feature of bidirectional systems in EVs is regenerative braking**,** which allows the vehicle to recover kinetic energy that would otherwise be wasted. During braking or deceleration, the electric motor switches to generator mode, capturing mechanical energy and converting it into electrical energy. This energy is then sent to the inverter, which converts it from AC to DC and stores it in the battery.

Inverter

Here, the inverter is used in converting the DC power obtained from the lithium-ion battery pack of the EV to useful AC power needed to run the vehicle's electric motor and, if necessary additional loads. The basic idea of an inverter is its switching circuits which are used to alternatively switch ON and OFF in order to generate an AC output in square wave or sine wave form from an DC input. The conversion process typically takes place in two stages:

DC-AC Conversion (Inversion Stage): During this stage, either a Mosfet or IGBT, full control switches, are used to turn on and off the DC input voltage to produce a pulsed or square waveform. The inverter regulates the time at which the switches switch to perform an operation that creates the to and fro motion like an ac waveform.

Waveform Shaping (Filtering Stage): In order to get a smoother signal which is normally required by most applications, filters are used to convert the square wave. Filtered waves are created by using low pass filters incorporating inductors and capacitors to the square wave and give out sinusoidal wave.

The half-bridge inverter configuration: The half-bridge inverter is one of the simplest inverter topologies and consists of two switching devices, typically MOSFETs or IGBTs, that alternately switch the load between two voltage levels: positive and negative. In this configuration: There is a three-phase inverter; six MOSFETs are used two for each phase. These MOSFETs are arranged in pairs across each of the three phases in a half-bridge configuration.

The MOSFETs are driven alternately: the former light can be ON while the latter is OFF, and at the same time the former can be OFF while the latter is ON. This creates an output voltage in turn with ac amplitude across the load.

Role of MOSFETs in Inverters: Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) are widely used in several inverters as switching devices because they have high switching frequencies and low on-resistance. MOSFETs offer high and efficient power control and conversion where signal switching occurs at high frequencies such as in inverters.

Drivers and MOSFET IRF3205 in Half-Bridge Inverters: The parameters of IRF3205 are required for its application in high current power electronics circuits like inverters because of features such as low on-resistance.

Operation in a Half-Bridge Inverter: In half-bridge inverter, Q1 and Q2 that are the IRF3205 MOSFETs are periodically activated and turned OFF to produce the AC voltage. When one MOSFET is turned ON, then the current flows through the load to produce a positive or negative half cycle of an AC waveform. The high switching speed of the IRF3205 makes the inverter to be very efficient at high frequencies hence reducing on the losses that occur while switching the device between ON and OFF state. The IRF3205 switches ON and OFF when it receives the gate drive signals it needs in order to work. The gate of the MOSFET is generally controlled by the PWM signal controlling the transition cycles of the switching operations. It is crucial that an appropriate gate drive circuit is used so that the MOSFET is turned all the way on or off in saturation or cutoff regions minimize heat produced by partial switching.

In a half-bridge inverter circuit, two IRF3205 MOSFETs are placed in series between the positive and negative terminals of a DC supply:

Upper MOSFET: Provided conductive contact with the positive terminal of the DC source.

Lower MOSFET: Connected with the negative terminal of the mentioned direct current source.

Load: Connected between the midpoint of the two MOSFETs and the ground point similarly the negative terminal of the power supply.

When the upper MOSFET is switched ON the load voltage becomes positive, and when the lower MOSFET is ON the load voltage becomes negative thereby creating a to and fro voltage across the load to create an AC voltage wave form. Correct gating of the two MOSFETs results in superior crossover control of the output waveform at the desired frequency (i.e., 50Hz/60Hz in an AC supply system).

Fig 9: Inverter

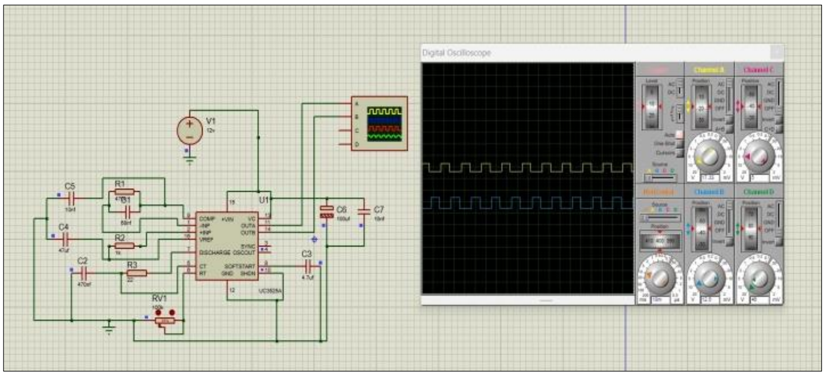


Fig 10: Sine Wave

Electrical Characteristics

Table 4: IRF3205 Specifications

	Parameter	Min	Typ	Max	Units	conditions
V(BR)DSS	Drain-to-Source Breakdown Voltage	55	_	_		VGS = 0V, ID = 250µA
ΔV(BR)DSS/ΔTJ	Breakdown Voltage Temp. Coefficient			0.057		Reference to 25°C, ID = 1mA
RDS (on)	Static Drain-to-Source On-Resistance					VGS = 10V, ID = 62A
VGS (th)	Gate Threshold Voltage	2.0	-	4.0	V	VDS = VGS, ID = 250µA
gfs	Forward Transconductance	44	-	-	S	VDS = 25V, ID = 62A
IDSS	Drain-to-Source Leakage Current	-	-	25	µA	VDS = 55V, VGS = 0V
		-	-	250		VDS = 44V, VGS = 0V, TJ = 150°C
IGSS	Gate-to-Source Forward Leakage	-	-	100	nA	VGS = 20V
	Gate-to-Source Forward Leakage	-	-	-100		VGS = -20V
Qg	Total Gate Charge	-	-	146	nC	ID = 62A
Qgs	Gate-to-Source Charge	-	-	35		VDS = 44V
Qgd	Gate-to-Drain ("Miller") Charge	-	-	54		VGS = 10V
td(on)	Turn-On Delay Time	-	14		ns	VDD = 28V
tr	Rise Time	-	101	-		D = 62A
td(off)	Turn-Off Delay Time	-	50	-		RG = 4.5Ω
tf	Fall Time	-	65	-		VGS = 10V
Ld	Internal Drain Inductance	-	4.5	-	nH	Between lead, 6 mm (0.25in.) from package and
Ls	Internal Source Inductance	-	7.5	-		center of die contact
Ciss	Input Capacitance	-	3247	-	pF	VGS = 0V
Coss	Output Capacitance	-	781	-		VDS = 25V
Crss	Reverse Transfer Capacitance	-	211	-		f = 1.0MHz
EAS	Single Pulse Avalanche Energy	-	1050	264	mJ	IAS = 62A, L = 138µH

Source-Drain Ratings and Characteristics

Table 5: Specifications

	Parameter	Min	Typ	Max	Units	conditions
Is	Continuous Source Current	-	-	110	A	MOSFET symbol showing the integral reverse p-n junction diode
Ism	Pulsed Source Current	-	-	390		
Vsd	Diode Forward Voltage	-	-	1.3	V	TJ = 25°C, IS = 62A, VGS = 0V
trr	Reverse Recovery Time	-	69	104	ns	TJ = 25°C, IF = 62A
Qrr	Reverse Recovery Charge	-	145	215	nC	di/dt = 100A/μs
ton	Forward Turn-On Time	-	-	-	-	Intrinsic turn-on time is negligible (LS+LD dominates turn-on)

Fig 11: Controller

Opening system in EV

The idea of constructing the opening mechanism of the EV by the Parallel System of multiple, independent access methods, offers redundancy. This is done in a way that the user has many choices to use to unlock and gain entry into the vehicle. This way each method can serve as backup, assuming that another system is not functioning, it enhances security as well as reliability. For example, one can use a key fob, an RF 315MHZ, Bluetooth or directly use the touch without the key.

Key System: The oldish key system is one of the most elementary ways of accessing a car still popular among the current EVs. It has either mechanical key or smart key embedded on its body. In many cases, the smart key uses signals to transmit information with the car's central locking system in real time. When the key is in a particular range, the vehicle unlocks on its own. The smart key system also normally incorporates the push-button start for enhanced ease of use as compared to the starter key installation.

Radio Frequency (RF) Remote System with Microcontroller: For implementing RF based remote control by Arudino, one require an RF transmitter and RF receiver module where remote (key fob) and the vehicle onboard systems will be able to communicate to each other, wirelessly.

RF Transmitter and Receiver Modules: Often a 433 MHz RF module is used, which is used for transmitting and receiving radio signals. This device is in a key fob OR a remote and sends signals to the receiver inside the EV's control system. From the given signal, the Microcontroller manages the functions related to the lock/ unlock of the actuators.

Working: The transmitter transmits different encoded signals, which should be decoded through a decoder like the HT12D/HT12E to the receiver. These signals are then received by the Microcontroller that in turn turns on or off the locking system, starter motor or unlocking and other control systems. For instance, pressing the button of the remote prepares a signal that reaches the receiver part; the Microcontroller then decode the signal and gives the right response which can either be to open or shut the doors.

Advantages: RF systems are inexpensive for keyless entry and the use of an Microcontroller means it can be integrated easily and adapted. The range of these RF systems is normally in the region of about 100 metres, depending on conditions.

Radio Frequency and Identification (RFID) with Microcontroller: RFID technology can be interfaced with Microcontroller using RFID modules, including MFRC522 which is used for closer access in instance, in automotive applications.

RFID Module: The MFRC522 RFID reader module is an integrated RFID reader which is capable of reading RFID cards or tags only if the cards or tag is placed nearby to the reader, to be more precise, the proximity of the card or tag must be around a few centimeters. The Microcontroller gets the datum from the RFID tag and analyzes the ID to allow the user into the automobile.

Working: The RFID tag or card have an identification number. When the card is inserted near the RFID reader, the module relays the tag ID to the Microcontroller port. Notice that the ID read by the Microcontroller is compared to a list of allowed IDs stored somewhere within the Microcontroller. If the given tag is authorized, the Microcontroller handles the opening mechanisms, for example, the vehicle's doors, or the ignition.

Advantages: RFID-based systems are reliable and comfortable for access control especially for proximity control. This is quite hard to hack since RFID works at close range. The system may also be enhanced regarding other functionalities, namely recording the access attempts or the interface to a smartphone app.

The Use of Microcontroller-Based System in EVs: Combined with a vehicle access system, the three RF, RFID, and Bluetooth all using a Microcontroller as the base. Here's how they might work together in an electric vehicle:

Microcontroller as the Control Hub: Microcontroller is the control system that communicates signals from Radio Frequency, Radio Frequency ID, and Bluetooth ensembles. It is noteworthy that each of the systems is able to produce actions like unlocking of the car or starting of the engine on its own.

Redundancy and Flexibility: If one of the systems is out of order or the corresponding access tool is missing, there are other systems established (Bluetooth or RF remote) to operate the vehicle. This flexibility improves on user convenience and guarantees uninterrupted use of the internet.

Security: For instance, applying these technologies at the same improves the general security of the vehicle. For example, the system could be programmed to allow only those actions or operations which were authorized with RFID and Bluetooth identification numbers; that means, there would be a two-factor control added to the system.

Smart Proximity Sensor

Proximity sensors are one of the essential components of the contemporary EV because they offer immediate information on the environment in question to the vehicle systems and drivers with regard to safety during maneuvering, especially in parking zones or at low-speed cruising. These are used in sensing the surrounding environment in order to offer alarms or even trigger pre-installed actions that will help the vehicle avoid an object or object on its path. Some of the most used are proximity sensors with ultrasonic and infrared (IR) features in most EVs. Ultrasonic sensing involves the use of high frequency sound waves that bounce to the nearby objects while I.R sensing is based on heat radiation or the measure of distance of the nearest object using Infrared light.

Obstacle Detection: Proximity sensors are installed on the front and at the rear of most cars, and sometimes on the sides for utmost coverage. The others send signals continuously, and the alerts are generated once an object is within a particular area of proximity. The distance between the vehicle and the object is determined by the time taken to receive back the signal from the sensors.

Parking Assistance: Smart Proximity sensors are predominantly required for automated parking or parking assistance systems. These systems assist the driver by identifying objects in parking zones during parking operations and either, providing key indications to the driver or even controlling the steering mechanism to maneuver into the confined lots. EVs employ these sensors for the fully automated parking system where the vehicle steers, accelerates, and brakes to park on its own.

Integration with EV Systems: Audio Alerts: WE found out that, when an obstacle is sensed, the *signal* through the speakers is given.

Functional Dashboard Tablet

A Functional Dashboard Tablet in an EV serves as the master control of all the relevant information that the driver needs during the management of the vehicle. It not only shows typical dynamic parameters but also universal vehicle parameters and different management systems and controls. The designs of EV dashboards are tablet-mounted, and this presents a very personal and engaging centre console that would provide the driver with all the relevant information they may need.

Essential Metrics Displayed:

Speed: A quick reference about the speed of the car is indicated real-time on the strip of the dashboard tablet especially when the digits are used instead of diagrams. In most modern vehicles, this system is a good one even in electric vehicles and has better accuracy and response to electronic sensing rather than mechanical ones like the speedometer.

Distance and Range: The dashboard also shows other vital data pointing to the range of the car. This is because, like most cars powered by batteries, it is important for a user to understand the approximate number of miles a car can cover with the available charge. The range meter constantly changes in line with prevailing driving scenarios such as speed range, road gradient, and consumption by other onboard systems.

Battery Charge Status: Another useful measure is battery status where the icon with the number inside indicates the remaining capacity of the battery in percent. Most systems also have the ability to break energy usage down even further and show which systems (or climate control, lighting, etc.) are using the most energy.

Throttle System

The throttle in an EV is meant to cover the amount of power electrical power to the motor for controlling the vehicle's speed. While internal combustion engine vehicles require a mechanical throttle to control the supply of fuel/air inside the engine, EVs have ETC –the driver's input signal is processed through the motor controller to modulate power delivered to the electric motor. A throttle controls the forward or backward direction of the car and the high, medium, and low options.

Forward Control: If the driver presses on the accelerator or moves the accelerator forward the car is moved in a forward direction. The throttle relays a signal to the motor controller and as a result, more power is supplied to the electric motor.

The general speed of the vehicle rises with the increase of power supplied but how much accelerator is pressed is determined by the driver.

Reverse Control: Every EV has a reverse switch or a button on the deck where the driver can change the direction of the vehicle. When the driver engages in reverse mode, the motor controller switches the flow of current through the motor to cause the motor to turn in the wrong direction and thereby moving the vehicle backward.

High, Medium, & Low-Speed Control

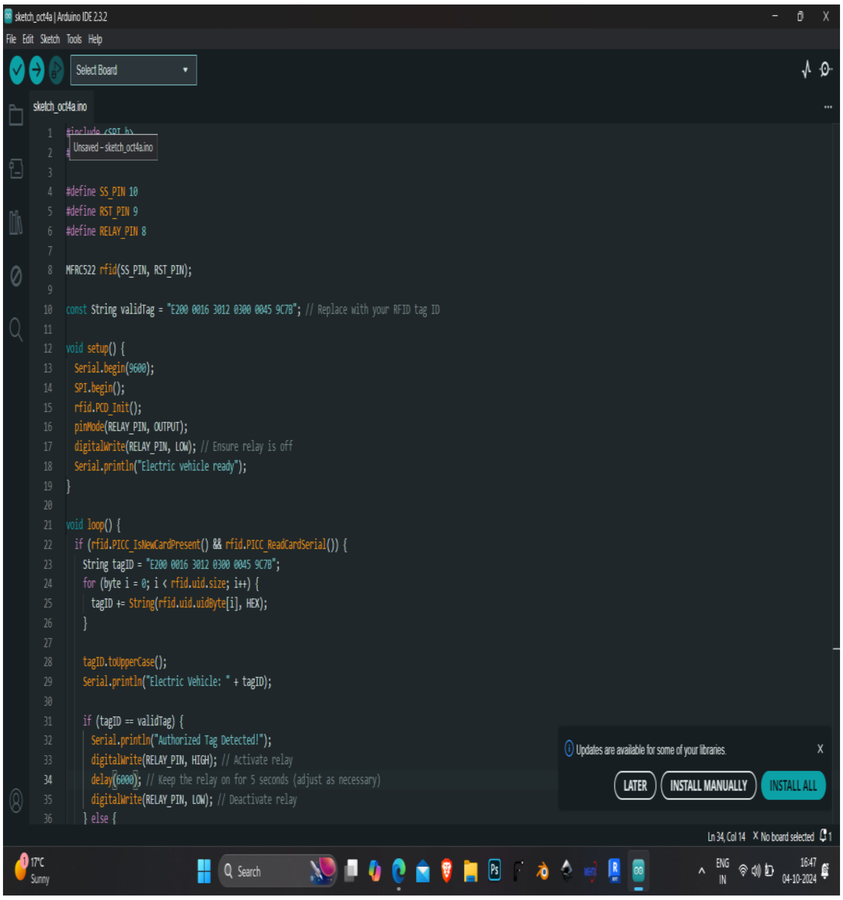
Another feature noticeably found in many EV throttle systems, and which is aimed at giving drivers better control of the car's speed and energy consumption, is speeds settings which may comprise three; high, medium and low. These settings enable the driver to select the required speed range fitting the current driving situation and to attain maximum performance while simultaneously consuming as little energy as possible.

Low-Speed Mode*:* Low-speed mode is normally employed alongside conditions that need delicate handling, including when parking, driving in a busy area or in slow-moving traffic.

In this mode, the rate at which the car accelerates is also low and now when the throttle is applied the car gains speed at a slow rate. The output power to the motor is cut by half or even less, which assists in terms of energy saving and has finer control at low velocities. Low-speed mode requires low energy consumption and in turn, has a deep impact on the battery hence proving to be economical to the vehicle. They are specifically suitable for city driving because most of the driving is done with erratic speed changes.

Medium Speed Mode: Medium-speed mode falls under the family of speed modes that can provide a set amount of acceleration as well as speed which can be used in normal conditions carried on roads; especially city and limited highway speeds. In this mode, the response of the throttle pedal is sharper than when it is in low-speed mode is which makes it easier for the vehicle to increase its speed as wished. The motor controller generally supplies moderate voltage to the motor whereby its performance is considered.

High-Speed Mode: The High-speed mode is for the conditions where higher performance is needed as with highway driving, overtaking, or driving in areas with less traffic intensity. This is in contrast to normal mode where the throttle pedal shows the motor controller from the accelerator pedal and provides full power to the electric motor making the vehicle move faster to a faster speed range. This mode offers the driver the most exciting way of driving the vehicle. High-speed mode drains power from the battery faster thereby reducing the range a car can cover. It is commonly applied where frequent changing of gears and operating at high velocity is needed, although its application erodes battery endurance.



Brushless dc motor

A Brushless DC (BLDC) motor is a type of electric motor that operates using a direct current (DC) power source but doesn't rely on physical brushes and a commutator to control the flow of electricity, unlike traditional brushed DC motors. When power is supplied to the stator windings, it generates a rotating magnetic field. The permanent magnets on the rotor interact with this field, causing the rotor to rotate. BLDC motors exhibit higher efficiency, better torque-to-weight ratio, and faster response times compared to brush motors, making them suitable for applications requiring precise control and high efficiency.

Calculations:

Power = 2000W

Suppose Avg Power Taken by the Electric Vehicle = 1000W

Ampere drawn = $\frac{1500w}{48v}$

= 31.25A

So as the Total Battery Capacity = 40A

= $\frac{40Ah}{31.25A}$

= 1.28h

Avg speed of electric vehicle = 60*km/hr*

Distance covered in 1.28*km*

= 60*1.28

= 76.8 *km*

DC TO DC Converter

In our project, the DC/DC converter is chosen for its ability to efficiently manage and convert electrical power between different voltage levels within the electric vehicle system. This converter ensures compatibility among various components, optimizes energy utilization, and facilitates seamless integration of diverse electrical systems. Its compact size and weight also contribute to efficient space utilization within the vehicle while maintaining optimal performance and reliability.

Headlight and Indicator

We have used fog lights as headlights to enhance visibility in low-light and adverse weather conditions. Positioned lower on the vehicle, these lights emit a wide, focused beam that reduces glare and improves road visibility. By opting for LED fog lights, we maintain energy efficiency, which is crucial in electric vehicles, ensuring optimal performance without compromising the vehicle's range. This design choice prioritizes safety and practicality, particularly in situations with limited visibility. The indicator system uses LED technology for clear, efficient signaling. Indicators, including turn signals and hazard lights, communicate the driver's intentions to other road users. Advanced features like auto-cancel, sequential signals**,** and integration with blind spot detection and lane-keeping assist enhance functionality. These lighting systems contribute to energy efficiency and safety while aligning with the EV's focus on optimizing performance and reducing energy consumption.

Fig 13: BLDC Motor

Fig 14: Fog Headlights **Fig** 15: Indicators

Table 6: Comparison

Feature/Specification	Paper 1: Bidirectional DC/DC Converter System for Solar & Fuel Cell Powered Hybrid EV	Paper 2: Solar Powered Electric Vehicle	Paper 3: Design, Analysis, and Electrification of Solar-Powered EV
Power Source	Solar panels (thin-film) with bidirectional technology (V2G/V2H)	Solar and fuel cell hybrid system with bidirectional DC/DC converter	Solar-powered with MPPT for energy optimization
Chassis Design	Delta configuration (1 front, 2 rear), designed with SOLIDWORKS and ANSYS for stability	No specific chassis design discussed	Lightweight chassis (no specific design tool mentioned)
Energy Efficiency	High due to solar energy utilization with MPPT and bidirectional charging	Enhanced efficiency via hybrid fuel cell and solar system	Efficiency via MPPT and energy management systems
Bidirectional Technology	Includes bidirectional power transfer (V2G, V2H, V2L)	Bidirectional DC/DC converter for fuel cell and solar energy transfer	No bidirectional technology
Battery Type	Lithium-ion battery (48V, 40A)	Hybrid system of fuel cells and batteries	Lithium-ion battery for solar energy storage and management
Wheel Arrangement	Delta configuration (1 front, 2 rear) for better stability	Not specified	Standard four-wheel configuration
Regenerative Braking	Yes, uses regenerative braking for energy recovery	No mention of regenerative braking	Yes, regenerative braking included
V2G/V2H Capabilities	Yes, supports Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H)	No V2G/V2H capabilities	No V2G/V2H capabilities
Solar Panel Type	Thin-film solar panels (lightweight and flexible)	Standard solar panels with fuel cell integration	Photovoltaic panels with MPPT

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