A Peer Review of Hybrid Electric Vehicle Based on Step-Up Multi-input Dc-Dc Converter and renewable energy source

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Abstract. Due to the rapid increase of environmental pollution caused by automobiles. To decrease pollution and to save our resources, there is an alternator to use an electric vehicle instead of a gasoline engine. The main drawback of a gasoline engine compared to the electric vehicle can pollute noise efficiency durability. When it comes to durability, efficiency, and acceleration capabilities of electric vehicles, they are more impressive. The electric vehicles involve HEVs and BEVs. Generally, ultra-capacitor, solar Photovoltaic (PV) system, batters, regenerative braking systems and flywheel are utilized in HEVs as energy storage devices. All energy storage devices are linked to this distinct dc-dc converter scheme for raising input sources' voltage. In the last few decades, most HEVs have incorporated multi-input converters in order to enhance their reliability and efficiency. There are several distinct multi-input dc-dc converter schemas utilized in HEVs. This research discusses their current and future trends as well as energy storage devices.

Keywords - Hybrid electric vehicle, dc-dc multi-input converter, solar PV energy, ultra-capacitor and Energy storage systems etc.

1. Introduction

The electric vehicles the replacements for the internal combustion engines as they are polluting atmosphere, creating a lot of noise and not as efficient as electric vehicle. When compared to an ICE (internal combustion engine), which generates power by burning a mixture of gases and fuel, an electric vehicle is powered by electric vehicle motors. As interest in electric vehicles has grown over the past several decades due to the rising carbon footprint along with environmental significances of fuel-based vehicles [1] [2]. The concept has been around for quite some time. The electric vehicle is of many type HEVs, hybrid electric vehicle is more renewable in terms of durability, efficiency along with acceleration capability [3] [4] [5]. According to the power supplied to the drive train, power sources can be fuel cells, ultra-capacitors, etc., HEV can categorize in various forms including Parallel hybrid vehicle, series hybrid vehicle, series-parallel hybrid vehicles [6] [7].

The utilization of batteries in power frameworks is indispensable for steadiness also, the consistent stockpile of force. Force frameworks with power capacity gadgets such as ultra-capacitors and batteries require bidirectional converter geographies with higher VCR (Voltage Change Proportion). [8] [9] a converter having high VCR, LVS (Low-Voltage Side) inductor current, straightforward control is planned. The design is extensible past 2 data sources. In Brilliant Lattice (SG), high productivity bidirectional dc-dc converters were proposed [10] [11] [12] [13]. In a bidirectional lift converter, which has the concurrent force drawing ability is examined yet for bidirectional activity, additional switches are embedded in geography. Considering the proposed writing survey, another and straight forward lift multi-input single output converter is suggested. The converter introduced a straightforward design of lift converter, hence empowering us for utilizing few essential lift converter conditions. The given proposed converter can bestretched out to a discretionary number of information sources as well as yield ports. We present a multi-input single output DC-DC converter for use with hybrid solar PV, ultra-capacitor, and battery systems. This may supply power to a load from a variety of distinct energy sources, all at the same time and in various ways. The multi-input converter scheme is one of a kind because it allows the
integration of more than two power sources with diverse power along with voltage ratings. Plug-in HEVs are relatively new as well as emerging technology in transportation sectors and power drain of the energy sector. The vehicles are called as extended-range electric vehicles, and they have an ICE and rechargeable battery pack. Once the battery is depleted by ICE, the HEV runs on electric power until the battery is recharged. HEVs utilizes less fuel along with emits less emissions. Convention vehicles is fuel consumption is more compare to HEVs (about 40 to 60 percent less) [14] [15] [16]. This expose is divided into seven parts. After this introduction, we will learn about various kinds of electric vehicles, as well as their power train designs are defined in segment forms of electric vehicles. Various DC-DC converters with multiple inputs topology and their control strategy utilized in electric vehicles are discussed. Multi-input DC-DC converter topology along with DC-DC converter’s Control procedures. The future scope as well as conclusions are included in the section of the future scales and conclusions [17].

2. TYPES OF ELECTRIC VEHICLES

There are four type of electric vehicles like BEVs (Battery electric vehicle), HEV, PHEV (Plug-in Hybrid electric vehicles) and Fuel cell electric vehicles.

2.1. Battery electric vehicle

This type of vehicle is completely controlled by power in BEVs and doesn't have any gas tank for storing extra fuel, therefore BEVs are additionally known as undefined BEVs comprise of huge battery- powered batteries for controlling the vehicles and they don't discharge any unsafe gasses to the climate [18]. The battery can be re-energized from network or some other outside power source by utilizing an attachment [19]. The drive train design of BEVs is extremely straightforward as displayed in Fig. 1. Furthermore, vehicle’s weight is additionally low. The principal necessity in BEVs is a high-force footing engine that decreases the vehicle’s effectiveness. BEVs are reasonable for brief distance, pause and run situations. The significant disadvantages of BEVs are re-energizing time as well as battery the executives. Tesla Model S, Nissan LEAF, BMW i3 Passage Center Electric, are instances of BEVs.

2.2. Hybrid electric vehicles (HEV)

Combination of convectional vehicles and combustion IC engine (ICE) by using more energy density of petroleum fuels give good parameters and long range operation. The main limitation of ICE is economy of poor fuel also environmental pollution [20] [21] [22] [23].

The reasons of,
- By compared with real operational parameters the fuel efficiency parameters of engine not matched.
- A vehicle operating in urban area K.E dissipation occurs.
- While stop and go processes low level of Hydraulic efficiency occurs.

Further battery powered electric vehicle (EV) high energy efficiency and zero pollution. Moreover, combination of ICE engine and battery electric vehicle is high preferable, because of combination use of ICE techniques and good established modern power electronics.

Working Principle of HEVs

Especially, any type of vehicle requires
- Produced sufficient power
- Dissipated sufficient amount of energy dependson driving range.
- High efficiency and low emission ofenvironmental pollution.

Generally, Hybrid electric vehicle has two /more power sources (gasoline/diesel) and energy converters (Battery-electric motor system) are known as Hybrid electric vehicle. A HEVs with electrical train power is known as Hybrid electric vehicle.

For recapturing parts of braking energy, which is heat transfer in ICE vehicles, a hybrid drive train generally has converter and bidirectional power source. Another is either unidirectional or bi-direction. The following HEV Patters:
- The load is powered only by one of the IC engine's power trains.
- Power is delivered to the load solely by electrical power train 2.
- At all ideal time both power trains 1 along with 2 delivers the power.
- Electrical power train 2 receives power energy from load.
- The Electrical power train 2 receives power energy from IC engine power train 1.
- At ideal time Electrical power train 2 charged power from IC engine power train 1 along with load.
- IC engine power train 1 distributes power energy to Electrical power train 2 and load at ideal time.
- IC engine power train 1 being transfers power to the Electrical power train 2 whereas Electrical power train 2 transfer power to load.
- IC engine power train 1 transfer power to the load also load transfer power to the Electrical power train 2.

**Type of HEV**
- Parallel hybrid
- Series hybrid
- Dual mode HEVs (Series-Parallel HEVs)

### 2.2.1. Series hybrid Electric vehicles:
The series hybrid train is drive train having two energy sources feed a single electric motor and its drivers vehicle [24] [25] [26] [27]. Fig. 1 shows the series hybrid drive train. The unidirectional power source in which unidirectional power converter is an IC engine is conducted with generator and generator’s output to power converter. The bidirectional power source is an electrical power (battery, PVs systems, and ultra-capacitor) linked to the bus. The power converter is linked to the traction electric motor. Alternatively, this motor can be controlled by a generator and a motor in reverse and forward directions of motor rotation. [28] [29] [30].

![Figure 1. Series hybrid electric vehicle.](image)

**Operation modes of series hybrid electric vehicle:**
- **Step 1:** Pure electric mode: vehicle is drive only by the battery when IC engine is turned off
- **Step 2:** Pure engine mode: when batteries either charged or draw any power from drive train, the traction power of the vehicle are regenerating from the IC Engine-generator. The electric machines work as electric transferred from an engine to drive wheels.
- **Step 3:** Hybrid mode: throughout time of deceleration / braking, electric motor performs as generator, which changes K.E of wheels in to electric energy it is utilized to the battery charging.
- **Step 4:** Battery charging and Engine traction mode: The generator of the engine produces power for charging batteries along with driving vehicle.
- **Step 5:** Regenerative braking mode: When an engine generated is switched off along with motor traction as run as generator, the generated power is making use for charging batteries.
- **Step 6:** Battery charging mode: Motor traction obtains no power while engine generator charger the battery.
- **Step 7:** Hybrid Battery charging mode: both motor traction and engine generator act as generator to motor charging batteries.
2.2.2. **Parallel hybrid Electric drive trains:**
As demonstrated in fig. 2,[31] [32] [33], the electric and motor engine work together for generating the force that moves wheels in vehicles with equal crossbreed drive systems.

*Power flow control in parallel hybrid electric vehicle:*

**Step 1:** Through the full throttle acceleration and startup process. Together EV& ICE divides the power output to drive the vehicle. The percent ago power showing between the EV&ICE as 20% to 80%.

**Step 2:** Through the stand and driving, the available traction power is delivered/ distributed by the ICE alone the electrical motor should be in off mode.

**Step 3:** Through the processes of deceleration or braking, the electric motor set as generator for changing the battery by power converter.

**Step 4:** Under low level load situation the traction power transferred by the ICE also ICE charge the after by the electric motor.

![Figure 2. Parallel hybrid electric vehicle.](image)

2.2.3. **Series- Parallel Hybrid Electric vehicle:**
Fig. 3 represents the Series-parallel HEVs, the structure is generally integrated having series and parallel HEVs features. Moreover, this structure requires an auxiliary planetary gear unit and electric machine to making the control complex.

![Figure 3. Series- Parallel hybrid electric vehicle.](image)

3. **ENERGY SOURCES OF HYBRID ELECTRIC VEHICLE**

3.1. **Fuel cell:**
Fuel cell is the device, which produces energy by chemical processes. Anode along with cathode are the two electrodes of a fuel cell. The electrodes are where the electricity-generating process takes place [34]. An electrolyte transfers charged particles from one electrode to the other, and a catalyst can speed up the process at the electrode in a fuel cell as well Hydrogen is used as a fuel. Fuel cells, on the other hand, require oxygen. Most of the oxygen and hydrogen used in power generating eventually combine to make water, which is a non-polluting byproduct [35] [36] [37].

3.2. **Regenerative braking system:**
An RBS is a kinetic energy recovery system that transforms moving objects' kinetic energy into potential energy or stored energy in order to decrease vehicle's speed and therefore improve fuel efficiency. Such
systems are referred to as kinetic energy recovery systems. There are many energy conversion methods in RBS, such as hydraulic, electromagnetic, flywheels, and springs. Currently, a hybrid RBS with an electromagnetic flywheel has also been developed. For each form of RBS, distinct energy conversion or storage technologies are used to achieve various levels of efficiency and applicability for that type of RBS. [38]. RBS is installed along the transmission system or on drive wheels of the vehicle and inhibits the movement of wheels under the action of a magnetic field or a magnetic field. Mechanical torque. When braking, these motion suppression mechanisms enable for energy to be created, as opposed to friction brakes, which are inefficient since they convert kinetic energy into heat. In order to accommodate the maximum load rate of energy storage system, braking force of RBS is restricted. As a result, when heavy braking is necessary, a classic friction brake system is needed for ensuring the vehicle’s safe functioning during the braking process. In addition to lowering fuel consumption, RBS can also lower the overall braking stress placed on the vehicle's friction brakes, resulting in less wear on the brake pads. RBS is utilized in almost all hybrid electric as well as electric vehicles. Moreover, public transportation for example bullet trains and buses utilizes RBS for reducing environmental impact of transportation fleets along with save money [39].

3.3. Photovoltaic systems:
PV (Photovoltaic) systems comprise of inverters and solar panels, as well as other mechanical and electrical hardware, which utilizes solar energy for generating electricity [40]. From small portable or rooftop systems to large-scale utility-scale power plants, PV systems’ size may also vary. Although photovoltaic systems can act as off-grid photovoltaic systems by themselves [41] [42].

3.3.1. Working of solar PV systems:
Solar panels create electricity by process recognized as the photovoltaic effect, which is caused by sunlight consisting of packets of energy called photons striking the panels. Every panel generates comparatively little power, but can be linked with other panels to generate more power (for example solar panels). Solar panels (or arrays) generate electricity in the form of DC (direct current). While several electronic devices (like laptop, mobile phone) use direct current, they are designed for operating on a utility network that gives (and requires) AC (alternating current). As a result, solar energy must be transformed from DC to AC through an inverter before it can be used. The AC electricity from the inverter can be utilized to power local electronic equipment or transmitted to the public grid to be used elsewhere.

3.4. Super Capacitor or ultra-capacitor
SC (super capacitor), known as an ultra-capacitor, is a high-capacity capacitor having capacitance value that is significantly higher as compared to conventional capacitors, nonetheless have low voltage limitations, that links the difference between rechargeable batteries and electrolytic capacitors. As compared to electrolytic capacitors, it generally stores 10 to 100 times more energy per unit volume or mass, can discharge as well as accept much more quickly than batteries, and can withstand a greater number of discharge and charge cycles than rechargeable batteries [43] [44] [45].

Types of Super capacitors:
- Double -layer capacitors (charge storage-electrostatically)
- Hybrid capacitors (charge storage-electrochemically and electro statically)
- Pseudo capacitors (charge storage-electrochemically)

3.4.1. Double-layer capacitors:
EDLCS (electrostatic double-layer capacitors) are devices that utilizes carbon electrodes or carbon derivatives that have significantly higher electrostatic double-layer capacitors as compared to electrochemical pseudo capacitance, allowing charge separation in a Helmholtz double layer to occur at interface between surface of conductive electrolyte and electrode. It is just a few angstroms (0.3–0.8 nm)
in separation between charges, which is significantly less than the gap between charges in a conventional capacitor.

3.4.2. Pseudo capacitors:
Electrochemical pseudo capacitors are made using metal oxide or conducting polymer electrodes that have high quantity of electrochemical pseudo capacitance in addition to double-layer capacitance, allowing them to be used in a variety of applications. Using Faradic electron charge transfer in conjunction with redox processes, intercalation, electro sorption, pseudo capacitance can be created.

3.4.3. Hybrid capacitors:
Similarly, to the lithium-ion capacitor, hybrid capacitors utilize electrodes with contrasting characteristics: one displaying predominantly electrostatic capacitance along with predominantly electrochemical capacitance, with former being the more common.

4. ELECTRIC VEHICLE CONVERTERS REQUIREMENTS

Though, few design considerations are important for automotive application

- Light weight
- Converters’ step-up function.
- Low current ripple drawn from battery or Fuel cell
- Low electromagnetic interference
- Small volume
- High efficiency

4.1. Multi-port DC-DC- converter
In PV power generation, converter, EVs, Micro grid and aircrafts application is utilized for meeting power demand as shown in Fig. 4. There is different type of converters, AC-AC converters, DC-DC converter, along with DC-AC converter. In Hybrid Electric Vehicle mostly used in DC-DC convertors and Inverter. Multi-port DC-DC Converter utilized in EVs, HEVs for interfacing the PV and Super capacitor and Battery to DC- bus in shown in Fig. 4, [46] [47] [48] [49].

![Figure 4. Multi-port converter topology.](image-url)
a. **Anticipated converter topology and Operation mode:**

**Mode-1:** First operation stage: \(0 < t < d_1 T\): \(S_1, S_2, S_3\) and \(D_3\) is ON. The \(L_1\) and \(L_2\) are charged through power sources solar and ultra-capacitor, in Fig. 6.

**Mode-2:** \((d_1 T < t < d_2 T)\): \(S_1\) is OFF condition and \(D_2\) is ON. The \(L_2\) are charged \(L_1\) is being discharge through sources solar and ultra-capacitor, in Fig. 7.

**Mode-3:** operation stage: \((d_2 T < t < T)\): \(S_1\) is ON condition and \(S_2\) is OFF and \(S_3\) and \(D_3\) is ON. \(L_1\) are charged with \(V_{pv}\) and \(L_2\) is being dischargethrough sources \(V_{pv}^{+}\) and Ultra capacitor \(V_{UC}\), as shown in Fig. 8.

By apply voltage second equilibrium low more than inductors \(L_1\) and \(L_2\) of capacitor \(C_1\).
The output voltage can be follows:

\[ L_1 = d_1[V_{pv} - r_1i_{L1}] + \left[(d_2 - d_1) [V_{pv} - r_1i_{L1} ] + (1 - d_2) [V_{pv} - r_1i_{L1} ] \right] \]  

(1)

\[ V_{c1} = \frac{V_{pv} - r_1i_{L1}}{d_2 - d_1} \]  

(2)

\[ L_2 = \left[ (1-d_2) [V_{uc} + V_{c1} - r_2i_{L2}] + d_2 [V_{uc} - r_2i_{L2}] \right] = 0 \]  

(3)

\[ V_{o} = \frac{(1-d_2) [V_{uc} + V_{c1} - r_2i_{L2}] + d_2 [V_{uc} - r_2i_{L2}]}{(d_2 - d_1)(1-d_2)} \]  

(4)

The current second equilibrium low more than the capacitors \( C_1 \) and \( C_0 \), the voltage of the \( C_1 \) is

\[ C_1 = (d_2 - d_1)i_{L2} = 0 \]  

(5)

\[ C_0 = (1-d_2)i_{L2} = \frac{V_{o}}{R_{load}} \]  

(6)

The battery is not used

\[ P_{battery} = 0 \]

\[ I_{battery} = 0 \]

b. The force the board strategy is as follows:

- Control signs, speed increase, and brake, recognize the order power.
- In the event that order power is not exactly the level of most extreme PV force as well as battery energy is not exactly the level of least energy; PV work at MPP and additional energy will be stored in the battery at the most extreme level. In this case, PV will produce an order power, whereas battery will remain off. FC is turned off in both scenarios.
- If order power exceeds the maximum extreme PV power, the PV board will work in MPP mode; moreover, the new order force will be classified as follows:

\[ P_{new \, command} = P_{command} - P_{pv} \]  

(7)

5. Conclusion and Future scope

In today’s world, hybrid electric vehicles are a major topic because of their low emissions, low fuel consumption, minimal commotion, as well as low operating costs. To understand the technology behind electric vehicles and the possible fuel sources, as well as the numerous multi-pologies used in HEV applications, this article provides a state-of-the-art overview. There is a significant problem with all EVs, and that is the energy storage device. In current years, headway stack is present in energy stockpiling appliances (storage device) that offer better guarantee as far as force thickness furthermore, energy thickness. Be that as it may, none of these energy stockpiling gadgets gives the necessary blend of the multitude of following highlights: high energy thickness, high force thickness, minimal expense. Hence, the idea of joining fuel sources (cross breed energy sources) is acquainted with acquires the better highlights.

Due to the multi-input converters’ utilization in EV applications, power loss was decreased and coordination cost has been minimized, while power security and reliability have been improved. Concurrent use of two or on the other hand more fuel sources are conceivable. With a reasonable knowledge, multi-input DC-DC converter can be superior decision in event that one has to incorporate at least two fuel sources into EVs. The following are the additional benefits of these converters,

- Converter’s Size is little.
- The cost of the converter is lower since fewer semi-conductor devices are used.
- Better checking of energy assets.

Future scope Power module crossover electric vehicles with multi-input converters have an essential role to play in automobile industry in the future, as traditional petroleum fuels are depleting at a rapid rate. In spite of this, there are certain drawbacks to utilizing such vehicles, which are discussed in the following section:

- Compared to ICE vehicles, power module crossover electric vehicles have a high capital cost.
- The power module’s size (fuel cell) is likewise significant disadvantage in such vehicles.
The strength along with reliability of power module (fuel cell) framework are less contrasted with inside ignition vehicles, particularly in few temperature and mugginess ranges. This means that if such disadvantages are overcome, energy component hybrids are the best solution for internal combustion engine vehicles.

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