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Charging System for Electric Vehicle and Hybrid Electric Vehicle in Running Condition: A Review

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Abstract

This study examines comparative studies of three different charging systems used in electric vehicles while they are moving or operating. It also deals with the idea of using an alternator at each wheel of the vehicle to charge the non-connected set of batteries, as well as a brief explanation of the principles, mechanisms, design, and constraints of fuel cells, solar panels, and regenerative brakes. These are some of the most widely used methods for charging an EV or HEV while operating a motor vehicle. This technique will only increase the range by a few miles and not much more because it consumes very little energy. However, using the alternator will boost the range to more than 90% of an infinite loop. To overcome range restrictions and charging downtime, creative on-the-go charging solutions are crucial as the demand for electric vehicles (EVs) and hybrid electric vehicles (HEVs) rise. Current and developing technologies in dynamic charging systems, such as solar-based in-motion charging for EVs and HEVs, conductive rail systems, and wireless inductive charging, are examined in this overview. This study highlights developments in on-road charging mechanisms and assesses their potential to increase the adoption of EVs and HEVs by examining the technological viability, infrastructure needs, and operational efficiency of these systems. In addition to offering insight into the future of dynamic in-motion charging systems for sustainable mobility, it ends by going over lingering difficulties such infrastructure costs, standardisation problems, and energy transfer efficiency.

Keywords: Electric vehicle, hybrid electric vehicle, fuel cell, solar cell, regenerative braking, range, battery, alternator

INTRODUCTION

Pollution rises as a result of the increased usage of automobiles, which releases toxic substances into the atmosphere. Thus, in today's world, replacing the IC vehicle is a challenge. The automotive industry is far more interested in creating alternative power-train technologies due to the growing need to reduce emissions and improve fuel efficiency [1].

However, the biggest obstacle to the widespread use of HEVs continues to be the constraints of battery technology, which include problems with weight and size as well as limited lifespans brought on by a high number of deep charging and discharging cycles [2]. Furthermore, a HEV's total efficiency is restricted and greenhouse gas emissions are still produced when an internal combustion engine (ICE) is used. Electric vehicles offer an alternative to internal combustion engines, despite their limited range. A number of techniques and technologies are employed to extend the vehicle's range. The majority of electric vehicles on

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the market now use fuel cells, solar panels, and regenerative braking, among other effective techniques for charging electric vehicles while they are in operation [3].

Regarding the fuel cell: because of the technology's quick development, fuel cell hybrid electric vehicles (FC-HEVs) have garnered a lot of attention to achieve high fuel efficiency and zero emissions [4]. Commercialization of FC-HEVs is still hampered by several major issues, including infrastructure, fuel reforming, hydrogen storage, and high costs. Fuel cell hybrid vehicle (FCHV) technologies have the potential to significantly lessen our dependency on oil and help cut down on the dangerous pollutants that cause climate change. Super-capacitor packs are occasionally employed as reversible power sources and energy buffers [5].

In addition to the fuel cell, an EV or HEV's batteries are also charged via a solar cell or panel. Manufacturers and designers have been driven by the concept of an environmentally friendly product since the inception of the automotive industry. However, it was not until the oil crisis of the late 1970s that the idea of solar electric vehicles (SEV) really took off [6]. One renewable energy source that is abundant and emission-free in nature is solar energy. Solar energy is a valuable resource on Earth that can yield optimal results through a thorough examination of the surrounding conditions. The solar panel's performance can be impacted by temperature, irradiance, humidity, direction, and shadow. One effective solution to all of these growing problems is the use of electric automobiles. Electric vehicles have been thoroughly researched and studied as a potential remedy for the environmental issues caused by traffic. In an effort to rescue the world from these issues, a great deal of progress has been made in the field of vehicle modelling, and a variety of methods have been tried and tested to assess how well electric vehicles operate [7].

Regenerative braking is a common technology found in all electric vehicles. When the regenerative braking system operates, there are certain limitations. For instance, the braking resistance is necessary to use up the energy recovered from the brake when the energy storage device's state of charge (SOC) surpasses the upper limit. The mechanical brake is now applied. Consequently, the safety of the vehicle and other associated operations would be impacted by the coordination control of mechanical braking and regenerative braking [8].

However, a common problem with all these approaches is that they are unable to supply the necessary energy to charge the battery at a rate that matches its rate of discharge. The range of electric vehicles can only be increased slightly due to the limitations of current methods.

In this study we will study the principles of working, construction and the limitations of fuel cell, solar cell and the electric vehicle's regenerative braking mechanism. And the study focuses on the idea of charging the battery of a running EV or HEV by using the alternators.

STUDY OF FUEL CELL

Fuel Cell

An electrochemical device known as a fuel cell uses a chemical reaction rather than combustion to directly transform the chemical energy of a fuel into electrical power. It is a highly efficient and clean method of generating electricity. In contrast to most batteries, which get their chemical energy from materials already present in the battery, fuel cells obtain their chemical energy from an ongoing supply of fuel and oxygen (usually from air). Fuel cells can continuously produce electricity if fuel and oxygen are available [9, 1].

Working of Fuel Cell

Fuel and air react electrochemically when they are delivered to a set of negative electrodes (called anodes) and air to a set of positive electrodes (called cathodes). Electrons are produced by the fuel's electrochemical reaction [1].

Electrons are consumed during the electrochemical reaction of oxygen in air. Usable electrical power is produced when the two are connected. An electrolyte layer sits between the electrodes of every fuel cell [1]. As the electrodes produce and consume electrons, the ions in the electrolyte flow between the air and fuel electrodes to maintain a charge neutrality between them. The electrolyte of Fuel Cell Energy gives rise to the platform's name, carbonate. Carbonate ions move between the fuel and air electrodes and are the basis for the electrolyte, which is composed of carbonates of potassium and lithium. Around 1000°F is the operating temperature of carbonate fuel cells. Without the need for pricey platinum-type catalysts, the electrode reactions can proceed efficiently when operating at high temperatures. Additionally, the temperature is high enough for the fuel cell stack to convert methane to hydrogen, a process known as reforming [1, 4, 10].

As a result, the cell can produce hydrogen straight from a fuel source that contains methane, such as biogas or natural gas. Fuel cells are an appealing energy option because natural gas and biogas are readily available. Inside the cells, methane is converted to hydrogen, which is then reacted to produce electrons [2]. Carbon dioxide is another product of the reforming reaction. Compared to other fuel-based power systems, fuel cells generate less carbon dioxide per kilowatt-hour of electricity due to their high efficiency. Furthermore, power is generated using biogas as fuel is carbon neutral. Since carbon dioxide is generated in the fuel electrodes prior to being combined with dilution air, it can be readily extracted before exhaustion, preventing emissions or offering carbon dioxide to a user as an industrial gas [4].

By releasing water instead of emissions, this combustion-free method enhances local air quality and helps our customers achieve their net-zero objectives. Because of its great efficiency, low carbon emissions, and negligible criteria pollutants, some US states have already classified some fuel cells as Class I renewable power generation [1].

Fuel Cell in Electric Vehicle

- Hydrogen energy is converted into electricity by fuel cell electric vehicles, or FCEVs, which operate on a similar propulsion system to electric vehicles as shown in Figure 1.
- FCEVs are powered by pure hydrogen gas, which is stored in a tank on the vehicle. They have a driving range of about 300 miles and can be refuelled in roughly 5 min, just like regular internal combustion engine vehicles [1].

STUDY OF SOLAR CELL

Solar Cell

A photovoltaic (PV) cell, sometimes referred to as a solar cell, is an electronic device that directly generates electricity from sunshine. It is the fundamental component of solar panels. When two different materials are near each other and exposed to light or other radiant energy, a phenomenon known as the photovoltaic effect occurs that causes an electrical voltage to be produced. Most solar cells are made of silicon, and as silicon takes on different forms from amorphous (non-crystalline) to polycrystalline to crystalline (single crystal), its cost and efficiency decrease. Solar cells produce electricity without the use of fuel or chemical reactions, in contrast to batteries or fuel cells. Additionally, they are completely non-moving, in contrast to electric generators [6].

Solar Cell Operation

- *Photon Absorption:* Semiconductor materials, most commonly silicon, are used to make solar cells. Photons, or light particles, from the sun can be absorbed by the semiconductor material in the solar cell.
- *Electron-Hole Pair Generation:* Photons that are absorbed impart their energy to the semiconductor material. The material's electrons are excited by this energy and separate from their atoms as a result [11]. Thus, in the absence of electrons, the material is split into pairs of negatively charged electrons and positively charged holes.

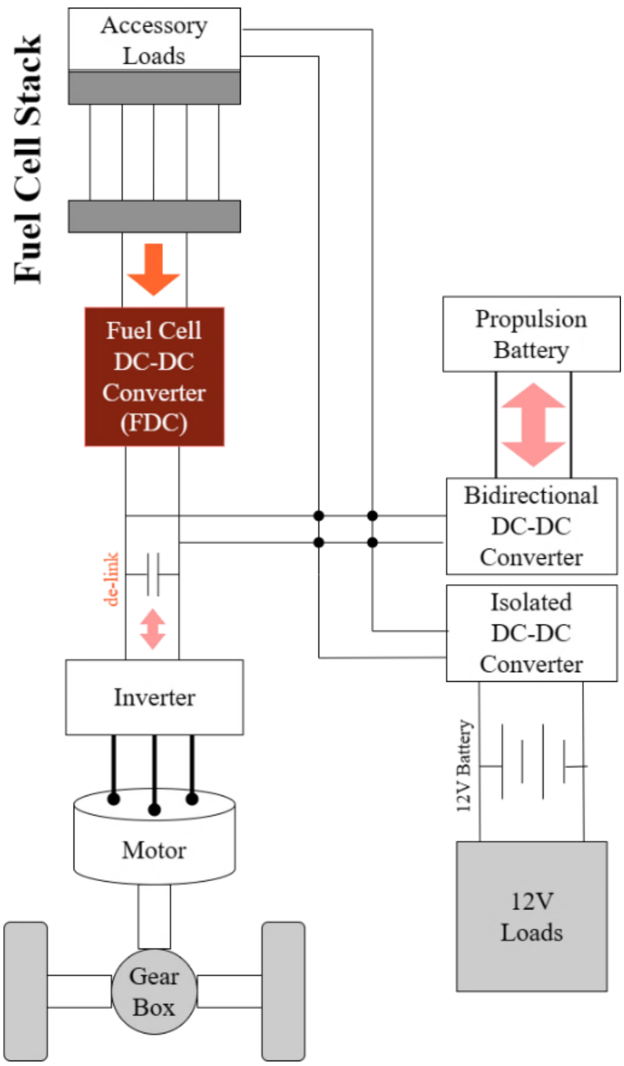

Figure 1. Block diagram of fuel cell electric vehicle.

- *Charge carrier movement:* The separated charges, electrons and holes, move in opposing directions due to the electric field inside the solar cell. Whereas holes travel in the direction of the positively charged side (the p-type semiconductor), electrons flow toward the negatively charged side (the n-type semiconductor).
- *Electrical Current:* By connecting the metal contacts on the top and bottom of the solar cell, an external circuit is formed. As a result, the electrons (electric current) moving from the negative side to the positive side can generate useful power.
- *Direct electricity (DC) Output:* A single solar cell normally generates a little quantity of electricity. A solar panel is composed of multiple interconnected solar cells that cooperate to provide a larger output voltage and current. This direct current (DC) electricity can then be used to power electrical equipment or stored in batteries for later use.

Working of Solar Elecric Vehicle

- The roofs of electric cars are equipped with solar panels. Light energy absorbed from the sun's rays is converted into electrical energy by the photovoltaic cells in the solar panels. The light energy converted to storage batteries is intended to be stored by the solar cells on the car's body [12, 13].
- *Storage of nickel-cadmium and lithium-ion:* The electrical energy generated during the conversion of light energy is stored in batteries. Free electrons can be converted by the batteries

into energy that drives the gearbox in a solar-powered car. The battery is recharged by solar energy [12, 13].
- Vehicles that run on solar energy can produce 90–175 V of electricity, which enables them to go 70–90 km between charges. Fuel consumption and operating costs are reduced in solar-powered vehicles because of their use of solar energy [12, 13].

STUDY OF REGENERATIVE BRAKING

Regenerative Braking in Electric Vehicles

By converting kinetic energy into a form that can be immediately stored or utilised, regenerative braking is a method of energy recovery that slows down a moving item or vehicle.

Through this mechanism, energy that would otherwise be lost as heat to the brake discs is recovered by the electric traction motor by using the momentum of the vehicle. Compared to conventional braking systems, this method is different [14–16]. These systems using electric motors as generators to recover energy, rheostatic brakes cause the energy to be instantly released as heat in resistors, or they use friction in the brakes to convert excess kinetic energy into undesired and wasted heat. Regeneration not only improves the vehicle's overall efficiency but also extends the life of the braking system by delaying the premature wear and tear of its mechanical components [17, 8].

Working of Regenerative braking

- The electric motors that drive an automobile are reversed when regenerative brakes are applied. It replenishes a small amount of range by feeding energy back into the electric or hybrid system, working in a manner akin to that of a generator.
- When these modest increases in battery range are utilized frequently, they can add up and eventually increase efficiency [18, 19].
- There are several methods by which drivers can engage the regenerative brakes. Regenerative brakes can be engaged by a paddle located by the steering wheel in certain electric and hybrid vehicles [18, 19].
- On the other hand, most cars with regenerative braking have smooth activation. When you press the standard brake pedal, the automobile is slowed down by the combined action of the regenerative and friction brakes [18, 19].
- When the car is coasting, certain systems have the ability to apply regenerative brakes. Known by another name, one-pedal driving, this feature allows drivers to focus on efficiency during longer trips when driving [18, 19].
- Regenerative brakes accomplish the same objective of slowing down and stopping a moving car, despite being completely different from friction brakes.
- When using regenerative brakes, the brake lights still illuminate as a safety precaution because they function in the same way as conventional brakes. As a result, the regenerative brakes engage instantaneously when you lift your foot off the accelerator, and the rear brake lights illuminate as if you were pushing the brake pedal [18, 19].

Problem Statement

All the above systems of charging the batteries of electric vehicle in running condition have some limitations:

Fuel Cell

- Expensive to produce because platinum catalysts are expensive [5].
- Inadequate infrastructure to facilitate hydrogen distribution [5].
  Gaseous fuel presents challenges in handling.
  In a cylinder that has been specially made, the fuel gas (oxygen, hydrogen, etc.) must be maintained as a liquid at very low temperatures and high pressures. This rise is the result of the cell's price increasing, which has several disadvantages.

- Most fuel cell technology on the market today is still in the prototype stage and has not yet undergone validation [5].
- Hydrogen is expensive to produce and has a limited supply.
- Fuel cell electrolytes are highly caustic, which presents several real-world difficulties.

Solar Cell

- Efficiency rate is around 20 to 35% [7].
- Solar cells consume more space [7].
- Cost and weight [7].
- Adverse weather conditions that affect driving your solar car will probably have trouble reaching this number if the panels are positioned incorrectly and there is a build-up of dirt [7].
- All other solar panels have their tilt slightly away from the sun, which reduces their capacity to collect energy. Furthermore, not all solar-powered vehicles are environmentally friendly [8].
- However, real-world conditions are not always ideal. The earth's surface receives only roughly 55% of the solar energy, with the remaining portion being reflected or absorbed by the atmosphere.

Regenerative Braking

- *Ineffective at slower velocities:* Car has less kinetic energy and needs less braking force when it is moving more slowly. Consequently, less energy is fed to the regenerative braking system, which leaves the battery pack with less charge.
  Additionally, some automakers believe that in certain circumstances, coasting might be more advantageous than regenerative braking [8].
- *Brake pedal sensation may vary:* Making sure your brake pedal is functioning is something you should always check when driving. While the brake pedals on electric and hybrid cars do function, you might not be accustomed to how they feel.
- *A possible decrease in stopping power:* Regenerative braking works perfectly in most circumstances where you slow down gradually, but it might not offer as much stopping power as traditional brakes.

For the same level of effectiveness, drivers of EVs and hybrid vehicles may need to apply more pressure to the brakes [8].

COMMON ISSUE

The primary problem with EVs is their limited range, which can be increased using these techniques. However, a common issue shared by all of these methods is their inability to provide the energy required to charge the battery at a rate commensurate with its rate of discharge. An electric vehicle's range can only be increased to a certain extent with the current techniques [20].

Solution

Connecting the four wheels of the vehicle to the alternator. The connection should be made in such a way that the alternator rotates with little energy loss or energy consumption, there will be two sections to the EV battery. The battery is one of the most important and costly parts of an electric vehicle. Because of this, we are unable to establish battery groups that are equal by looking at increasing weight and cost. The first group of the battery will consist of the necessary EV ratings. To achieve the rated output needed for the EV, this group will use a series-parallel configuration of small battery packs, either 12 or 24 V. In the latter group, just a tiny battery pack of 12 or 24 V is to be used. The first group of the battery will be providing the supply to all the components of the EV and the second group of the battery will be connected to all four alternators connected to the wheels of the vehicle [21–25]. The EV will work on the supply of the first battery group and simultaneously, as the EV is in moving state, according to the alternator's operating principle, which describes it as a device that transforms mechanical energy into electrical energy, the alternators attached to the wheels will begin producing electrical energy. Due to which the battery in second group will start charging. The BMS of the battery should be programmed in such a way that when the battery of second group gets fully charged, then one of the small battery packs of the first group should get separated and the charged battery of the second group will get connected to the main battery system. After being separated, the battery will once more replace the charged battery, and the alternators will begin to charge it. We will go through this again for every tiny battery pack in the first group. The batteries will consequently be continuously charged and discharged. Although it might not be an infinite loop, the EV's range will increase significantly more with this method than with the other three.

CONCLUSION

A solar cell is an apparatus that directly transforms light energy into electrical energy by using the photovoltaic effect. Regenerative braking is a technique for recovering energy that reduces the speed of a moving vehicle by transforming its kinetic energy into a form that can be stored or used right away. Through this mechanism, energy that would otherwise be lost as heat to the brake discs is recovered by the electric traction motor by using the momentum of the vehicle.

These methods can help extend the limited range of electric vehicles (EVs), which is their main drawback. All these approaches, though, have one thing in common: they are unable to supply the energy needed to charge the battery at a rate that corresponds with its rate of discharge. The existing methods are restricted in their capacity to extend an electric vehicle's range.

The idea of using an alternator at each wheel of the vehicle to charge the non-connected set of batteries might not be an infinite loop, the EV's range will increase significantly more with this method than with the other three.

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