Wireless Charging for Electric Vehicles

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Wireless charging modules for electric vehicles (EVs) are being increasingly studied. Two techniques of transferring power to EVs via charging systems can be used: conductive charging and wireless charging. Some notable studies, as presented in this work, focused on developing more effective wireless-charging modules for electric vehicles to pave the way for the creation of more sustainable urban transportation. It is also important to note that attaining this sustainable urban mobility is dependent on using clean energy sources (like solar photovoltaic). As a result, some techniques were discussed to supplement wireless charging and hence reduce the size of the needed energy storage device for urban mobility.

Keywords: wireless power transfer ; wireless charging ; solar electric vehicle ; solar paint ; structural battery

1. Introduction

In 1891, Nikola Tesla developed the wireless power transfer (WPT) concept based on capacitive coupling [1]. There is no physical connection between the vehicle and the charger in wireless charging [2][3]. Coupling plates known as a transmitting end (at the roadside) and a receiving end (at the vehicle side) are used in most electric vehicles (EVs) wireless chargers [4]. EV charging via an inductive power transfer (IPT) system is gaining a lot of attention [5][6] in recent times, though it can also be done via capacitive power transfer (CPT), laser, microwave, and other methods.

In 1977, the Lawrence Berkeley National Laboratory demonstrated the very first IPT-based EV dynamic wireless charger [7]. Wireless charging systems are available in both mobile and fixed configurations. When using the dynamic (mobile) wireless charging technology, a vehicle can be charged while driving; when using the stationary (fixed) wireless charging technology, a vehicle must be parked. This was a revolutionary technology which begged for more research at the time. This was evenly met with numerous studies around the subject [8][9][10][11].

There are some benefits of wireless charging systems. First, it allows for convenient, adaptable, and safe EV charging without requiring direct human contact [12]. Second, the total cost of charging is considerably lower than the traditional conductive charging [12]. Third, the charging structure is practical, making it very suitable for residential use with minimal maintenance [13]. Finally, dynamic WPT technology allows for vehicle charging while moving [14][15]. These merits make the WPT desirable technology for automotive applications towards the achievement of a more sustainable mobility in cities.

2. Outlook for WPT Application in EVs

2.1. Overview

Researchers have welcomed the progress made in WPT applications in EVs thus far, but are skeptical about the current technology's capacity to sustain the charging infrastructure for EVs at the requisite efficiency [16][17][18]. The ability to lower gross vehicle weight by employing a smaller battery (energy storage device) [19][20] and the energy storage device's ability to keep charge over extended charge and discharge cycles [21][22] are at the heart of the problem. The focus of this discourse, however, is mostly the technologies that may aid in reducing battery size. The current efficiency of wireless charging in EVs is low as compared with the plug-in charging receptacle (wired charging) approach [23]. However, if WPT is properly combined with modern technologies such as solar photovoltaic (PV) roofed vehicles, structural batteries, and Solar PV paints, the required charge holding ability and gross weight reduction can be obtained. As a result, the discourses that follow, which can be seen as methods for weight reduction and employed alternative energy technologies, will pave the way for more study into WPT applications in EVs.

2.2. Solar PV Roofed Vehicle

Traditionally, researchers have only looked at the long-term viability of solar PV in the construction of electric vehicle charging stations [24][25][26][27]. However, only a few authors/institutions have looked into the possibilities of combining solar PV technology with electric vehicles that have solar PV cells mounted on them. Some institutes conducted experiments but most of the published documents were reviews [28][29].

The experiments done by NEDO, Sharp Corporation (Sharp), and Toyota Motor Corporation (Toyota) on public roads from 2019 were an example of an institute's work [30]. The purpose of the trials was to assess effective increment in cruising range and fuel efficiency of electrified vehicles with high-efficiency solar batteries.

Toyota built a demonstration car with solar panels on the roof, bonnet, rear hatch door, and other elements of the "Prius PHV" for public road trials. Toyota was able to obtain a rated power generation output of around 860 W by improving the solar battery panel's efficiency and enlarging the on-board area, which is roughly 4.8 times higher than the commercial model Prius PHV (equipped with a solar charging system). This demo car, in addition to significantly increasing its power generation throughput, uses a system that charges the driving battery both while the vehicle is parked and while it is being driven, a progress that is expected to result in significant increases in electric-powered cruising range and fuel efficiency.

With research being done in this area and solar PV technology increases, it is expected that electric vehicles would use a solar PV charging system in conjunction with other charging technologies such as WPT that use a clean energy source. The solar charging system could also be used to provide direct energy to the drivetrain, which eliminates the requirement for an energy storage device (battery) or reduces the battery's size as done in [31].

2.3. Structural Composite Batteries

The recent breakthrough in technology by researchers at Chalmers University in Sweden [32] has brought structural batteries into the spotlight and given them a fresh viewpoint. Integration of lithium-ion batteries into fiber-polymer composite constructions to carry mechanical stresses [33][34] while also storing electrical energy has a lot of promise for reducing total system weight [35][36]. When compared to existing commercial battery systems, energy storage composites with integrated lithium-ion pouch batteries achieve a better mix of mechanical performance and energy density [36]. Automotive, aircraft, spacecraft, marine, and sports equipment are all potential uses of energy storage composites with integrated lithium-ion batteries [37]. As a result, it is in the best interests of researchers to devote their efforts toward investigating the viability of structural batteries with WPT technologies, particularly for city transportation solutions. This is due to the fact that structural batteries considerably lessen the weight reduction challenge.

2.4. Solar PV Paints

Solar paint that generates electricity from water vapor has been developed by a team of researchers from the Royal Melbourne Institute of Technology (RMIT) [38]. The paint works by taking moisture from the air and breaking the water molecules into hydrogen and oxygen utilizing solar energy. After that, the hydrogen can be used to generate renewable energy. Titanium oxide, which is already present in normal paint, is also present in this solar paint. The titanium oxide aids the paint in breaking down absorbed moisture into hydrogen and oxygen particles using sun energy. After that, the hydrogen can be used to generate renewable energy. A hybrid vehicle (hydrogen powered internal combustion and electric drive) can greatly benefit from this solar PV paint, especially with certain automakers pursuing the net zero emission dream via hydrogen combustion vehicles. The demand for battery on-board the vehicle would be expected to be substantially reduced as a result of the additional energy provided by the WPT technology.

The University of Toronto also produced quantum dots, often known as photovoltaic paint [39]. They are nanoscale semiconductors that can absorb light and convert it to electricity. To use the full scientific phrase, 'colloidal quantum dot photovoltaics' are not only cheaper to make, but also substantially more efficient than typical solar cells. These dots have the potential to outperform regular solar panels by up to 11% [39]. In principle, we will be able to paint quantum dots on our roofs and other surfaces in order to convert sunlight into power at some point in the future. This can easily be applicable to automobile painting [40][41]. When properly integrated with WPT, a significant reduction in weight could be attained.

Finally, perovskite solar cells are especially compelling since they can take on a liquid state, making them a perfect option for solar paint. Spray-on solar cells, for example, were developed by researchers as a technique to spray liquid perovskite cells on surfaces [42][43]. In 2014, the University of Sheffield developed the world's first spray-on solar cell [44]. To create a sun-harnessing layer, a perovskite-based combination was sprayed over a surface.

2.5 Conclusion

In conclusion, the aforementioned techniques, if combined with wireless charging methods, can provide the required clean energy for urban mobility for a sustainable transportation. Now, it is recommended that investigations should be conducted into the feasibility of such hybrid energy sources approaches. This can be achieved through experimental and numerical studies.

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