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A Comprehensive Review of EV Charging Systems with Reactive Power Support for Enhanced Grid-Connected V2G Performance

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Abstract: Electric vehicles are gaining popularity because they emit less pollution and are less reliant on fossil fuels. By integrating smart grid charging stations with distributed renewable energy sources, energy efficiency and carbon reduction can be achieved. In this paper, the focus is on brief information about the electric vehicle, charging stations, stability of charging electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) as they become more popular. It is recognized that increased usage of the traditional power grid for charging purposes can lead to higher costs and strain on the grid. Therefore, the paper suggests incorporating local, renewable energy sources such as photovoltaic (PV) panels and wind converters into the traditional grid to enhance its efficiency. PV panels are capable of converting sunlight into electricity, while wind converters convert the energy of wind movement into mechanical power. This review paper provides a comprehensive analysis of Electric Vehicle (EV) charging systems integrated with reactive power support to enhance the performance of Grid-to-Vehicle (V2G) systems. It explores various charging technologies, control strategies, and communication protocols, highlighting their role in improving grid stability, voltage regulation, and overall power quality. The paper emphasizes the importance of reactive power compensation in optimizing the grid-connected operation of V2G systems and supporting the transition to sustainable energy.

Keywords-Electric Vehicles, Battery Charging, Vehicle to Grid and Grid to Vehicle Technology, Power Converter.

Introduction

Recent advances in battery and electric power train technology have been expedited by aggressive marketing and significant government assistance. Battery manufacturing costs have reduced dramatically during the previous three years. EVs are likely to play a larger part in future automotive market.

As a random load, EVs will impact the distribution network's overall load characteristics, making load forecasting more difficult, and affecting the distribution network's substation design and grid. Thus, while planning and designing the grid, the influence of EV demand should be thoroughly recognized, and planning limitations should be reinforced to ensure that the planned distribution grid can completely meet the shifting EV needs [4]. Although some research has been conducted, the number of thorough review articles accessible that address the issues mentioned about the obstacles and challenges associated with the sustainability of integrated PV-EV charging is limited [5]. Additionally, there are currently no clear recommendations that address charging system and EV charging timing issues. Thus, this chapter provides an overview of the different charging station layouts and control topologies that may be used to manage EV charging stations effectively.

This paper has a lot of good things going for it. An initial review of current charging systems and electronic power converters is needed. The second step is to look at how the equipment works together in different operating modes to see if common AC and DC bus EV charging systems, as well as different large-scale EV charging pattern mechanisms, can be used.

EV Charging Facilities and Integration

Electric vehicles are gaining popularity because they emit less pollution and are less reliant on fossil fuels [6]. By integrating smart grid charging stations with distributed renewable energy sources, energy efficiency and carbon reduction can be achieved [7]. It is possible to have a Microgrid that is both linked to the grid and separated from it, where dispersed energy sources and storage devices are used locally by a variety of load types. However, widespread adoption of high-capacity EV charging stations increases demand for charging infrastructure, which in turn increases demand on the power grid [8]. Power converter topologies and local renewable energy sources are used to help people who have trouble using a lot of energy. Tesla and Nissan are two of the companies that make electric cars. They build the infrastructure for charging stations. As a result, electric-vehicle charging stations that use renewable energy cut charging costs and emissions while improving the synchronization of utility grid[9].

There are a lot of ways to charge electric cars, from hybrid (renewable energy, BSS, and the grid) to dedicated (electricity generated by the vehicle). This raises the question of whether or not charging electric cars with a hybrid system is better than with a single source of power. Electric cars can be charged at a lower cost by using free electricity from renewable sources like wind and solar. This can also help reduce the amount of fuel used to run the grid, which can help save money. In addition, if the grid doesn't have enough electricity to meet the needs of the electric cars, they can be charged directly from the grid or with the help of Renewable Energy Sources (RES). Energy buffers can also be used with batteries. Batteries can be used to store extra energy from renewable sources like wind and solar. Electric cars may also benefit from extra services provided by the energy they use. As a side note, it's important to note that stand-alone renewable systems have a lower penetration rate than those that are connected to the power grid. [13]. The reliance on the main grid as a reliable source/load capable of compensating for the volatility in renewable energy sources. Solar energy is the preferred renewable energy source for EV charging since it may be produced during high-cost power grid tariff hours. Thus, solar-powered EV charging stations may help lower the cost of electricity. The photovoltaic module has a basic construction, a compact footprint, is lightweight, and is easy to carry and install. Additionally, the photovoltaic system doesn't take long to build and can be connected in a variety of ways based on how much electricity it can charge. To be used as a source on site, it is easy to find. Photovoltaic energy production is, on the other hand, very dependent on the temperature and sunlight in the area. In other words, PV electricity isn't continuous during the course of a single day of operation. It's also short-lived, meaning it happens at timed periods (minutes to hours). When PV panels are connected to loads without using an auxiliary system, this has an effect on the charging system. As a result, storage devices may play a critical role in stabilizing and moderating the unpredictability of solar energy production [53-56]. This paper suggests the use of an energy storage device in conjunction with a photovoltaic system to provide constant power to the EVs load regardless of PV power variations. Integration of storage devices with photovoltaic panels and power grid maximizes the use of renewable energy, resulting in reduced operating costs and increased efficiency.

DC Microgrid systems are widely employed in DC-powered households and industrial 0applications because to their easy voltage management and real-time control [9–11]. Figure 1.2 depicts a schematic representation of an EV charging station with a grid-connected ESU. DC microgrids are developed and operated in an unique topology that incorporates hybrid energy sources [12,13]. Low voltage microgrids were initially suggested in 2002 and are presently undergoing significant enhancements as a result of distributed generating [14]. This low voltage microgrids system is comprised of a variety of dispersed energy sources coupled to a variety of AC or DC loads. AC microgrids saw a similar evolution in 2004, with the addition of 10 kW, increased dependability, increased efficiency, and simplified control [15]. Similarly, DC micro grids are utilized for data transmission and ESUs with shared renewable energy [16]. An

EV-PV converter connects the microgrids to EV charging stations, which allows them to run only on renewable energy, like electricity from the sun or the wind. [17–19].

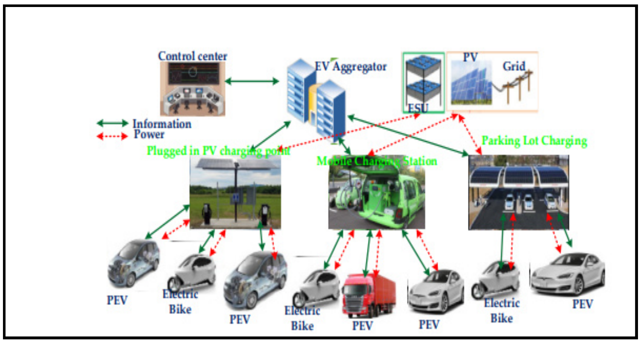

Fig. 1. A general schematic of a charging station.

Types of Electric Vehicles

People in China, the United Kingdom, the United States of America, and Germany still buy electric cars the most. Electric cars are becoming more popular all over the world. BEVs are a subset of HEVs and PHEVs. Hybrid electric vehicles (HEVs) are also a subset (BEV).

Hybrid electric vehicle

Internal combustion engines and electric motors make up the parts of a hybrid electric vehicle. The battery in this car is charged by the engine and the kinetic energy that is released when the car is going up and down. They are called "hybrids" because of the power converter that they use that combines a gas engine with an electric motor. Hybrid electric vehicles have become very popular around the world because they can run at full speed without needing to be charged. This is because they can run at full speed without needing to be charged.

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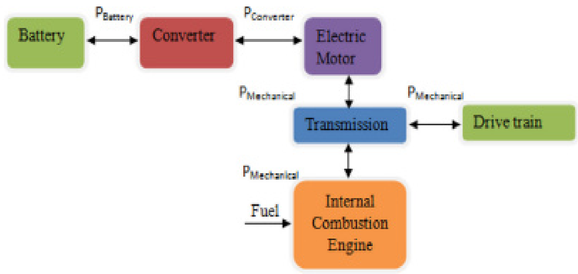

Fig. 2 Power flow of parallel HEV

By electrifying the drive train, they may also drastically reduce their fuel use. The HEV may be connected in a number of topologies, depend on the kind of hybrid system. In a series hybrid, the wheels are powered only by electricity. The motor is powered by the battery or the generator. Either the battery or the generator is used to power the motor. Battery power is supplied to the electric motor via an integrated circuit engine. Battery or engine/generator power is determined by a computer that monitors the amount of energy being generated. Both the engine/generator and regenerative braking are used to power the battery pack [24]. Smaller internal combustion engines are common in series HEVs, which have bigger batteries and larger motors. Using ultra-caps, which increase the battery's efficiency and hence cut down on waste, they may do this. When braking, they store the kinetic energy and release it during acceleration. The following are some of the benefits of a series hybrid drive train for them: Since the internal combustion engine and drive wheels are mechanically decoupled, it is possible for the IC engine to operate within a small range of performance that is optimized for torque and speed. In contrast, there are some disadvantages to using a series hybrid drive train. They are. It will be less efficient because the energy has to go from mechanical to electrical and then back again.

It needs a big torque engine and two electrical products to move the driven wheel. This is because these vehicles have big engines and generators, so they're used by the military, businesses, and the public. [25]. Parallel hybrid drive trains use less power because the engine is connected directly to the wheels. This means that the power train components can be moved more easily than in a series hybrid drive train. In order for a wheel to move, it needs power. There are three ways this can happen: through the engine, the motor, or both. hybrid cars can be used alone or in conjunction with parallel hybrids (the combination of single electric motor and ICE). Regenerative braking helps recharge small battery packs, which are common in this kind of car, and it does this by braking. It connects the motor, generator, and engine in a hybrid system that splits the power between them. They can be put together in both series and parallel ways in a single frame. If you want to drive your car, you can use an engine or a battery. You can also charge your battery at the same time. Each part's speed and torque are used to figure out how much power the wheel gets. When things like speed and load are changed, you can make your engine run more efficiently. Parallel HEV's power flow can be shown in figure 3.2.

Plug-in hybrid electric vehicle

PHEVs have both a gasoline engine and an electric motor (PHEV). People who drive these cars use gas, but they have a big battery that can be charged with electricity. There are a lot of good things about plug-in hybrid electric cars: Reductions in the use of petroleum It is thought that PHEVs use 30 to 60% less oil than traditional cars do. A plug-in hybrid car reduces the country's dependence on oil because most of the electricity used in the United States comes from the country itself. Emissions of greenhouse gas It's common for PHEVs to emit less greenhouse gas than traditional cars. Some of the time, however, the amount of gas that is released depends on the process that is used to make electricity. There are a lot of advantages to nuclear and hydroelectric power plants over coal-fired power plants, such as: Getting recharged takes a while. When you charge over a 240 V home or public charger, it takes one to four hours instead of a long time with a 120 V household socket. As little as 30 minutes is all it takes to get 80% of your battery's power. True, these cars don't need to be charged. People who don't charge these cars won't be able to drive far or get good gas mileage. Estimates of how much fuel is used Plug-in hybrid cars can run on either gasoline or electricity, or both, and the EPA looks at their fuel efficiency when they drive in both cities and highways. The largest solar-powered charging station in China, which was built in 2015, can now charge 80 electric cars a day. The company has started a project in Shanghai to see how well the electric car can use renewable energy to power the electric grid, too. There were more solar photovoltaic electric charging stations in Japan in 2015 than there were petrol stations. [26] This is what happened in 2018: The top five countries that sold electric cars were China, Europe, the United States and California. In the next few years, there will be a lot of new models coming out. Many of them should be reasonably priced by the end of the next few years. When it comes to cutting down on carbon dioxide emissions, the plug-in electric car has become a great choice for people.

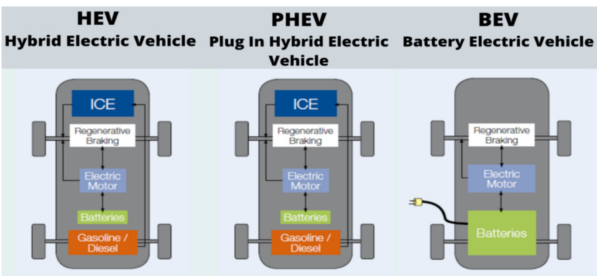

Fig. 3. Classification of Electric vehicle[43]

India has a lot of electric vehicles. There are still very few electric cars (EVs) on the market in India. Sales of electric cars haven't changed in the last two years. They've stayed at 2000 units each year. Car sales are expected to grow at a rate of 28.12 percent every single year from 2020 to 2030. This means that all new cars will be electric by then. Even though the Reva (Mahindra) electric car was first shown off in 2001, only a small number of them have been sold so far. In 2010, Toyota made the Prius, and in 2013, they made the Camry, both of which are hybrid cars. Electric buses and hybrid cars are already being tested in a few places. In the last few weeks, Bangalore's Municipal Transport Corporation started running electric buses on a busy section of the city's road. In a survey, three-quarters of car and two-wheeler owners in Ludhiana, India, said they were excited about the idea of switching to electric cars. People who drive electric cars in Telengana, a state in India, won't have to pay road tax. Charges for electric cars in Telengana State Electricity Regulatory Commission (TSERC) were put in place in 2018. They cost INR 6. TSERC also set a service charge of INR 6.04/kWh for the whole state. With the help of the Power Grid Corporation of India Ltd, Hyderabad Metro Rail has installed EV charging stations at its stations. This is thanks to the company. To start with, the power grid will be in charge of EV charging stations on the Hyderabad metro line, which is the first of its kind in the country. People in Hyderabad are also looking into electric cars as a way to get around. 131 public charging stations have been approved by the New Delhi government this year, and they can be used by the public. With the goal of getting 25% of its cars to be electric by 2020, the Delhi government came up with a new plan in November 2018. It included incentives and infrastructure for charging in both residential and non-residential areas, as well as a plan for how to do it. Electric cars won't have to pay road tax, parking fines, or registration costs because of this policy. By 2023, there will be a charging station every three kilometres. An EV charging station is also being built on the Mumbai-Pune expressway by Magenta Power, a private company.

Conclusion

In conclusion, the integration of Electric Vehicle (EV) charging systems with reactive power support plays a crucial role in enhancing the performance of Grid-to-Vehicle (V2G) systems. This review highlights the importance of efficient charging infrastructure in ensuring grid stability, especially with the increasing penetration of EVs. The ability to provide reactive power compensation from EVs not only aids in voltage regulation but also supports the overall power quality of the grid. Various charging technologies, including fast charging and bidirectional charging systems, have been explored in terms of their impact on both the grid and EV performance. The study further discusses the potential of smart charging strategies and demand-side management, which can optimize the flow of energy and mitigate the challenges associated with grid congestion and energy imbalance. Additionally, the role of communication protocols and control systems in enabling seamless interaction between EVs, charging stations, and the grid is critical. As the adoption of EVs continues to rise, the development of hybrid and renewable energy-integrated charging systems will be essential in addressing future energy demands. Overall, this review underscores the significance of reactive power support in the evolution of V2G systems, suggesting a promising pathway for achieving a sustainable and resilient power grid in the era of electrification.

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