Benefits of Vehicle-to-Grid (V2G) Technology

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Abstract— As a result of the recent energy crisis and concerns about the state of the environment, more people are opting for electric vehicles over the more typical internal combustion engine vehicle. This article provides a comprehensive overview of vehicle-to-grid (V2G) technology and assesses the effects of EV charging schemes on electrical grids. This research proves that vehicles with the capability of a V2G application provide a number of benefits, including active and reactive power regulation, harmonic suppression, and load balancing. In particular, the effects of EVs are explored in depth, as they vary depending on their penetration levels and charging characteristics. Moreover, our research demonstrates that different charging and vehicle aggregation procedures have a substantial influence on the economic benefits of V2G technology.

Indexed Terms- Vehicle to Grid (V2G), Electric Vehicles (EVs), Power Network, Grid Stability

I. INTRODUCTION

The transportation sector continues to rely on fossil fuels for 95% of its energy, with detrimental social and environmental implications [1]. This has led many experts in the field to believe that a widespread switch to electric transportation is not only viable but also desirable. Plug-in hybrids (PHEVs) use a combination of gasoline and electricity from the grid to power their wheels, whereas battery electric vehicles (BEVs) use electricity as their sole source of propulsion. According to the International Energy Agency, in order to stabilize greenhouse gas (GHG) emissions and effectively combat climate change, electric vehicles will need to account for at least 40% of new vehicle sales worldwide by the year 2040 [2]. It is projected that there will be a huge rise in the number of electric vehicles (EVs) during the next few years as a result of their potential to lower emissions of greenhouse gases and other air pollutants.

Using a communications infrastructure that works in both directions, the smart grid allows electricity providers and their consumers to manage and keep tabs on power consumption in tandem. The smart grid is an advanced electrical grid that will replace the current power infrastructure with an "Internet of energy" in the near future. Vehicle-to-grid (V2G) is a crucial network service in the smart grid, and it has attracted a growing amount of interest recently. The most promising strategy for the transfer of energy as well as information in a manner that is bidirectional is known as vehicle to grid (V2G). The V2G network is built by electric vehicles that connect with smart meters in order to exchange information and transfer energy between each other. In the beginning, the development of V2G technology was impeded by a conceptual concern over the prediction of vehicles available for charging or discharging [3]. This was due to the fact that it depended on the individual behavior of each vehicle owner. While adding these vehicles to the grid for charging will increase demand on the electricity supply, the ability does exist to discharge the stored energy back to the grid when necessary, given the typical usage pattern of automobiles. In a vehicle-to-grid operation, the owners of the vehicles could potentially supply the grid with electricity if they were financially paid for doing so.

A literature review has been done in this study and based on the findings of this analysis, it is abundantly clear that, if equipped with V2G capabilities, these vehicles could provide significant generation capacity. Additionally, there are prospects for the supply of grid capabilities like frequency response and peak reduction, in terms of magnitude, are comparable to those given by existing pumped storage hydroelectric plants. Only electric vehicles (EVs) can use the V2G application, which is principally the vehicle's capability to consent to the direct flow of power into the Distribution Network. The concept of V2G allows us to create an array of distributed energy storage devices that can be made immediately available. Investigations are being conducted into the usage of electric vehicles (EVs) as demand response resources as well as the benefits of unidirectional vehicle-to-grid benefits. The purpose of this study is to demonstrate, via the use of appropriate scheduling and adaptive pricing that a bidirectional charger is capable of contributing to the grid in both a financial and regulatory capacity. Through the vehicle-to-grid (V2G) mode, electric vehicles have been receiving an increasing amount of consideration for their potential to play a part in lowering the economic cost and carbon emissions of the power system, in addition to playing a role in the integration of renewable energy power sources.

II. ADVANTAGES OF V2G

Recent research shows that electric vehicles (EVs) have clear advantages over other conventional energy-saving technologies, particularly in terms of how quickly and easily they can be implemented while still maintaining a safe and sustainable environment [4]. Since these EVs are more cost-effective to operate, their popularity in the market is projected to grow, especially in congested urban regions. In this work, we focus on the advantages and disadvantages of a V2G system and examine and analyse its application to the deployment of V2G and G2V peer-to-peer (P2P) energy trading. We take into account the two primary links needed to put the idea of V2G into action: Power connections are the first and foremost, as they allow for the transfer of electrical energy to and from the vehicle. The second type of connection is logic and control connections, which enable us to indicate when and where to send electricity based on our feedback.

A. Decarbonization and Reduced GHG

All countries now agree that developing clean energy and improving energy quality is essential in light of the rising global energy crisis and related environmental issues in recent years. Global Sustainable Development places a high priority on reducing the effects of climate change [5]. To accomplish this goal, the production and use of energy will need to undergo a transition to one that produces less carbon. When it comes to the energy sector's low-carbon transition, climate governance, and the route toward sustainable development, electric vehicles (EVs) played a significant role [6]. Grid operators and vehicle owners alike are interested in V2G ideas because of the environmental benefits they provide. The emission from the traditional vehicle is dispersive and difficult to control. The transportation industry is still heavily reliant on fossil fuels on a global scale, which has a wide range of devastating and unfavorable effects for both the environment and society. The EVs can be charged from central power generation sources or distributed renewable energy sources. Renewable energy sources are environmentally friendly, however, the emission from the central power plant can be treated with ultra-low emission technology to reduce the carbon emission. From generation to grid connection, renewable energy sources are very efficient, with an overall value of over 70%, compared to traditional power plants that use fossil fuels, which have an extremely low efficiency of around 30% [7].

When compared to vehicles powered by internal combustion engines, electric vehicles have the potential to reduce CO2 emissions by 62–65 percent in the United Kingdom by the year 2030 [8].

The decarbonization of ancillary service markets, peak shaving of high-carbon electricity sources, and the widespread use of electric vehicles are all promising pathways toward mitigating climate change. There is a decrease in emissions, and it has been estimated that the implementation of V2G techniques in the United States might eliminate the need for 6.5 million barrels of oil equivalent every single day [9]. They provide a potential backup for renewable power sources such as wind and solar power, which supports the efficient integration of power production that is intermittent.

III. IMPROVEMENTS IN GRID ANCILLARY SERVICES

In order to ensure grid reliability, maintain a balance between supply and demand, and provide assistance for the transfer of electricity from the seller to the consumer, the power system requires ancillary services [10]. V2G systems have the potential to present grid operators with additional opportunities, such as frequency control, regulation of active power, managing the reactive power, reduction in peak load, and suppression of harmonics in the power network.

The supply and demand for active power can be brought into balance through the utilization of frequency regulation. At the moment, the primary method for regulating frequency is accomplished by the cycling of massive generators [11]. The application of massive generators is expensive and increases carbon emissions. Reactive power can be balanced between supply and demand by regulating voltage. Each individual EV can act swiftly in response to its own individualized controllable regulating signals. By making the appropriate selection for the current phase angle, the charger is able to adjust for inductive or capacitive reactive power. When the grid voltage gets too low, the ability to charge vehicles can be disabled; when it gets too high, charging can be enabled again.

According to research conducted in Europe on the topic of frequency control, the potential profits range anywhere from 0 to 9,600 € per year per car. In Denmark, it was discovered that revenues based on secondary and tertiary control might vary anywhere from 72 euros to 1,920 euros per year per car [4]. Due to the critical need for reactive power support in the grid system, the system is able to harvest supplemental reactive power from the capacitive devices of EVs and EV chargers to supply the high reactive power needs of inductive devices. When the grid frequency rises over a certain upper-frequency threshold, electric vehicles are able to take in real power, and when the grid frequency falls below a certain lower-frequency threshold, electric vehicles are able to inject real power. For that reason, it can help maintain a consistent grid frequency. Similar to how they can aid in frequency management, EVs can also help maintain stable voltage levels.

IV. ENHANCING THE GRID'S TECHNICAL PARAMETERS

Additionally, V2G has the potential to enhance the technical performance of the grid in facets such as its reliability, stability, efficiency, and generation management. The flexibility of the grid is increased as a result of V2G, allowing for better utilization of intermittent renewable sources. Authors [12] did a simulation analysis of a system with 50,000 PEVs and ten units were carried out, EVs were charged from renewable sources as loads and discharged to the grid as sources. According to the findings of this study, the smart grid model that incorporates renewable sources has the potential to cut emissions while simultaneously saving the transportation and electricity industries at least $3.58 per car each day.

Depending on how price signals are sent out, price control may be an efficient technique to manage power scheduling and reduce peak loads on a distribution feeder [13]. However, this will depend on how the price signals are sent out. If several electric vehicles are being charged at the same time, certain feeders may become overloaded as the percentage of electric vehicles on the road continues to rise. The utility may communicate high prices during periods of peak demand or low prices in order to increase power consumption when demand is low. Since the demand for electricity would fluctuate between two extremes, a straightforward price control scheme would be unstable. The shift in load is an obvious V2G function that contributes to the operation of the grid. In this instance, the V2G power constitutes the supplementary component of the load demand and is then added to the distribution grid's base load. It is clear that the peak load may be reduced using the V2G control approach, while at the same time the valley can have its capacity increased. In addition, the charging of electric vehicles can take place during the night, when wind power plants are more likely to provide surplus power. In addition, the V2G operation has the potential to function in a manner that enhances the power quality of the grid by reducing line losses and voltage deviation [14]. It has been discovered that the overall power losses have been cut down and that there has also been a reduction in the severity of the load limit violence experienced by each transmission line. It is clear that the voltage drop in the buses with significant loads can be alleviated with the appropriate regulation.

Electric vehicles act as a power reserve, bridging the gap between planned and actual electricity consumption [15]. Discharging EVs might reduce peak demand if planned generation is unable to satisfy load needs. Electrical vehicles (EVs) have the capacity to store excess energy generated when the planned output exceeds the actual need. With the help of EVs, the load demand profile can be trimmed to fit the expected generation curve. Load levelling, like peak shaving, requires an EV to charge while load demand is low and discharge when peak load occurs [10]. Load levelling aims to smooth out the overall load profile, while peak shaving concentrates on just the peak [16].

When a generator is "spinning reserve," it is connected to the grid and actively producing power, allowing it to respond to the operator considerably more quickly than a generator that is not spinning and therefore not online. Because of their quick response time, EVs are able to help synchronize the grid much more quickly than traditional generators, which can take several minutes or more to get going [17]. In the event of a failure in the transmission-level generation, the grid's frequency can be restored in a matter of minutes thanks to the EVs' ability to deliver their full capacity.

V. FUTURE CHALLENGES

In spite of the fact that V2G systems offer numerous advantages, an increase in the number of EVs may have an effect on the dynamics and performance of the power distribution system due to the overloading of transformers, cables, and feeders. This results in a decrease in efficiency, the possible need to start additional generators, and the production of voltage deviations and harmonics. The elimination of these obstacles is possible with the establishment of a suitable infrastructure as well as appropriate standards for grid operators. In order to provide stronger support for the V2G idea, EV batteries will need to have an increased life cycle, use materials that are both less expensive and lighter in weight, and be more efficient. One individual electric vehicle has a negligible effect on the power system because the battery storage capacity is modest in these vehicles. As a result, the goal of the V2G architecture is to coordinate the flow of electricity between the grid and a group of electric vehicles (GEVs).

CONCLUSION

In this study, electric vehicles (EVs) equipped with a vehicle-to-grid (V2G) system and various charging strategies are taken into consideration. Additionally, the paper discusses the advantages of V2G technology by examining the effects that charging has on grids. The V2G technology improves significant aspects of an electric grid, including the grid's dependability, efficiency, losses, and overall stability. It is recommended that the V2G must involve a large number of EVs to have a good impact on the grid. Smart parking lots and fast-charging equipment can play an important role in the exchange of energy and provide active power to the grid using batteries and capacitors. The development of the V2G P2P energy trading network shall be operated on a large scale with flexible prices and timing to greatly improve the smart grid.

The potential benefits of vehicle-to-grid technology for society and the environment are more challenging to categorize, but they are undeniably important. The reduction of air pollution and the slowing of climate change, together with the improved integration and penetration of renewable energy sources, are all benefits of this. Overall, there would be many benefits to society from a VG2 transition. The proposal persuasively makes the transport sector part of the answer to transportation issues. This shift might enable automobiles to help power networks become more efficient (and profitable), cut greenhouse gas emissions, make room for low-carbon energy sources, and save money for owners, drivers, and other users.

In conclusion, V2G would be helped tremendously by the dissemination of additional and improved information about the technology, as well as the financial and environmental repercussions of this technology, to customers as well as other engaged sectors, including specialists in the field.

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