

Deployment Strategies of EV School Buses with Vehicle to Grid (V2G) in the US School System

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Abstract— Governments across the world are pushing for speedier adoption of electric vehicles (EVs) in order to meet their target for transition to a greener and cleaner environment that has low or zero carbon emission. Transportation being one of the major contributors to environmental pollution because of incessant burning of fossil fuels. EVs are being considered to be the best possible solution to alleviate vehicular pollution. However, proliferation of EVs create additional burden on the power grids. The consumption of electrical power is steadily rising because of even-growing population and the demand is particularly higher during summer months due to higher use of air conditioners. To ease this pressure on the grid the novel vehicle-to-grid or V2G technology is being employed whereby idle electric vehicles can be put to use as giant batteries that can send power back to the grid to supplement its output. With the wide scale adoption of electrical buses is schools this turns out to be a feasible option. Battery driven school buses are best suited for this. These vehicles remain idle for major portion of the day and also during summer months and can be effectively utilized for generating electricity using their batteries. However, there are challenges involved in the implementation of this strategy. Besides lack of charging infrastructure and limited knowledge of owners about the nature and benefits of the implementation there are also problems of rapid battery degradation, lack of control on the vehicle and the process and high costs involved. Nevertheless, using literature review this article explains the rationale behind adoption of the technology and highlights, the strategies that can be adopted to effectively exploit this novel technology to make the most out of idle electric school buses to support public utilities. To an extent electric school buses and the v2g technology can be potentially helpful for stabilizing

supply of electricity during peak hours and improve efficiency of supply chain management of several industries including the power sector.

Keywords— *electric vehicle, EV, vehicle-to-grid, V2G, electric bus, school bus, electric school bus, charging, deployment, deployment strategy*

1. Introduction

The modern era is looking for solutions to the greenhouse gas (GHG) emissions and cut down on the CO₂ emissions harming the habitat. A large part of that involves bringing down vehicular pollution, one of the major contributors to CO₂ emissions. This has resulted in the adoption of electric vehicles (EVs) especially in the sphere of public transportation. So far as adverse impacts on environment that are leading to climate change are concerned, fossil fuels have been among the key contributors till date [1]. The use of conventional fuels in running modern transportation has been responsible for almost 15% of net carbon emissions at the global level [2]. Electric Vehicle refers to a motor vehicle that has rechargeable batteries which can be connected to the electrical grid and can also be charged externally, from the vehicle's battery pack, and which can be used effectively for powering the drive systems on the vehicle or drive wheels for propulsion [3]. Electric school buses have emerged as the preferred alternative, replacing their diesel-driven predecessors, as the clean, cost-effective, reliable, alternative. The other benefits of adopting EVs for commuting to and from schools are the improvements in children's health and reduction in air and noise pollution within the

communities. But in this article, we highlight another aspect of this changeover to battery-driven vehicle, the electric school buses. These electric school buses once armed with vehicle-to-grid (V2G) technology, have the possibility to turn into the most critical of battery storage sources that can offer steadiness, capacity, permanency and backup or alternative power to the grid. At the same time, they can prove to be a major driver of the transition to a grid that is based on renewable energy. Vehicle-to-grid technology will enable school buses running on electricity to provide emergency power to the grid as and when required besides earning additional revenue for school districts from provision of electricity as income from other services [4].

2. Literature Review

Over the last few decades, issues pertaining to environmental pollution and green energy have emerged as mammoth challenges for scholars and scientists, motivating them to look for ways to save our planet from impending climatic disasters. Almost all recent studies have pointed out that transportation industry is the biggest and the most important consumer of energy and hence the key factor driving air pollution [5]. That is why it is essential to concentrate on the discovery and development of alternative sources of energy that can be used as fuel and to consider novel transportation systems as the key methods for the reduction of negative environmental impacts or consequences. Technological development in the fields of transportation and energy consumption play crucial parts in the development of various strategies to transition to a clean and green energy-based environment and Vehicle to Grid or V2G is one such technology that allows pushing energy back from the battery of an electric car to the power grid.

2.2 Battery Energy Storage

There are 6 key energy storage technologies. These are

- Thermal storage
- Compressed air energy storage
- Hydrogen
- Pumped hydroelectric storage
- Flywheels, and
- Batteries

The electric car plays an important part in storing energy using batteries [6]. Batteries are considered to be more efficient compared to majority of other

forms of energy storage, due to scalability (Nunes and Brito, 2017). The Battery Energy Storage System (BESS) technology has been developed for storing electric charge using batteries developed specifically for this storage purpose, for instance lithium-ion EV batteries [6; 7]. Presently, lithium-ion batteries are certainly the most extensively used batteries in Battery Energy Storage Systems. Developing V2G technology means that these batteries can be used as energy storage system while they remain installed in the electric car. These mobile energy storage systems are used for supplying their stored energy back to the electricity grid as and when necessary [8].

2.3 V2G Technology

The proliferation of electric vehicles and the development of smart grid has resulted in the conception and construction of vehicle-to-grid (V2G) technology that encompasses pulling unused power from the vehicle into the smart grid. The charging device used in the vehicle-to-grid technology absorbs electricity from the battery used in the vehicle and basically just drives it back to the grid, and the power then continues its journey towards the location that is closest to where the electrical power is required [9]. EVs have the ability to draw energy from the grid (during those times when the cost and demand are both low) and discharge energy back to the grid (during those times when demand and costs remain high) and this is made possible by the novel Vehicle to Grid or V2G Technology. Battery-based, V2G enabling technologies such as vehicle-to-grid (V2G) serve as energy storage devices for peak loads on the grid.

Application of V2G technology primarily focuses on the synchronization of discharging and charging of the batteries along with maintaining a balanced charging plan that can alleviate the outcomes of pressures on the power grid, power stability, and balance of power [10]. Progressions in EV Technology have resulted in the emergence of aggregators which have the capacity to amalgamate and combine with the grid to offer viable and exciting strategies related to charging and discharging [11].

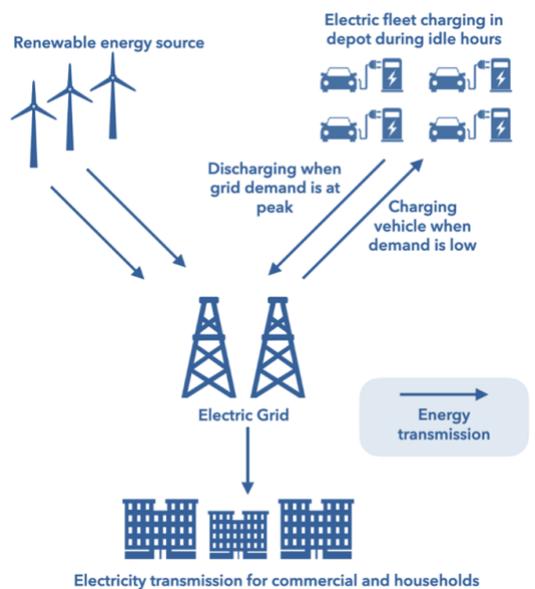


Figure 1. Functioning of V2G [12]

2.4 EVs to Support the Grid

V2G technology transforms EVs, for example electric school buses (ESBs), into mobile batteries that can be utilized for enhancing stability of the Electrical Grid. This class of Distributed Energy Resources (DERs) is crucial to the way electric grid has evolved. Variable renewable energy from a plethora of sources when used in larger volumes can cause voltage fluctuations of the electric grid [13]. This is buffered by energy storage, from batteries in ESBs and other EVs which balances the intermittent availability of energy from several sources like wind and solar energy. To add an incentive, it is possible for utilities to cut down their emissions through the use of ESBs as DERs when there is a surge in demand, rather than burning up fossil fuel reserves to address short-term requirements [14]. Despite being a novel technology with relatively new infrastructure, EVs provide a potential solution for stabilization of the grid [15]. Such technology has the potential to provide an effective solution to the problem of achieving clean energy targets such as aiming for zero-carbon emission by 2045. It can also provide an added benefit to consumers by potentially lowering the cost of electric vehicle ownership. It also provides added income opportunity to the owner of the vehicle as the owners can sell back superfluous power generated using their vehicle and thus equalize other costs [16].

2.5 Benefits of V2G

There are several benefits of an electric vehicle (EV) that include reduction in dependence on oil, increase in charging efficiency and reduction in emission of carbon dioxide. EVs have a unique advantage. It is possible for them to connect to the grid applying the V2G vehicle-to-grid technology [18]. There is limited usage of EV for vehicle-to-grid applications which makes it possible for vehicles to access the distribution network directly [19]. The concept of V2G aids in creating a broad array of distributed energy storage devices that will be available instantly and in introducing various applications and types of batteries into the market [20].

V2G technologies allow idle EVs to transfer the power back from batteries to the grid which makes this technology particularly useful at a time when any area or region is experiencing pressure on power supply due to peak electricity demand since it is possible for V2G to provide power back to the grid to bring down the strain on the grid. V2G technology can also provide the fleet managers a significant amount of savings in terms of cash back since units (kWh) of electricity are returned to the grid which will result in lower costs generated from utility providers [12]. Majority of the vehicles remain stationary for at least 95% of the time, which makes it possible for the V2G technology to leverage that inactivity and makes a two-way exchange of energy possible amongst the vehicles and grid [21]. The energy from the EV batteries is available to the electric grid to serve peak needs, with the vehicles recharging during non-peak hours. Making use of EVs as decentralized electric storage resources brings down the need for capital investments required for the grid to support ever-increasing demand to the minimum and at the same time lowers the cost of operation [22]. When the demand for electricity, was at its peak and available only for premium pricing, the electric school bus used V2G technology and contributed to reduction of carbon emissions in Beverly, Massachusetts and led to lesser need to fire up expensive fossil fuel “peaker” power plants [23].

For the implementation of V2G, it is necessary to consider 2 key connections:

- An electrical power connection that connects a vehicle to the power grid for transmission of electrical energy.
- Logic and control connections that would be used for sending feedback signals indicating the time when power needs to be sent and the direction in which it is to be sent.

2.6 Challenges Associated with V2G Technology

V2G is believed to be the principal solution that can be considered for reducing the cost of charging associated with EV fleets [12]. Despite the multiplicity of benefits that can be derived from the V2G technology, there are quite a few challenges that need to be effectively handled. These challenges, that have been discussed in the following paragraphs, broadly include lessened battery life, communication overhead between EVs and grids, and changes in distribution network infrastructure.

2.6.1 Degradation of batteries

An area of major doubt pertaining to the deployment of V2G technology is that the procedure might hasten the degradation of the battery life of an EV. Depth of discharge and cycling frequency affects a battery's degradation and determines the extent to which and the speed with which energy of a battery is withdrawn [24]. In most battery technologies, such as lead-acid and AGM batteries, there is a correlation between the depth of discharge and the cycle life of the battery (Federal Batteries, 2020). Users are of the opinion that the occurrence of higher number of charging and discharging, might result in more rapid degradation of the EV battery when compared with the common usage. The cost of battery production has been declining constantly. Nevertheless, it can still make up 40% of the total cost of an electric vehicle [26].

Generally, the primary preference of the users is to extend the life of their EV batteries that will result in cost reduction from the point of view of battery replacement. In addition, EV manufacturers remain reluctant to provide warranty on their products for V2G service due to the concern pertaining to degradation of batteries. A large number of research have been conducted with the purpose of proving that V2G causes degradation of the EV batteries or otherwise [26].

The researchers and scholars are divided in their view on the impact of the vehicle to grid technology on vehicle batteries. There are sections of researchers who are in favor of the technology while others are against it. In 2017 the University of Hawaii carried out a study that provided results against the V2G technology. This study pointed out that there is a lot of strain on the battery cell caused by the unmanaged charge and discharge patterns by V2G that ultimately results in the loss of capacity of the EV battery. According to these researchers, application of V2G technology twice a day, has the

potential to cause as much as 75% reduction in the capacity of the battery over the long term (5 years). On the other hand, using V2G daily could lead to a battery capacity reduction of up to 33% [12].

On the contrary, a study carried out by the University of Warwick in 2017 pointed out that degradation of EV batteries can be controlled using the V2G technology. The same study pointed out that controlled V2G is far superior option than allowing the batteries to age naturally over a period of time. Battery degradation has the potential to cause a lot of damage to EV fleets resulting in lower driving range and reduced residual value over the longer term [12].

2.6.2 Strain on the Charging Infrastructure & Utility Grid

Electric vehicles have witnessed exponential growth and the minimization of the strain on the power infrastructure makes it imperative that the EV charging demands be well-adjusted with supply limits of the existing grid. Vehicle-to-grid or V2G charging is being construed as one of the key promising solutions that can potentially handle this challenge [22]. Although EVs are intended for transportation primarily, they can also serve as fast-response load and make power for the Distribution Network when parked, in this case when plugged into the supply grid and enabled to transfer power to the grid [26].

Loading the EV fleet to the grid is the basic concept for employing the V2G technique. A time-of-day tariffs framework highlights the peak hours in the morning and evening and the off-peak hours and helps to employ V2G during peak hours and G2V during off-peak hours [27]. The process, however, could strain the power grid if not correctly scheduled. Unscheduled power insertion from the EV fleet alters the electrical parameters such as voltage drops, current, line losses, and system harmonics.

The prerequisite for bringing EVs into the mainstream transportation system is interoperability [28]. When larger number of vehicles become V2G compatible, it becomes necessary that the EV owners are able to utilize and benefit from different charging stations even if they remain the customers of a single service provider. In order for V2G to succeed it must have the capacity to be implemented across a wide variety of platforms without being highly expensive. There should be higher uniformity when it comes to intelligent charging and expenses involved in charging or for the injection of power into the grid. This necessitates having some kind of benchmark or need for interoperability from the policy makers

that will support the construction and maintenance of charging infrastructures [17].

2.6.3 Efficiency of Charging

The emergence and proliferation of electric vehicles has a significant influence on the electricity grid because of the electrification of vehicles in the transportation sector. As a consequence, several different techniques must be employed to reduce the impact of charging on the grid to the minimum. Among the available techniques is the strive to arrive at a smart coordination between various different apparatuses or constituents of the electric vehicle charging network. This is necessary to make sure that network has adequate electricity that can be used to support the charging requirements of the electric vehicles [29]. The uncoordinated charging of large numbers of electric vehicles is likely to lead to such glitches in the distribution network devices as low-voltage operation and overload [30]. Whether an ICE (internal combustion engine) or EV the average car remains in parking for almost 95% of the day [22]. V2G connectivity presents the opportunity to administer, control and enhances the efficiency of the grids by leveraging a huge number of EVs for energy storage, having inconsequential cost of capital and operations. Smart charging can be used as the point of focus for putting EVs to use as decentralized resources for storing electricity that can provide assistance to the overall power systems and minimize, and in due course prevent, reinforcement of the grid. From the point of commercial feasibility, use of V2G technology in the future is likely to involve giving a discount on consumption of electricity to the drivers of electric vehicles as an incentive for all those who would be ready to offer their EVs for the purpose of storing energy [21]. A scheduling strategy can be employed for reducing the charges necessary and accomplish a load curve that is smoother, and is more suited for online scheduling of vehicles [30].

2.6.4 Phase unbalance and voltage instability

The increase of renewable energy sources on one side and the advent and subsequent growth of electric cars on the other, has made costly expansion projects of low voltage networks necessary in numerous cases. Taking the help of alternative methods such as V2G or Vehicle to Grid applications, such expensive expansion actions can be worked around [31]. Voltage instability issues could cause significant disruptions of functioning systems as the operations run close to its optimum

stability limits [32].

EVs have a few distinct features because of which it is impossible to predict and calculate their consumption of energy and requirements for power cannot with the same level of accuracy as conventional loads (for example domestic, commercial and industrial). To add to the difficulties, a lot more power is required for charging batteries for an EV over a shorter span of time [33]. And since a number of EVs are getting charged by single-phase private charger, phase imbalances pose a significant challenge. There can be significantly low levels of EV penetration, resulting in minor phase instabilities. In cases, where EV penetration is very high and chargers are unevenly distributed among different phases, VUF may be more than acceptable limits [34]

2.6.5 Lack of Control and High Cost

In order for the V2G grid to turn out to be reliable and can be put to use as a storage for energy, a significant number of EVs need to become part of it. The key concern of the EV owners pertaining to V2G emanates from the owners' perception regarding the lack of control. For the average electric vehicle user, energy markets still remain relatively less known and understood and hence V2G is considered to be risky to a certain extent and despite EV owners knowing that it is good, they do not fully comprehend the manners in which it works [17].

A key conceptual barrier to comprehending vehicles as a source of power is the primary belief that their power can't be predicted properly or may even be unavailable simply due to the fact that they would be on the move. It is true that the power available from a single vehicle plug is likely to be or may be unpredictable. However, the availability of thousands or a substantially large number of vehicles is predictable to a large extent and can be estimated from the data generated by traffic and road-use [15].

If V2G is not utilized for majority of the electric vehicles, then the requirements pertaining to energy storage as well as the general investment cost for the grid is likely to remain substantially high [17]. However, no additional investments in hardware is necessary for the electric vehicle batteries, which make them far more cost-efficient form of energy storage.

A study conducted in 2015 discovered that economic analyses that favored V2G were unsuccessful in capturing a large number of the costs associated with its implementation that are apparently less obvious. On inclusion of these less obvious costs, the study concluded that V2G was

not an economically efficient solution [35].

2.6.6 *The load profile of electric vehicles*

Electric vehicles as also distributed networks present different issues in front of the policy makers, which makes it essential and in a way better to project and be prepared for heavy load coming from the rapid increase in the number of vehicles beforehand in order to avoid any undesirable effect on the functioning of the supply grid [36]. In order for the V2G grid to be reliable and be used as a storage for energy, it is essential to have a large number of EVs as a part of it [17]. However there is significant dearth of detailed information pertaining to the use of each vehicle, which make it impossible to fully analyze both the necessary and the damaging influence on the supply grid [37]. Highland Electric Fleets (Highland) has partnered with Borg Warner, Thomas Built Buses, Synop and Proterra to pioneer commercial V2G technology powered electric school buses (ESBs) that ensures grid stability while bringing down the cost involved in fleet electrification for school districts as well as fleet operators [38].

3. **Electric School Buses are Preferred Choice**

Despite several problems in adoption, the economic value of certain varieties of V2G are found more elevated than others and is more than adequate to offset the originally elevated costs of electricity driven vehicles, and has the potential to speed up their adoption [15] Among the EVs that can be utilized for the V2G technology, electric school buses are more frequently being considered or christened to be the ideal use case for vehicle-to-grid technology [39].

A huge number of school buses are required in the U.S. despite the fact that they sit idle for major part of the day. Maximum number of school buses are used only a few hours per day in transporting students when the school is in session, and remain parked almost throughout the summer months, when demand for electricity is often remains at the peak [38]. On an average, school buses remain parked for nearly 18 hours per day when the school is in session and nearly 3 months during the summer. It makes a lot of sense to give these idle vehicles another assignment for extra income. The times during which they are not being utilize for students' transportation, it is possible to use these

electric school buses as miniature sources of power that are mobile and can supply power using their battery storage [40].

Battery operated electric school buses or BEB is a fully electric bus, that uses battery pack to store electrical energy and provides power to the engine. Hence, BEB batteries are charged by plugging into an electric charge point which is connected to the power source. About 3,000 BEBs are currently in operation, and this has grown by about 24% over the past one year. This growth of BEBs is not only expected to expand but also diversify into other applications like school buses which are currently the least dominant area for electric buses and the majority of them still run on diesel with a significant less percentage using alternative fuels like Propane or natural gas. Multiple manufacturers are now offering such electric school bus models which meet the seating needs and distance being covered by each bus with single charge effectively meeting the current needs of space and range of school buses [41].

School buses have certain unique characteristics, which make them an ideal source of energy storage and emergency power. The usage patterns, being time bound and rhythmic that too for almost the whole fleet being used simultaneously and being parked for hours allow them to be used as a large source of energy storage, especially during periods when the electric grid is most vulnerable. If all yellow school buses currently in operation, everyday across the United1 States were replaced with a V2G-capability electric bus of the same size and capacity, it would add more than 60 gigawatt-hours (GWh) to USA's capacity to store electricity [4].

Electric school buses have the capacity to bring greater benefits, if they are outfitted with technology that allows them to deliver power back to the grid. Vehicle to Grid (V2G) technology provides school buses to provide grid stability especially during emergency when power is being sucked out of the grid, thus also providing a revenue stream to school districts for providing these invaluable services. Policy-makers, manufacturers, school administrators and transport operators should collaborate to unlock these benefits by creative public policies and partnerships [42].

Electric school buses can also play an important role in stabilizing supply chains. Efficient management of supply chains necessitates

balancing of cost, excellence, swiftness, and elasticity in response to changes in market demand [43]. This is what exactly the ESBs will help in – to handle peak demand in the power sector.

4. Problems of Procurement

EVs are emerging as the future of supply chain management (SMC), propelling technological advancements, urging responsible consumption of energy, and bringing about better connectivity [44]. Electric School buses are expected to play an important part in the faster adoption of e-mobility. They have the same manufacturers and supply chains as other medium and heavy duty (MHD) electric vehicles (EVs) and would assist the evolution of these supply chains through creation of larger volume of work which would result in the rationalization of costs due to a stronger supplier base and lowering of prices of components [45].

One of the primary challenges with eMobility programs is the cohesiveness between government objectives and what OEMs and the supply chains can deliver on a sustainable basis. Complex supply chains and economies of scale are involved. EV technology is proven to be a workable solution but the supply chains which will be supporting these technologies need to be upgraded to an industrial scale to handle and support the production capacity and financial sustainability to reap the full benefits of this transition [46]. Huge upheavals in jobs, company business direction and entire industry groups may see different strategies to address these changes in order for eMobility to progress and succeed. While government strategies may vary at the time of addressing this change, it will be imperative to have a common policy in effect; particularly related to the automotive sector activities that affect the political economy of eMobility programs [47]. Manufacturing continues to be a key hurdle for the growth and expansion of the market for electric school buses because of supply chain disruptions for major components like high-voltage power electronics and chassis and increases in the price of raw materials [48].

5. Strategies

Electric School buses that run on batteries are fast emerging as the finest candidate in the drive toward establishing grid that has low carbon emission. It commences with the vision to cut down the carbon emissions by switching over to electrified fleets from diesel-powered vehicles [49]. U.S. electric utilities are constantly trying to explore the ways in which electric school buses can be made to function as enormous rolling batteries that can

provide support to the power grid, making the greater generation renewable electricity possible and make provision for disaster relief, using the vehicle-to-grid or V2G technologies. More than 15 utilities spanning across 14 states have earmarked and dedicated experimental electric school bus V2G programs, that will make it possible to store electricity in the bus batteries that can be discharged onto the grid later. The stored power of the batteries of these electric buses has the potential to help stabilize the fluctuations in the energy conditions, lessen the demand for additional power and hence the need for setting up additional generation units to exploit more resources. This can be achieved through the shaving of peak energy requirements and providing mobile technology to generate emergency power that will supply to shelters and other essential facilities.

It is a matter of common knowledge that school buses operate daily following set schedules and more often than not, sit completely idle during vacations, especially in the summer months and during parts of the school day when electricity demand is particularly high. They can be deployed effectively without sacrificing their current utility and are thus ideal for the adoption and implementation of this novel technology. The power that they would be providing to the grid or the buildings have the potential to offer substantial revenue that can help pay for the use of these electric school buses, which will be a win-win situation for both the schools and the public utilities or other entities that use this electricity [23].

Electricity driven school buses that are being utilized to implement the V2G technologies present an opportunity to develop and roll out an equity-driven plan given the safer environment, the health benefits and sustainability that are likely to be augmented in communities that still remain underserved. In these communities, residents face much elevated levels of pollution and continue to face higher susceptibility to adverse impacts of climatic changes. Several V2G utility programs have been proposed, several such programs have been deployed. They all have one thing in common – the focus on better serving these underserved communities, that have been identified through such indicators as the number of students who are eligible for free and reduced lunches or average income of their families.

Battery driven electric vehicles, connected cars and plug-in hybrids, are those vehicles that are capable of connecting to the grid. Policy makers, regulators, legislators, and automobile manufacturers need to promote these connected vehicles. The principal characteristic of a connected car is that it is able to draw energy from the grid,

the lion's share of which is generated from non-petroleum resources, and use that to replace the energy derived for petroleum. Once a fleet of battery driven electric buses is set up, vehicle-to-grid collaborations or V2G will automatically come in as the next logical development.

The advantages of using V2G technology are augmented using another type of connection that involves a wireless internet communications link which will make it possible for the electric buses to serve as a quick response resource that is dispatchable easily and has a distributed generation. The dual advantages of substitution of energy and providing support to the grid address a wide array of economic, environmental and energy challenges that are interrelated and include exhaust emissions, import of petroleum, energy security, power generation capacity and the reliability of such power generation, utilization of renewable energy, and costs pertaining to technology and infrastructure. Electricity driven school buses have the potential to provide all these benefits, through the use of V2G technology which help them return the power they draw from the grid, back to the grid at the time they are parked idle [50].

The EPA is providing rebates to applicants for electric school buses and can plan on building electric bus fleet. Exploiting the concept of bi-directional charging, including vehicle-to-grid (V2G), as a probable energy source for the grid can be provided and at the same time the operators can earn additional revenue for fleet in the future. However, V2G technology is not ready for extensive or large-scale use yet. It is necessary for the customers to first understand where the technology is positioned at the moment and how they can focus on the reduction of the energy costs without compromising on operational availability [51]. EV component supply chains face problems because of disruptions caused by recent pandemic and lockdowns, disruptions at US ports and geopolitical instabilities which calls for onshoring of production to make supply chains less vulnerable and stabilize ESB production [48].

6. Conclusion

Vehicle-to-grid or V2G refers to a charging technology that can prove to be mutually beneficial for consumers as also the energy companies. It makes unidirectional flow of energy from the battery of an electric vehicle back to the power grid possible. This technology will enable the vehicle owners to take the best advantage of their existing electric vehicles, as these vehicles essentially turn into giant size mobile batteries that run on wheels and provide assistance to the grid in terms of

sharing its burden during peak hours by sending energy back to the grid.

This technology and the complete process becomes especially important at a time when the grid is generating energy from such volatile renewable energy sources as wind and solar. The application of vehicle-to-grid (V2G) holds a lot of promise from the perspective of optimization of the demand for power, determination of the variation in load on the grid, and increase in the sustainability of smart grids. Vehicle to grid technology makes room for bidirectional energy exchange between electric vehicles and the power grid. This offers several services to the power grid, which includes but is not restricted to regulation of power grid, spinning reserve, shaving of load during peak hours, leveling of load and providing compensation to the reactive power. Since the application and execution of vehicle to grid technology is a complicated problem which has various conflicting objectives as well as constraints, optimization techniques are usually employed.

By ensuring a successful implementation of the V2G concept it would become possible to enhance the efficacy, dependability and stability of supply grids and power distribution networks. Electric vehicles can be used as a power source to charge the batteries and distribute from the same batteries during peak demand which increases reliability of the system. V2G application enabled vehicles have load balancers, ability to regulate active power, the suppression of harmonics, ability to provide reactive power support, shaving peak loads thus lessening utility operational costs and overall maintenance and servicing costs which in turn heightens load factors thereby contributing positively to revenue generation, bringing down carbon emissions and monitoring renewable energy sources.

A massive number of school buses are required in the U.S. despite the fact that they remain idle for major portion of the day. Among these the electric ones can easily be turned into backup batteries for the grid which, in turn, can provide them a fresh lease of life besides providing the school districts the necessary financial boost. The buses can be put to overnight charging, as the grid has lower stress at night and cost of charging is also low, and then during the day these buses can send the energy back to the grid. This is the time when the grid comes under a lot of stress due to constant running of air conditioners. It is therefore possible to sell the energy back at a higher rate and earn a decent revenue to supplement. Though at a nascent stage the technology holds a lot of potential for achieving the economic and environmental goals outlined by the government. To an extent electric school buses

and the v2g technology can be deployed for effectively handling and stabilizing the supply of electric power during peak demand hours using batteries of idle school buses which can help to enhance the efficiency of supply chain management of several industries including the power sector.

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