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Vehicle to Grid Technology

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Abstract : *Adverse effects of fossil fuel burning and internal combustion engine vehicles have alarmed nations worldwide. Governments are taking steps to promote the use of Electric Vehicles due to less carbon emissions and to pacify the environmental issues. The added load of Electric Vehicles poses a threat to the existing grid which leads to instability of the grid. The problem of demand supply mismatching can be solved by integrating the renewable energy sources with Electric vehicle charging station resulting in bi-directional flow of power. Vehicle to Grid technology helps the utility with active and reactive power support by feeding power from battery pack to grid and vice versa. Vehicle to Grid describes a system in which electric vehicles, plug-in hybrid, fuel cells electric vehicles are connected to the power grid to provide high power, spinning reserves, regulation services etc. The perspective of this study is to evolve a smart charging schedule based on the load on grid, time of use of the EV and other factors in order to minimize cost of charging for electric utilities and EVs as well as promote profits to EV owners.*

Keywords - *Bi-directional Power Flow, Demand Supply Mismatch, Electric Vehicle (EV), Smart Charging Schedule, Vehicle to Grid (V2G).*

I. INTRODUCTION

Nowadays, the demand of electricity is increasing which requires the enhancement in power generation. The diminution of fossil fuels has also become a matter of concern to the world. The prolonged use of fossil fuels also leads to environmental hazards such as GHG and CO2 emissions. To promote sustainable, low emission development, many countries are adapting renewable energy sources to meet the load demand. Integration of renewable energy sources such as solar and wind has become possible but they are more variable and uncertain than conventional sources; also, it requires changes in the power system planning and operation. Therefore, it is necessary to build an energy storage system which will improve the power quality of the grid which leads to increase in the capital cost of the system. Electrification of Transportation sector assures a reduction in the environmental issues. It is an effective solution to reduce GHG emission caused by combustion engines. Additionally, electric companies can improve power quality by employing EV integration. Electric vehicles have become very popular in recent years and a continuation of this trend can be predicted in the near future until the day most of the transportation sector will comprise of EV.

A big portion of vehicles are expected to be parked during a major part of the day. This idea can be used to facilitate V2G technology. During these idle times, plugged-in EVs can be used to support bidirectional power flow between utilities and EV batteries.V2G is the latest attraction in the field of EVs and their integration with electric grid. According to this concept, bidirectional flow of electric power is taken into consideration, that is power can be taken from grid to charge EV batteries during off-peak hours and power can be provided to grid during peak hours from EV batteries to reduce utility load. This paper reviews and analyses the application of electric vehicle in a V2G system by highlighting its benefits and overheads offered by such a system.

II. Methodology

2.1 Grid to Vehicle (G2V)

The concept of Grid to Vehicle (G2V) includes the smart charging schedule which controls the charging rate of battery for EVs (increased or decreased) when needed. It is the unidirectional power flow between the grid and EV. The realization of Grid to Vehicle is inexpensive as it includes the simple controller to manage the charge rate. The average personal vehicles on the road are only about 4-5% of the day, which means most of the day the vehicles are parked. In order to plan a scheme for a proper dispatch of power, the grid operator needs to rely that sufficient vehicles are parked and can be connected at any time during the day.

G2V can provide auxiliary services to the grid such as spinning reserve and power grid control. This improves the flexibility of the power grid operations. The flexibility of the power grid operation is significantly improved due to these auxiliary services. One of the prime requirements of the implementation of grid to vehicle is having an energy trading polices set up between the EV lenders and the power utility. In order to encourage the participation of the customers, this trading process should ensure the income for EV owners when they charge their EV during off peak hours and reduces the charges during peak hours. Additionally, overloading of the power utility can be avoided during the peak hours. Therefore, G2V implementation achieves maximization of profits by optimizing the operation of the system. However, these services are limited by the ability to provide ancillary services to power the grid. Functions such as peak load shaving, reactive power support, voltage and frequency control are the services which can only be possible to achieve with V2G. The diagram of Grid to vehicle is shown in the Fig.1.

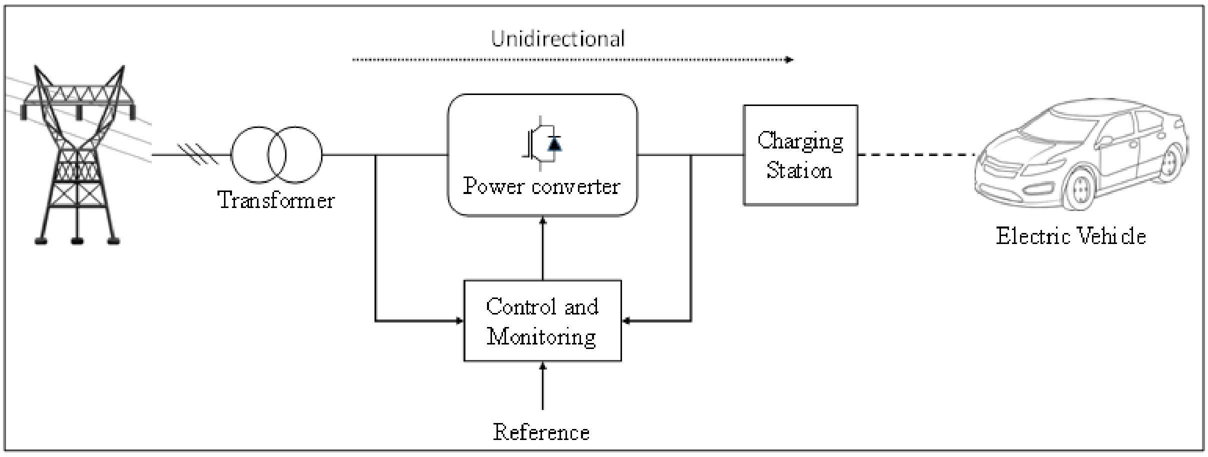

Figure 1: Block diagram of Grid-to-Vehicle

2.2 Vehicle to Grid (V2G)

V2G technology facilitate to push back the energy to the power grid from the battery of an electric vehicle, also, it can be charged and discharged based on various signals such as energy production or consumption. It helps to mitigate climate change by allowing our energy system to balance more and more renewable energy. It is the one step forward of G2V, the idea is to develop the smart charging-discharging schedule where the vehicles will store the energy during off-peak hours and discharge it during the peak hours as required. This can be achieved through the use of a 'smart grid' concept which is an electrical network that can process information, controls the flow of electricity to fulfil the end users varying power demand and is able to provide communication between generation sources and end users.

When a vehicle is in idle state, the on-board battery is connected to an electrical grid through appropriate communication devices to provide functions such as load-shedding, peak shaving etc. This concept works on the balance of the 'off-peak' and 'peak' demand. The block diagram of V2G technology is shown in the Fig. 2. Also, the technology of Grid to Vehicle and Vehicle to grid is shown using the demand-generation curves in the Fig. 3.

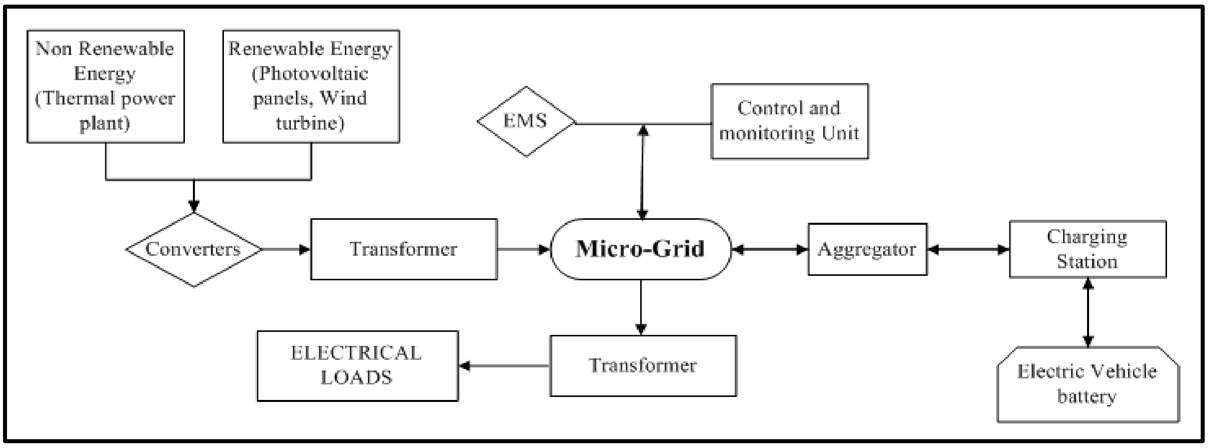

Figure 2: Block Diagram of Vehicle to Grid Technology

The components of the block diagram are explained below:

1. Energy Sources: It includes Renewable and Non-renewable energy sources. Renewables includes Photovoltaic panels (solar to electrical), Wind turbines (wind to electrical). Non-renewable includes any of the fossil fuel power plants, and is treated mostly as the base load power plant.
2. Electrical loads: The system that consumes electricity are known as electrical loads. It may be residential, commercial, industrial, etc.
3. Aggregator and charging system: Aggregator an intermediate between electric vehicle (EV) and operator of power grid. They are responsible for the management of EVs to provide owners with their own orders and to increase the profitability of the power grid in the electricity market. The aggregator, based on the information obtained, decides the set of EVs to charge / discharge command. These decisions are based on the regulation market price and regulation reference announced by the grid operator “TSO” and “DSO”. There is only one aggregator which manages the various EVs from different charging stations. The command from the aggregator is followed by the charging station where the vehicles charge or discharge according to the requirements.
4. Control and monitoring Units: In order to integrate EVs into the power grid, the control devices have to be continuously monitored and controlled by the power system administrator. In addition, the administrator also has to constantly upgrade infrastructure to manage the charging and discharging of the vehicles. An energy management system (EMS) can be defined as a collection of computer-based tools that are used by grid operators in order to control, monitor and optimize the performance of the power generation and transmission system. Also, it can be used in small systems like micro-grids using SCADA/EMS or EMS/SCADA computer technology.

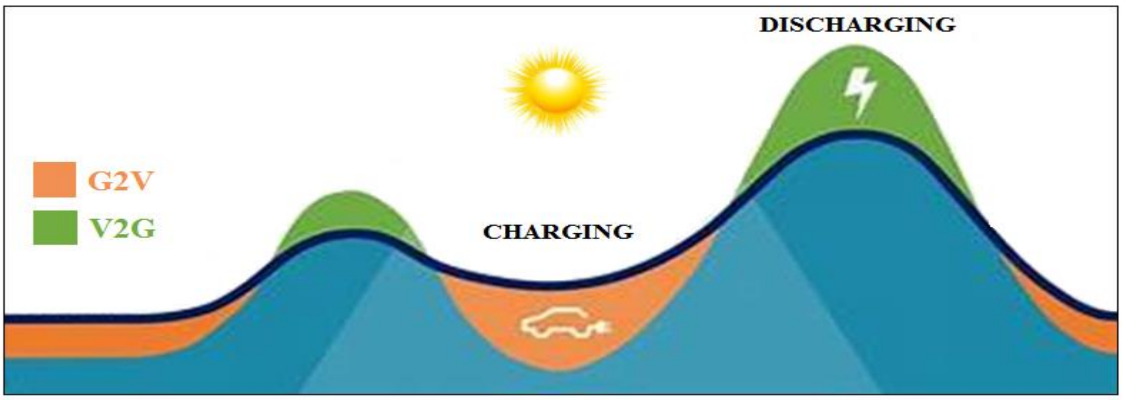

Figure. 3. G2V and V2G using demand-generation curves

2.3 Proposed Model of V2G

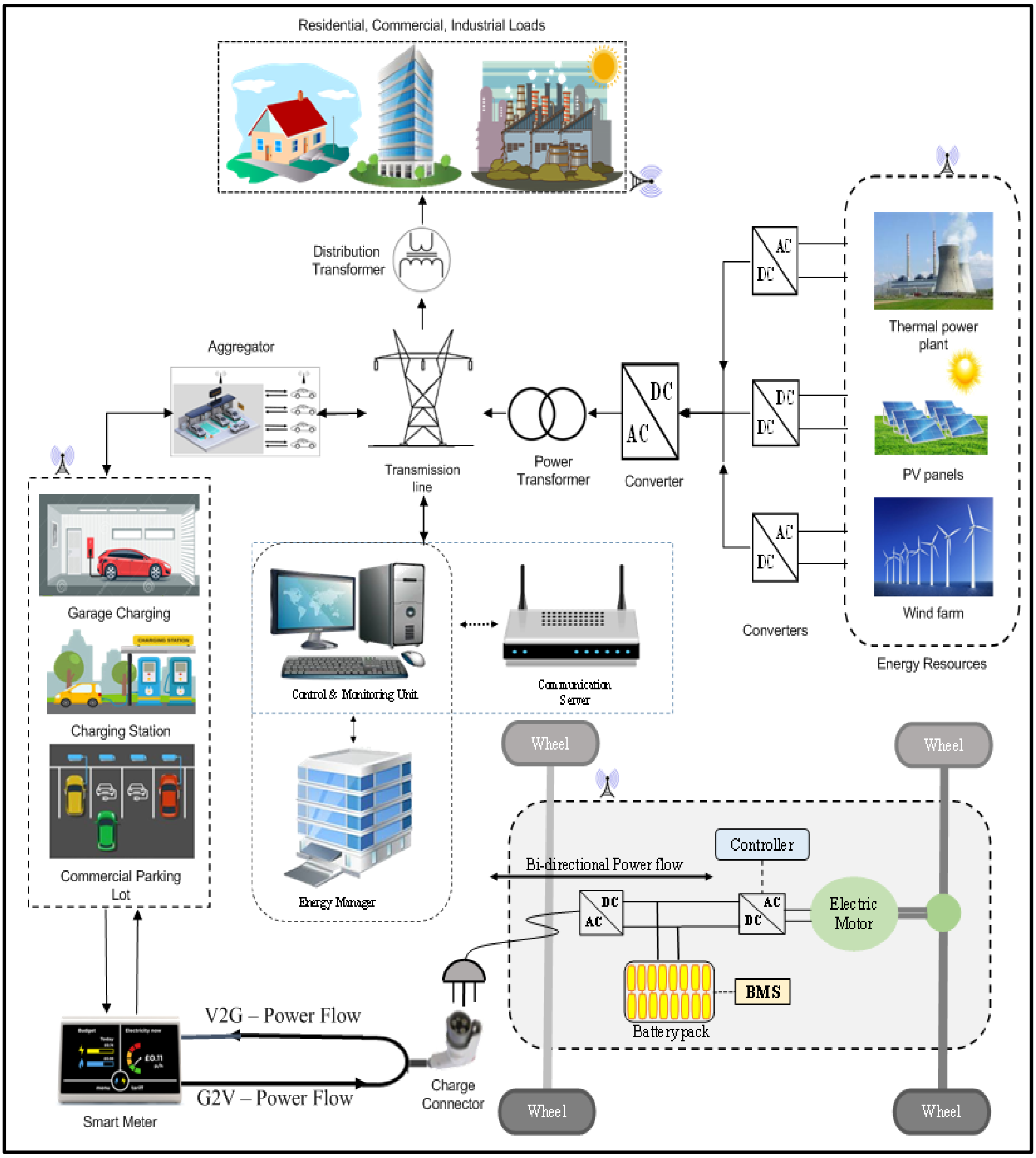

Figure 4: Proposed Model of V2G

The power generated from the renewable & non-renewable sources is converted into AC with the help of a power electronics converter and is stepped up using the transformer before entering into the grid. The power from the grid is stepped down using the transformers and is supplied to the loads. The Energy manager will monitor the generation and the demand. If there is demand-supply mismatching then it will give the command to the aggregator. Aggregator is the interface between the grid and charging station. As the demand increases the EM will give the command to discharge the vehicles in the charging station and vice-versa. With the help of smart meters, the data of discharge and charge is recorded and monetary transaction takes place. This requires the development of a smart schedule based on the previous load demand curves and data available. The entire system is connected to a communication server to avoid inappropriate communication.

2.4 Benefits of V2G

2.4.1 Ancillary Services

It becomes obligatory to provide the ancillary service in the power system to maintain the reliability of grid, to equipoise the demand and supply and to transmit the power supply from seller to purchaser. As the concept of V2G is bidirectional it provides higher quality ancillary services that is better frequency and voltage regulation, peak power shaving, load management and providing efficient spinning reserves. For Bidirectional power supply each vehicle can be used separately or it can be connected to the aggregator. The aggregator is responsible to govern the group of Electric vehicles in order to supply the suitable load for the services and utility sector.

a. Frequency and voltage regulation: Because of higher market value and the lesser stress on the power storage system of an electric vehicle the regulation service becomes the first step in implementation of V2G technology. To achieve balanced supply and demand of active power the regulation of frequency is adopted and for balanced supply and demand of reactive power the voltage regulation service is consider into account. The cycling of large generators is use to achieve the frequency regulation but it has the higher cost. The fast charging and discharging rates of EV batteries make the V2G system an effective substitute for frequency regulation. Electric vehicles respond quickly to regulate signals that is managed by each EV separately. The voltage control is fixed in the battery charger which helps in compensating the inductive or capacitive reactive power by selecting the appropriate current phase angle. To stabilize the frequency three types of control is defined as primary, secondary and tertiary control by Union for Coordination in Transmission of Electricity. During the charging process of the battery, it provides the regulation down and when the regulation up is required the battery of EV is either disconnected from the charging or it can also provide the supply back to the grid.

b. Load Balancing and peak shaving: V2G can manage the load by supplying the power back to grid during peak hours and charging the battery during non-peak hours. The scheduling of charging and discharging the EV battery helps to balance the load of the system. Peak power shaving also offers additional benefits such as reducing various unwanted factors like line losses, delay transmission, transmission congestion, etc. It also helps in reducing the stressed operation of a power system, thus adding to its longevity in terms of lasting. This leads to avoid heavy investments in installing peak power plants.

c. Spinning Reserve: The extra generating capacity is made available by switching on the additional generators which is connected to the grid and are known as spinning reserves that is the reserves are provided with online generator which will change the output instantly in response to major transmission outages. With reference to the time of request the additional power supply is made available in short time duration. However, the capital cost of these reserves is higher. V2G integration solves this issue by meeting sudden demands for power. In the case of spinning reserves the EV owners are paid for service as well as for their capability of providing the power supply during the spontaneous event like generator failure. In case of sudden peak requirement at the factory or workstation the employees EV would remain connected to grid and can be called upon for addition power supplies.

2.4.2 Renewable Energy Integration

In V2G technology the renewable energy resources are used to buffer and store the energy generated by the periodic wind and solar power plants. When grid power from renewable energy resources is too high, the main power plants must reduce the production to restore balance or the distributed generator units must be curtailed. Vehicles can help match consumption and generation by discharging and charging. EVs also store excess renewable energy. The time of day for which maximum power is available is around 1 pm for solar, whereas wind energy peaks overnight around 4.30 am. The regular model for the peak electricity predicts higher demand between 4 and 8 p.m. This stored energy is used for driving needs or to provide power to the grid during peak hours. V2G increases the flexibility for the grid to better utilize seasonal renewable energy resources.

2.5 Challenges

2.5.1 As compared to the traditional electric vehicles only employing G2V, EVs employing V2G have much more charging/discharging cycles. This leads to faster battery degradation. The degradation becomes worse with a deeper battery depth of discharge, operation at low temperatures and operation at the extreme points of SOC. The measurement of equivalent series resistance (ESR) of the battery helps predict life cycle of the battery. An increased ESR indicates a deteriorated state of the battery. Using the battery in the middle SOC range is a good way to slow the degradation

2.5.2 V2G implementation requires high initial costs owing to the requirement of smart grid and bidirectional-charging infrastructure.

2.5.3 The charging/discharging cycles likely to have an appreciable impact on the distribution equipment. The possible loss of transformer life could significantly impact the reliability, security, efficiency, and economy of newly developing smart grid. The life of a distribution transformer can be considerably improved by using a controlled charging scheme.

2.5.4 The demand for EVs has grown significantly in recent years. This guarantees the requirement for extra generation capacity.

2.5.5 There will always be a degree of uncertainty in the minds of EV owners as to whether the amount of charge left will be sufficient for the trip back to home if they take part in V2G activities. This problem can be mitigated by using properly planned and appropriately distributed charging stations.

2.5.6 As mentioned before, smart grid is the backbone of V2G implementation. However, smart grids are vulnerable to a lot of problems and hence has to be constantly monitored to detect abnormalities, measures need to be taken to resist hacking of communications and power networks. Additionally, the power quality, reliability and efficiency also need to be closely monitored.

2.6 Projects Implemented

2.6.1. MASERA (Micro grid for Affordable and Sustainable Electricity in Remote Areas) Project

MASERA micro grid project was launched by EDF, Enedis and NTU(Singapore). This project demonstrates the reliability of off-grid and microgrid solutions which are developed in order to operate smart grids on islands where there is no access to the main grid; taking into account the geographies, the current lack of infrastructures, and the need of independent and reliable power supply. It is located at the Semakau landfill, an offshore microgrid testbed that combines multiple RESs to create solutions to address regional electrical problems. The main components of this project include **-** Bifacial photovoltaic panels (50kW), Lithium-Ion storage system, Nissan Leaf electric vehicle, V2G software platform and bidirectional charging hardware, EDF's Distributed Energy Resource Management System, Reliable & Smart metering infrastructure

2.6.2. EDISON Project

EDISON project looks over how large fleet of EV can be integrated in a way that supports the grid while benefitting both car owners & public by reducing CO2 emission from vehicles. It is demonstrated on the Danish island of Bornholm and has been simulated to estimate the impact of EV fleets. The project focuses on EVs as DERs (Distributed Energy resources) and represents primarily a large power consumer, which can provide some balancing power during peak hours. The aim of this project is to improve the utilization of variable wind energy supply by coordinating the charging and discharging of EVs and, satisfy the EV owners energy needs. Also, their aim is to obtain a rough model that allows them to develop the data collection, forecasting and optimization of operational aspects of the overall system.

2.6.3. INVENT (Intelligent Electric Vehicle Integration) Project

INVENT is a project directed by Nuvve at the University of California, San Diego campus. It is the largest Vehicle grid Integration (VGI) project in California. The primary goal of the project is to determine the capability of electric vehicles to transfer power from and to the grid. Additionally, services such as demand charge management and frequency regulation of the grid are also explored. Benefits of this project include stabilization of electric grid, support integration of RES, revenue generation and a Virtual Power plant. This development reduces the cost of maintaining the

Infrastructure costs as well as Energy costs of Electric vehicles. This is a small step at eventually achieving its goal of being carbon neutral by 2025. GiveTM is a software aggregation platform developed by Nuvve and it helps control the entire operation by enabling the EV batteries to store energy and discharge energy when needed.

III. CONCLUSION

Vehicle-to-grid capabilities provides important services to grid operator, which includes the balancing of renewable peaks and valleys, providing spinning reserves, and balancing frequencies. In further studies it will be shown that V2G improves the technical performance of the grid in areas such as power quality, efficiency, stability and reliability. V2G technology also encourages the use of renewable energy sources like solar and wind energy which is beneficial in account of environmental conditions. The challenges to the V2G technology include battery deterioration, reduced life of PEV, need for comprehensive communication between vehicles and the grid, effects on distribution equipment, infrastructure changes, social, cultural and technical problems and increased cost of generation. These challenges can be mitigated by certain specific measures as mentioned in the paper. In addition to the points mentioned before, the benefits of V2G also include economy of operation for both EV owners and grid operators as well as environmental benefits. These benefits far outweigh the drawbacks and challenges as pointed out in the paper.

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