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Research article

Potential performance analysis and future trend prediction of electric vehicle with V2G/V2H/V2B capability

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Abstract: Due to the intermittent nature, renewable energy sources (RES) has brought new challenges on load balancing and energy dispatching to the Smart Grid. Potentially served as distributed energy storage, Electric Vehicle's (EV) battery can be used as a way to help mitigate the pressure of fluctuation brought by RES and reinforce the stability of power systems. This paper gives a comprehensive review of the current situation of EV technology and mainly emphasizing three EV discharging operations which are Vehicle to Grid (V2G), Vehicle to Home (V2H), and Vehicle to Building (V2B), respectively. When needed, EV's battery can discharge and send its surplus energy back to power grid, residential homes, or buildings. Based on our data analysis, we argue that V2G with the largest transmission power losses is potentially less efficient compared with the other two modes. We show that the residential users have the incentive to schedule the charging, V2G, and V2H according to the real-time price (RTP) and the market sell-back price. In addition, we discuss some challenges and potential risks resulting from EVs' fast growth. Finally we propose some suggestions on future power systems and also argue that some incentives or rewards need to be provided to motivate EV owners to behave in the best interests of the overall power systems.

Keywords: Distributed Storage; Electric Vehicle (EV); Renewable Energy Source (RES); Vehicle to Grid (V2G); Vehicle to Home (V2H); Vehicle to Building (V2B)

Abbreviations:

BEMS	Building Energy Management System
BEV	Battery Electric Vehicle
DG	Distributed Generation
EV	Electric Vehicle

G2V	Grid to Vehicle
HEC	Home Energy Controller
HES	Home-Energy-Storage System
HEV	Hybrid Electric Vehicle
ILP	Integer Linear Programming
ISO/RTO	Independent System Operator/Regional Transmission Organization
LSE	Load Serving Entity
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
RES	Renewable Energy Source
RFID	Radio Frequency Identification
RTP	Real Time Price
SOC	State of Charge
V2G	Vehicle to Grid
V2H	Vehicle to Home
V2B	Vehicle to Building
VPP	Virtual Power Plant

1. Introduction

The comprehensive upgrade of the power grid including the integration of the Renewable Energy Sources (RES) and distributed systems has drastically changed how electricity are being provided from the grid side as well as how the customers consume the electricity. The development of Smart Grid brings new opportunities to break the inherent pattern and push the system to a new level. For decades, supply has always had to follow demand, which sometimes might cause huge power waste and is also not economical. In modern power systems, the supply-demand relationship can be balanced more efficiently by implementing demand response in which demand dynamically reacts with the generation supply [1–3]. On the other hand, RES has been widely exploited and generating more and more energy. Figure 1 [4] represents the growth of USA Renewable Electric Energy (major purpose of RES) from 2003 to 2018, it shows how it has developed in the past few years and where it is predicted to be in 2018. From the chart we can see that the hydro power holds a majority amount of energy but rather stable, follow by the wind generation. Although RES can provide green energy to the power grid, their intermittent nature can lead to power grid fluctuation [5]. Distributed energy storage systems have been implemented rapidly as a way of mitigating the fluctuation brought by RES so as to further leveraging the whole power systems [6]. By dispatching energy on distributed level, those energy storage systems can store energy for future utilization where there is a surplus and consume to supply electricity when there is a shortage [7].

As a future trend, Electric Vehicle (EV) has attracted more and more attention for its low or even null carbon emission and potentially large power capacity if aggregated [8–12], which can be utilized to provide supportive services. This would require EV not only can charge like a conventional appliance but also can discharge as power supply when needed. To enable the discharging, the power systems need to provide infrastructure support for bi-directional energy transmission between EV and grid. When EV is charging from the grid, it is referred as Grid to

Vehicle (G2V) [13,14]. When EV is discharging and sending the electricity to grid, it is called Vehicle to Grid (V2G) [15–17]. Similarly to the principle of V2G, EV can also discharge its battery surplus energy back to residential houses to realize energy's local utilization, called Vehicle to Home (V2H) [18], or back to buildings, called Vehicle to Building (V2B) [19,20].

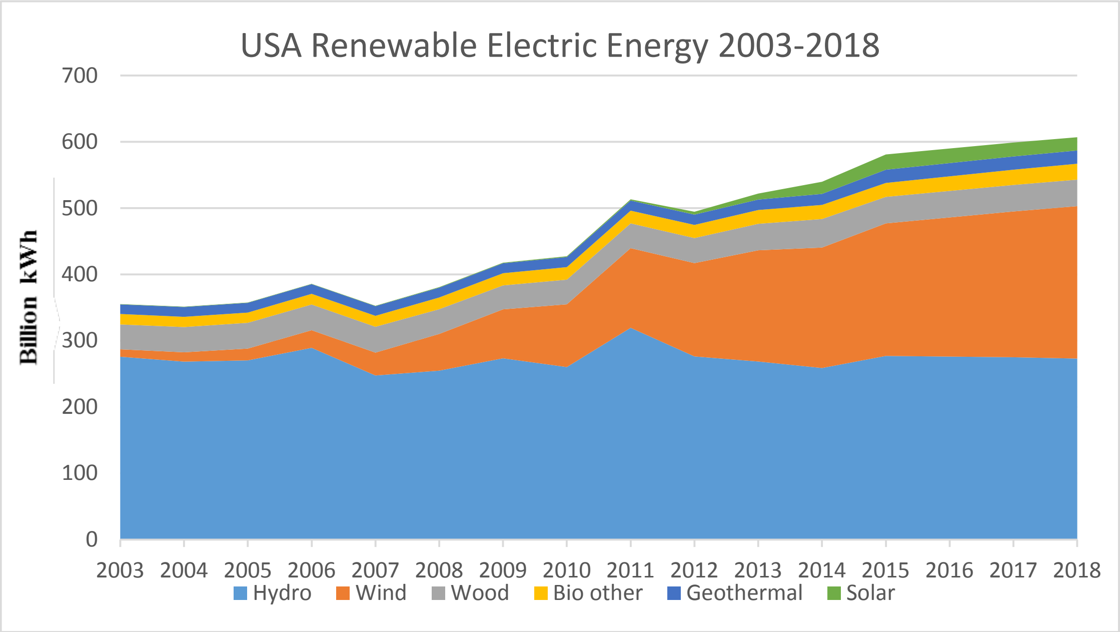

Figure 1. Renewable Electric Energy capacity of USA during 2003-2018 (Billion kWh).

Although right now these three discharging modes are still under experimental stage and haven't yet been prepared for large-scale implementation [21], the benefits on the whole power systems brought by these concepts are encouraging. Improvements on the grid's performance including more efficiency, reliability and stability. With the EV's market share increasing, the benefits will become more significant. However, without rational scheduling, deregulated charging/discharging might cause serious problem when the quantity of EV reaches a certain amount [14,17]. This paper aims to provide the discussions on the opportunities and challenges when EVs operate as potential distributed storage systems.

The rest of the paper is structured as follows. In Section 2, we provide the background knowledge on Smart Grid and EV. Then a brief introduction of the three discharging modes is presented in Section 3 along with discussions and comparisons. In Section 4, we use data analysis to demonstrate residential demand response, which schedules the charging/discharging operations according to the real-time price (RTP) and the sell-back market price. In Section 5, challenges of technical limitations and also cost and social obstacles are discussed. Finally, in Section 6, conclusions are made and future predictions are provided.

2. Background

Our legacy power grid was conceived long time ago when electricity demand was quite simple. In most cases power generation was localized and built around communities, to provide one-way power transmission. The continuously developed Smart Grid has introduced a bi-directional transmission mode where electricity and information can be exchanged between utilities and customers. It integrates distributed generation (DG) sources and combines network communications, controls, automations and new technologies to make the whole system more efficient, reliable, flexible, and secure [22]. A subsystem that lays between the grid and distributed generation sources is called Microgrid. Compared to the centralized grid on the system level, Microgrid has the following features: first it has almost the same functions as large-scale power grid from generation to transmission and also equipped with backup storage; the most significant difference is that it can work off-grid, referred as the “island mode” [23–25]. When sudden power outage happens, it can automatically switch from grid-based mode to island mode to continuously supply its covered area.

Similar to Microgrid, some other different concepts have been proposed like the Virtual Power Plant (VPP) and Nanogrid. Except for the difference on structural level, they all share the same basic functions. From a hierarchical structure prospective, all these small-scale distributed power subsystems can be recognized as a technology system capable of aggregating small group of electric power received from other distributed power sources until the quantity becomes large enough to influence the electric market [21,26]. In general, these grid-connect distributed systems can work together to further strengthen reliability and flexibility of the power grid.

One great feature of Smart Grid is the integration of RES [21,24]. The renewables are taken from passive, natural sources which are green and potentially inexhaustible. It has the exciting potential to become a permanent replacement for fossil fuels. Centralized RES such as large wind farms and solar generators have been produced all over the world [21]. The annual energy capacity is considerable and will keep growing. Distributed local power generation from solar roofs and small wind turbines is becoming available. According to [27], the total electricity generated by RES in US will reach nearly 250 GW in 2040, sharing 16% of the total generation mix. However, RES is featured with its highly distributed and mostly stochastic patterns, which can cause unstable power system and may further lead to electricity market fluctuation [14].

One solution is to use EV battery as distributed storage to help mitigate the pressure brought by RES. This type of distributed storage system can also assist grid related systems like Microgrid, Nanogrid and VPP [25,26]. EV was initially designed to save energy and reduce carbon emission, while its potential as distributed storage system has also been recognized and exploited. EV’s battery can store the surplus energy generated by RES. Then the stored energy can be utilized either by sending back to Grid (V2G) or directly absorbed by Smart Homes (V2H) or local buildings (V2B). As predicted in [28], the quantities of EV owned out of all vehicles worldwide will reach 30% by 2016, which means a considerable array of EV batteries can be potentially aggregated and dispatched for usage by conventional organizations such as the Independent System Operator/Regional Transmission Organization (RTO/ISO) within local Microgrids or on national level. The statistics in Figure 2 [29] shows a forecast for the cumulative worldwide sales of Battery Electric Vehicle (BEV), Plug-in Hybrid Electric Vehicle (PHEV) and Hybrid Electric Vehicle (HEV) from 2013 to 2020, which intuitively reflects the tremendous demand for EV in future.

In general, EV can leverage the electricity market through smart dispatching. More intuitively, by changing its charging-discharging period, we can enable charging when price is low and discharging when price is high. Based on typical electricity price trends, low price always happen between midnight and the next morning. This night-charging pattern perfectly meets the human living habits—charging when sleeping. Also during daytime when prices are high, those parked EVs with surplus battery energy can discharge back as distributed energy storage. Based on [16], most of the EVs will remain idle for more than 90% of a day and after arriving at destinations like the workplace and shopping mall from home, there still have surplus battery storage that can be utilized. If managed properly, both utilities and costumers can benefit from it.

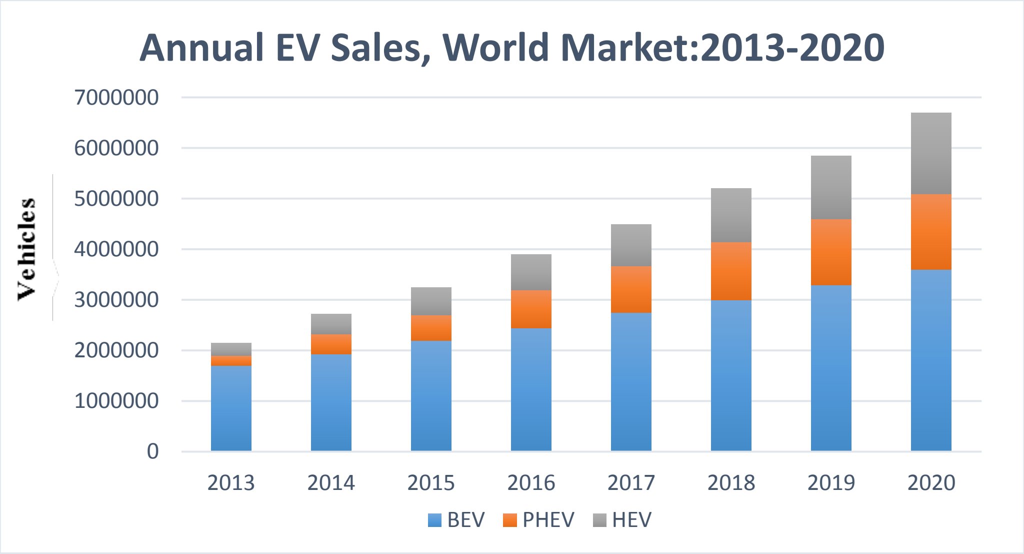

Figure 2. Annual light duty electric vehicle sales worldwide 2013–2020.

However, EV's development can also lead to chaos. In our opinion, the large scale increment of EV's market share will inevitably impact the electric system generation and distribution patterns, further leading to changes in the electric price curve [30]. It is likely that the uncoordinated "night charging" would ultimately bring in new peak loads to the power system. Smart charging/discharging through coordination, scheduling, or optimization is a solution to these problems. With the price information and control signals plus some other ancillary operations, the smart charging/discharging can be implemented in a grid-customer friendly manner. Next, we will specifically illustrate the smart discharging (V2G/V2H/V2B).

3. EV Function

With the participation of EV, the Smart Grid can become smarter. Figure 3 shows a comprehensive grid system that incorporates EV and RES. By smart scheduling for EV charging/discharging, it is likely to mitigate the fluctuation of electricity price and further flatten the demand curve. The smart scheduling algorithm needs to decide when to charge the EV battery and when to discharge the battery and where to discharge. The decision can be made by the consumers based on the RTP and the sell-back market price, or made by utility based on the supply and demand curves. In our opinion, the value of smart scheduling is in realizing the EV battery's full potential as a tool for stabilizing the power grid. In other words, it can function to mitigate the fluctuation of electricity price and further flatten the price curve as much as possible. As we mentioned earlier, EV has three discharging modes, namely, V2G, V2H and V2B, respectively. We then give a brief discussion of each discharging mode.

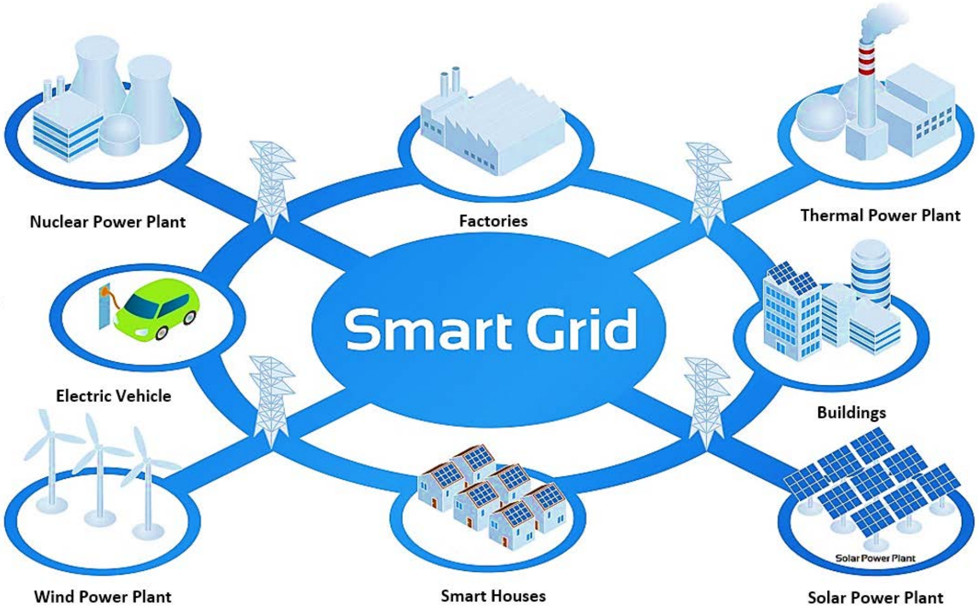

Figure 3. General system structure of Smart Grid with EV/RES (From [31]).

3.1. V2G

As a significant technology due to the great potential, V2G can realize group integration and automation from central power grid to distributed generations plus RES [16]. In V2G, surplus energy aggregated from EV fleet can be transferred back to grid to accomplish supportive tasks such as peak load shaving, regulation services (e.g., keep voltage and frequency stable) and spinning reserves (e.g., meet sudden demands for power in emergency) [9,16,17]. Its working process can be seen as thousands of small rivers flowing into the sea. Both utility companies and customers can benefit from this action, while also creating a more environmentally friendly solution. It is only lacking supportive equipment and real-time control [32].

To enable V2G, power system integration which represents a bi-directional charging systems that contains software based smart controller and seamless communication network is required. In V2G, the surplus energy from EV fleet is generally sent back through long-way transmission lines for central reallocation and this long-distance power transmission will cause substantial loss and high cost [29].

As an example of implementation, a smart parking lot with capability of bi-directional transmission and Radio Frequency Identification (RFID) authentication might be pre-required as supplementary infrastructure to enable the two-way energy flow and aggregate the surplus energy from EV fleet. Utilities will need to pay those EV owners the market price for the surplus energy or provide some other kind of incentive. Though frequent charging/discharging shortens the battery life which incurs cost, it has been proved that the revenue for sending surplus energy back to utility company is greater than the shortage lifetime of battery cost [16]. EV owners who are willing to participate in V2G can receive an ID issued by utilities or power market to collect rewards, either direct deposit or coupons. This ID can be linked to their mobile phones or credit cards to ensure the transaction and information exchange between utilities and owners.

3.2. V2H

In V2H, surplus energy from EV battery are sent back directly to residential houses to realize the energy digestion locally. Figure 4 [33] represents a typical smart home with EV as the storage system. All the smart appliances including EV are controlled by the Home Energy Controller (HEC). The smart meter connected with HEC can provide bi-directional information exchange between utilities and residential customers. Utilities can read meter data from residential households and customers can receive pricing signals, including future predicted price. The HEC can run an optimization algorithm to determine the charging/discharging periods [18]. In general, when the price is low, the HEC will schedule EV battery to charge; when the price is high, the HEC will stop purchasing the energy from utility and schedule the EV battery to discharge to power home appliances. In this case, the residential customer will save the electricity expense. V2H can also provide service in emergency such as during the power outage.

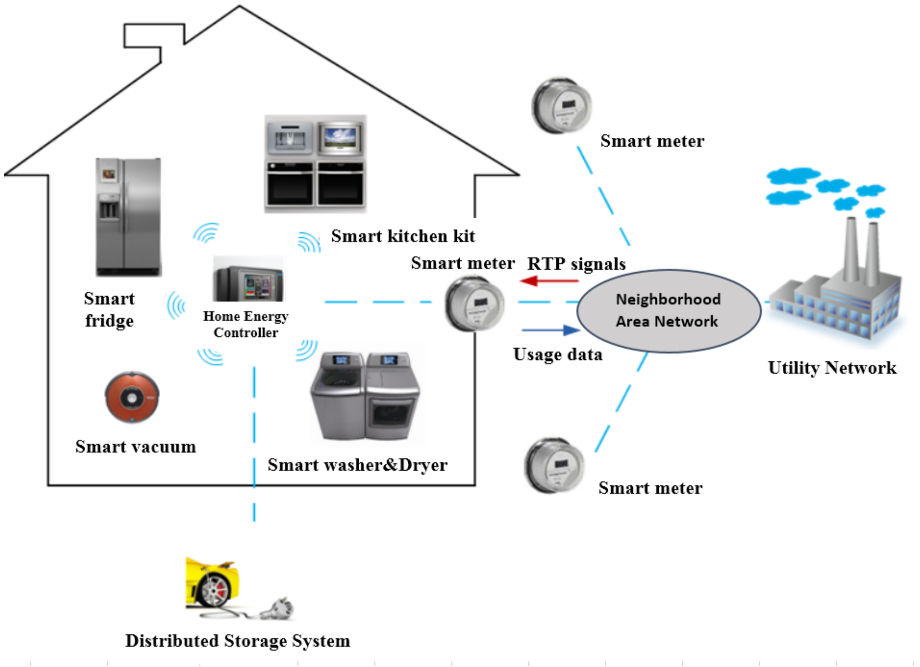

Figure 4. Smart Home with EV as Potential Storage System.

In our opinion, V2H is more efficient to utilize the surplus energy from EV battery. Comparing with V2G, V2H has much less power losses as the long-distance transmission is no longer exist. Also, it is easier to accomplish in terms of infrastructure support. There is no need to upgrade the equipment or communications networks at the grid level, as everything is done at the individual home. In addition, it is relatively convenient for the customers. All you need to do is to plug in your EV's charger that connected to your smart home and let the central controller to take over.

The storage can be integrated with RES to form Home-Energy-Storage System (HES). Most popular RES for residential applications is from solar PV panels mounted on rooftop [29]. The PV panels convert solar energy into electricity during day time and store the energy inside the home battery. After sunset, the battery begins to discharge back to home to power the appliances. This daily cycle makes this house as an energy ecosystem and provides a good performance without human supervision at a relatively low cost. One example is an off-grid self-sufficient smart home demonstrated by Nissan, "Leaf-to-home" [34]. The house was completely powered by solar panel and Nissan Leaf. It was shown that Leaf could completely power a typical Japanese home up to 2 days, or 20 hours for a typical US house [35]. The current challenges lie on EV's battery capacity and the price of HES installation.

3.3. V2B

As the middleware of V2G and V2H, V2B is a concept that has been paid less attention compared with the other two. On one side, V2B is similar to V2H in the sense that EV will operate as the distributed alternative power supply that can discharge its surplus energy locally to buildings without long-distance power transmissions. The buildings can be office towers and supermarkets, and etc. [20,36]. On the other side, V2B is also similar to V2G in the sense that V2B in general needs to aggregate the energy from EV fleet and the energy aggregation needs the infrastructure supports, such as small-scale smart parking lot with bi-directional power flow capability. A software building energy management system (BEMS) is also needed to supervise the operation. BEMS will execute based on its built-in optimization algorithm and the data from smart meter, to further manage the whole building's operation [29].

In contrast to V2H, cost saving in V2B is usually not the main reason to develop such systems. It is envisioned that V2B mainly aims to sustain the operation of buildings when unexpected outage happens, by keeping its core systems and critical loads from shutting down [19,20]. Enterprise buildings can be more efficient in terms of V2B implementation, as the arriving/departure patterns are more constant and the regulations and policies can be easily enforced. Other buildings like shopping malls and hospitals need to provide incentives for EV owners to participate [29]. Although V2B still remains in the conceptual level, the potential is attractive.

4. Data Analysis

In our previous work [32], we studied the smart charging/discharging of EV in a smart home. Here we modify the previous model to incorporate the transmission power loss factor in V2G and the battery degradation cost due to frequent discharging. Specifically, we consider a smart home equipped with smart appliances (e.g., clothes washer, dryer, dish washer, etc.) along with EV that are directly controlled by the HEMS. We consider three operation modes for EV, that is, charging from utility (referred as G2V), discharging to grid (i.e., V2G), and discharging to home (i.e., V2H). In our model, the RTP and the sell-back market price are received from smart meter with capability of future prediction. Based on the two prices, the HEC runs an optimization algorithm that schedules EV operation mode in order to minimize the cost subject to a set of constraints.

For the problem formulation, we first define EV's state of charge (SOC) in terms of the remaining energy at the beginning of time slot h as S^h. Clearly, the SOC at any time cannot exceed the capacity of the battery, denoted by S_{max}. Moreover, to avoid over-discharging that may damage the battery, the SOC should not drop below certain lower bound, denoted by S_{min}. The constraint on SOC is then written as follows

$$S_{min} \leq s^h \leq S_{max}, \forall 1 \leq h \leq H. \tag{1}$$

The SOC for the next time slot is determined by the SOC at the beginning of current time slot and the operation mode during the current time slot. Let c^h and D^h denote the charged and discharged energy during time slot h, respectively. We then have

$$s^{h+1} = s^h + K_c * c^h - K_d * D^h, \forall 1 \leq h \leq H-1, \tag{2}$$

where $K_c$and K_d are the efficiency factors for charging and discharging, respectively. We also set the upper bounds on charging and discharging as C_{max} and D_{max}, respectively. Therefore, another constraint is formulated as

$$c^h \leq C_{max}\ and\ D^h \leq D_{max}, \forall 1 \leq h \leq H. \tag{3}$$

In addition, we set the initial SOC as S_0 and constrain the end SOC to reach a certain end value S_H after each optimization cycle,

$$s^1 = S_o\ , s^H + K_c * c^H - K_c * D^H = S_H. \tag{4}$$

The optimization objective is to minimize the total cost subject to the constraints (1) to (4),

$$\text{Objective} : min \sum_{h=1}^{H} \left(C^h - D_{V2H}^h - D_{V2G}^h + De * D^h\right) \tag{5}$$

where

$$C^h = P_h^R * c^h, \forall 1 \leq h \leq H, \tag{6}$$

$$D_{V2H}^h = P_h^R * K_d * d_{V2H}^h, \forall 1 \leq h \leq H, \tag{7}$$

$$D_{V2G}^h = P_h^M * K_d * K_{pl} * d_{V2G}^h, \forall 1 \leq h \leq H, \tag{8}$$

$$D^h = d_{V2H}^h + d_{V2G}^h,\ \forall 1 \leq h \leq H, \tag{9}$$

Here $C^h$and $De * D^h$ denote the cost of charging and the cost of battery degradation, while D_{V2H}^h and D_{V2G}^h denote the revenue generated from V2H and V2G, respectively. P_h^R and P_h^M are the RTP and the sell-back market price, respectively. D^h consists of energy discharged in both V2G and V2H, De represents the degradation coefficient, and K_{pl} represents the additional power loss factor during the long-distance energy transmission under V2G. We further assume that EV can only work in one operation mode at any time slot, that is, at most one of the value of C^h, D_{V2H}^h and D_{V2G}^h can be non-zero. Therefore, the optimization problem is formulated as an integer linear programming problem (ILP).

To generate simulation results, we set the EV battery capacity as 25kWh which can provide 100 miles of driving range. S_{min} is set as 20% of the capacity and the efficiency factors are K_c= 0.9 and K_d= 0.85. Maximum charging/discharging rate bounds are set as 3.5 kWh per hour and 5 kWh per hour, respectively. We consider EV's operating duration is 13 hours from 18:00pm with 20 kWh as the initial SOC until 6:00am next morning to complete charge (i.e., 25kWh as the end SOC). Simulation results are shown in Figure 5.

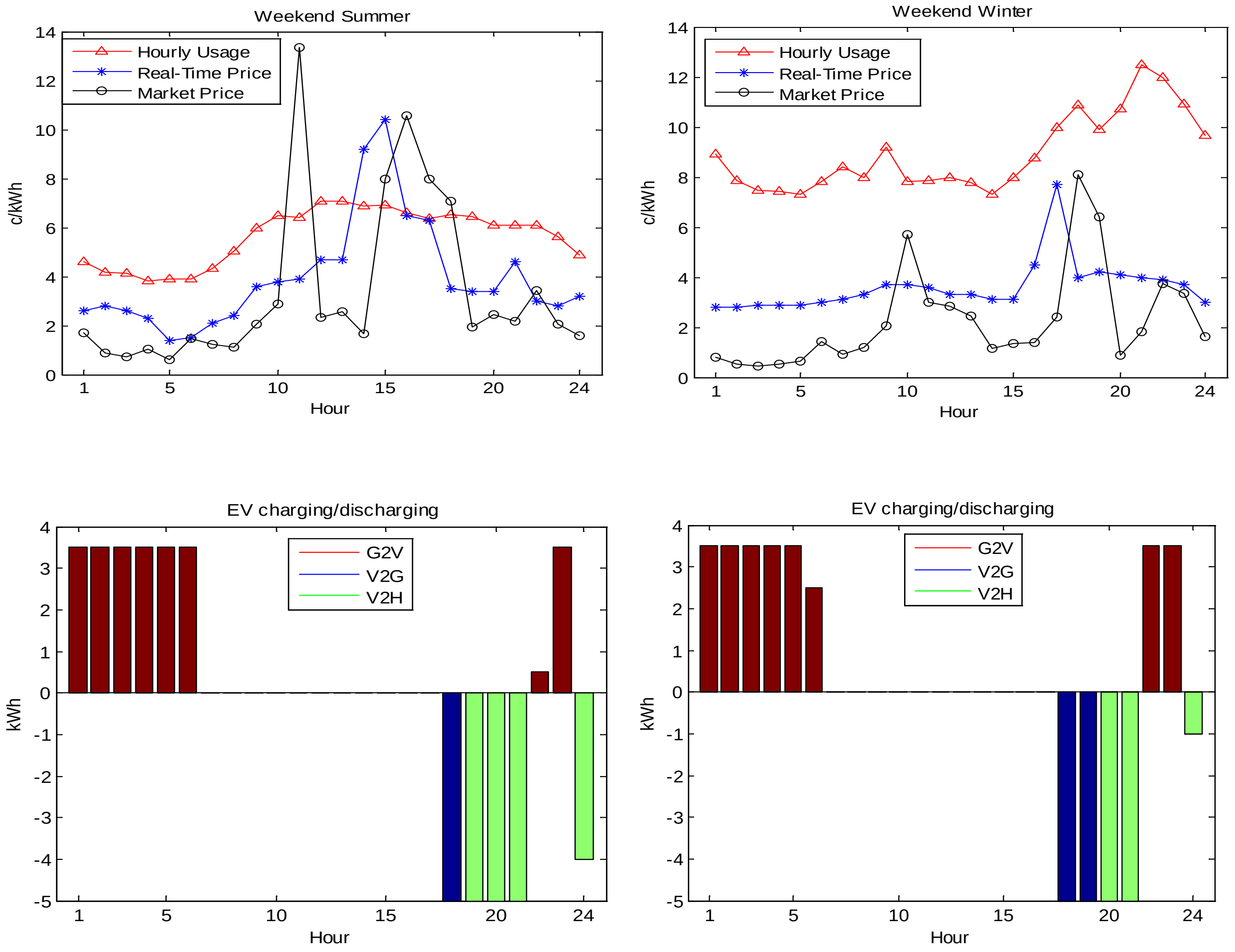

Figure 5. Optimization scheduling of EV with V2G/V2H.

For an easy comparison, we simply combine the hourly demand, the RTP and also the sell-back market price into one figure, which data are from MECOLS [37], ComEd [38] and PJM [39]. The top two charts from left to right show the data groups from some weekends in summer and winter, respectively. During winter, low temperature causes a heavy use of heaters and an increase of indoor activity. Consequently it is shown in the data that the usage is higher during winter season in general. We select the price data with intense fluctuation in order to obtain exemplar results. The bottom two plots in Figure 5 are the corresponding EV hourly operation mode. The red, blue and green bars represent how much energy is being charged in G2V, discharged back to grid in V2G, and discharged back to home in V2H, respectively.

It is shown in the simulation results that when the sell-back market price is significantly higher than the RTP, EV operates at V2G mode (i.e., at hour 18:00 during summer and hours 18:00 and 19:00 during winter). However, EV does not always operate at V2G when the market price is higher, such as at hour 22:00 in summer. Instead, EV operates at V2H mode. This is because the power transmission loss factor makes the V2G less beneficial compared to V2H. When the RTP is relatively high, EV operates at V2H mode to supply the power to the home appliances instead of purchasing the energy from utility, such as hour 21:00 in summer. During midnight when the RTP is low, EV charges the battery in G2V mode. Due to the set of constraints in the optimization, the complete operation schedule cannot be all intuitively explained, but it follows the general trend.

Generally speaking, EV would work under G2V mode at valley RTP, or under V2H mode at peak RTP, or under V2G when the market price is significantly higher than RTP.

5. Discussion

Table 1 compares V2G/V2H/V2B in various perspectives. We can see that V2H is the simplest and easiest to achieve from the perspective of supportive infrastructure. V2B is very much similar to V2H, but requires more technology support such as the aggregators [40–42]. In regions where it is quite difficult and expensive to upgrade the infrastructures whatever laid underground or built overhead, such as urban areas, V2H/V2B can be easily set up. In addition, the power losses are quite small since it does not require long-distance power transmission.

On the other hand, V2G requires the expensive installation of aggregators and power lines that support bi-directional electricity transmission between PEVs with grid or Microgrid [43,44]. Corresponding communications between PEVs with load serving entities (LSE) can cause pressure on the network resources and even GPS system [45]. In addition, the power losses during the double-distance transmission could be significant. According to [30], it is estimated that there will be 2200-4400MWh power from EV that can be potentially utilized in 2020. Considering the tremendous amount of energy, even a small percentage of power loss can lead to a huge waste.

Table 1. Different approaches for delivering energy from PEV batteries.

	V2G	V2H	V2B
Supportive Infrastructures	Aggregator Long Transmission Lines Large Scale Smart Parking Lot	HEMS Smart Meter (Home)	BEMS Smart Meter (Building) Small Scale Smart Parking Lot
Characteristics	Large Scale EV fleets (different places) Complex Operation System Level Communication Need More Regulation Sophisticated Structure Need Incentive	Small Scale (Home) Single EV Easy Operation Home Level Communication Can work automatically Easy Structure	Small Scale (Building) EV fleets Local Building Level Operation and Communication Need Regulation Need Incentive Complex Structure
Applications	Ancillary Services Reactive Power Support Operate at Large Scale	Operate at Home Level Single EV Easy Implementation	Operate at Building Level Provide Backup Power Connect with V2G

However, V2G is more powerful since it is a grid-level energy transmission and the range of the services it can support is much larger. For example, V2G could help shave peak load demand, balance load, and support ancillary services like voltage and frequency regulation. The reinjected power might also be stored for future use as the spinning reserve [46]. In situations such as generation failure, V2G can also help stabilize the whole system by directly injecting power into grid.

When EV serves as distributed storage, one issue is the battery operation convergence, which we call it as BOC. It is the joint effect led by market electricity price fluctuation and human self-interest. As we know, the autonomous scheduling of V2G/V2B/V2H mainly relies on the price fluctuation and the human's rational behavior. Specifically, people are willing to use their EV's battery as storage because of the monetary incentives provided by the price fluctuation [47]. As a result, people would likely charge their EVs when RTP are low (G2V), supply power to homes or buildings when RTP are high (V2H/V2B), or sell back to grid when the market prices are much higher than RTP (V2G) [37,38]. In general, EV could help flatten the price curve and shave the demand peak.

However, as the quantities of EV increasing, this behavior would bring in new peaks and gradually changing the price curves [48,49]. If all the people use the same RTP and market price for optimization, it is highly likely to have synchronous activity, which causes new peaks in demand curves and eventually affect the price curves. The influence could lead to temporary small-scale price fluctuation, such as within a period of minutes. This small-scale influence cannot be seen intuitively from the price curve and will not change the price pattern. Or the influence could lead to large-scale drastic price fluctuation due to long-time demand changes. The changes in demand can be reflected from gradient variation between two consecutive time points. For instance, Figure 6 shows the RTP for three consecutive days. Sudden increase in price from hour 55 to 56 indicated a sudden surge in the demand.

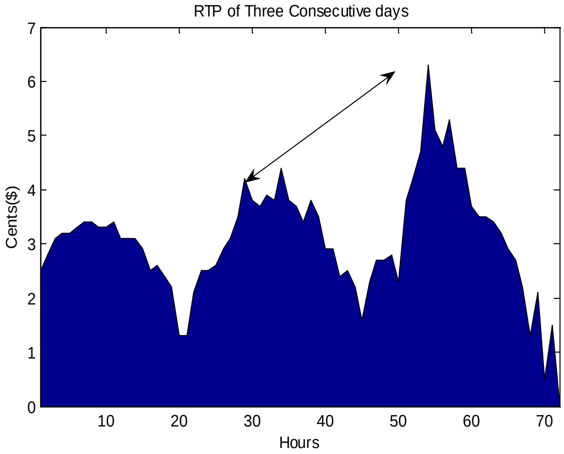

Figure 6. RTP of three consecutive days.

Since high penetration of EV could bring unstable factors to the power grid, the surplus of EV power would need to be treated carefully. In some point, it might be better for the central grid to predict future electricity consumption and price trend, then make central decision on when and how much extra energy is needed from distributed EVs. In this centralized mode, the EV would only discharge when needed.

6. Conclusion

In this paper we mainly surveyed the operation modes when EV serves as distributed storage. We emphasized on three discharging operations and analyzed each mode in terms of their advantages and disadvantages. Based on our discussion, we argue that V2H/V2B are a simple and efficient way to digest distributed surplus energy locally. On the other hand, V2G is more powerful to support grid-level services. However, V2G could lead to huge energy waste caused by the long-distance power transmission and also the potential price fluctuation along with V2H/V2B, referred as BOC.

One possible way to resolve this BOC problem is to pay more attention on the system level and set a hierarchy between the power grid and EV owners. When grid predicts peak demand, the load service entity (LSE) accompanied with ISO/RTO will send out messages to encourage EV owners to take part in peak shaving. As incentive, they might acquire credits or coupons on their registered account to encourage this behavior. As for the residential users, people could receive a voluntary opt-in request to provide the user a choice to join. After certain period of time, system can predict how much energy the user can provide based on the feedback, and then the central power grid, or even Microgrid on the distribution level, would be able to benefit from it.

In the future, EV rest stops need to be localized through on-board map systems. Some locations or buildings can serve as charging points, and the on-board map systems enable people to easily search from among public and private charging points to choose the most convenient option. To make it more flexible, Vehicle to Vehicle (V2V) can be explored also in the future. Under the allowance of EV owners, a battery power exchange can be completed through a special charger. As a premise, regulations need to be investigated, and security precaution needs to be put in place to protect the user as well as the grid systems in order to form a more comprehensive networked energy system.

Conflict of Interest

All authors declare no conflicts of interest in this paper.

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