Review of the Impact of Vehicle-to-Grid Schemes on Electrical Power Systems

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Abstract The vehicle-to-grid (V2G) describes plug-in electric vehicles (PEV), such as battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV), communicate with the power grid and sell demand response services by either returning electricity to the grid or by restricting their charging rate. Simultaneous charging of EV fleet can lead to an excessive loading, under-voltages and energy losses in distribution networks. On the other hand, the EVs in their idle mode has the ability to feed power back to grid which is useful for active power balancing, peak shaving, and stability enhancement. This paper reviews the V2G schemes to assess their impacts on the electrical power systems. The framework for coordinated operation of EVs with renewable energy sources in the various electricity markets was reviewed. The EVs' capability in energy loss minimization and provision of ancillary services such as frequency and voltage control was also investigated.

Keywords Ancillary service · Demand-side management · Electric vehicle · Optimal charging scheme · Vehicle-to-grid

1 Introduction

Electric vehicles (EVs) have been introduced into the market globally owing to the fact that EVs could significantly contribute towards the targets of the greenhouse gas emission reduction. The increasing share of EVs may have impact on power system performance, e.g. distribution network losses, peak power demand, voltage profiles, efficiency, reliability, and stability [1]. EVs are capable of delivering active and reactive power support, thus providing ancillary services for frequency regulation,

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voltage control and spinning reserve. Tracking of renewable energy sources such as wind and photovoltaics (PVs), load balancing and current harmonic filtering is possible with EV technologies [2]. The technology requirements, economic costs, challenges, and strategies for vehicle-to-grid (V2G) interfaces of both individual plug-in EVs (PEVs) and vehicle fleet in the power system were reviewed in [2]. In [3], the review on different power levels and infrastructures was compared based on the amount of required power, charging time, cost, component ratings, and other factors. The impact analysis of coordinated/uncoordinated charging on distribution network performance was presented in [4]. This paper aims to present the review on EVs' participation in electricity market, coordination of EVs and renewable energy sources to improve the network performance in minimizing the system losses. The comprehensive review for the role of EVs' contribution to frequency regulation is also carried out covering various types of interconnected systems, frequency controller structures, and methods adopted for frequency control.

2 Electric Vehicle Chargers and Charging Schemes

Based on the nature of the EV charging, the EV chargers are broadly classified as (1) Unidirectional and bidirectional and (2) Conductive and inductive. Based on the type of the converter, the EV chargers are categorized by basic converter, multi-level converter (with some advanced switching techniques), and advanced wireless charger.

The architecture of the review work is presented in Fig. 1. Different V2G schemes have been adopted depending on the electricity market an individual EV or EV fleet is proposed to participate in, and/or also depending on the type of renewable energy sources the EV is coordinated with, and the objectives of the scheme.

3 EVs Participation in Electricity Market

EVs have been participating in the various electricity markets, such as flexible electricity ramp, ancillary services, electricity buying bidding, and social welfare (see Fig. 1). Moreover, a significant cost saving in EV charging can be made when the EV charging methods are in response to the time-of-use (TOU) electricity prices.

A comparison between an uncontrolled EV charging and a market-based charging was addressed in [5]. The objective was to maximize social welfare where a "fairness constraint" was proposed. In [6], participation of EV in the flexible ramp market was presented to clear the market under uncertainties and variations in net load. In [7], the deterministic algorithm and fuzzy linear programming (FLP) were adopted for optimal bidding of coordinated charging for EVs. The FLP approach resulted in more aggregator's profits considering different uncertainties in ancillary service prices and deployment signals for regulation up, regulation down, and responsive reserves. In

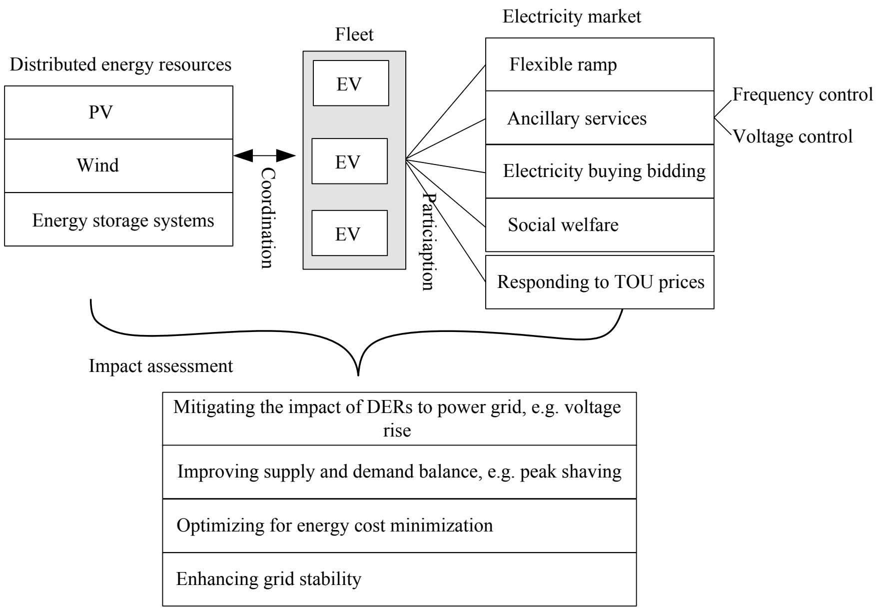

Fig. 1 Impact assessment of V2G schemes on the electrical power grid

[8], two optimization methods, namely global and divided, were used to represent forecasted information based on a statistical model when EV fleet was participating in a day-ahead market. This study was extended to a numerical analysis, and the two proposed optimization approaches were implemented to the Iberian day-ahead electricity market [9]. This work was intended to support an EV aggregation agent in optimizing their buying bids. Optimal EV bidding strategies for the day-ahead market, such as (a) spot market, (b) spot market and downward reserve sessions, and (c) spot market and reserve sessions, were compared in [10] to assess the impact of forecasted errors.

The EV charging methods in response to time-of-use (TOU) prices were reported in [11–13]. In [11], learnable partheno-genetic algorithm (LPGA) was presented, and the results were compared against tabu search (TS), genetic algorithm (GA) and ant colony optimization (ACO). In [12], a discretized optimization model was adopted, where minimizing the costs that EV users are required to pay was considered as the objective function, and the product of unit price and power drawl during that time was taken as input variables. The problem was solved with an intelligent heuristic algorithm. The reduction in cost of 51.52% and 39.67% was obtained with an optimized charging pattern for single EV and multi EV models, respectively. A decision tree model was proposed in [13] and results showed that a careful choice of TOU rates helps to reduce fuelling cost, increase the incentives and simultaneously minimize the grid impacts due to EV penetration. The problem of coordinated charging and discharging of EVs was proposed as a linear problem in [14] for a day-ahead market. The objectives were defined as to minimize charging costs and maximize profits obtained from energy trading.

4 Coordination of EVs with Renewable Energy Sources

Coordination between EV charging and discharging and many distribute energy resources (DERs) has been carried out to mitigate the adverse system impacts resulted from the DERs, to facilitate the supply and demand balancing (e.g. peak shaving), and to bring economic benefit for the system operation.

The charging/discharging strategies for PEV batteries were devised in [10] to mitigate the adverse impact (i.e. voltage rise) due to higher power generation from solar PVs in a distribution network in New South Wales, Australia. Marra et al. and Alam et al. [15–18] have also addressed the utilization of PEV batteries for mitigating the voltage rise impact due to PV penetrations.

A method using valley searching, interruptible and variable-rate energy dispatching of EV batteries was adopted in [19] to ensure a secure energy balance with a coordinated wind-EVs model, considering uncertainties in wind power production and driving patterns of EVs. A smart charging of EVs was proposed in [20] for wind power balancing. The wind generation and EV loads were first nominated in the day-ahead market and then a smart controlling of EVs was achieved to minimize the forecasted errors. A fuzzy chance-constrained unit commitment model was proposed in [21] considering demand response (DR), EVs and wind power. EV charging station fitted with PV panels, fuel cell, and energy storage was proposed in [22] to accomplish sustainable transportable electrification.

A stochastic dynamic programming method was used to minimize cost of EV charging as well as to have reduced impact on distribution grid. The coordination of wind-PV-EVs was reported in [23] based on stochastic optimization model considering uncertainties in PV and wind power generation. Similarly, a novel control strategy was proposed in [24] to coordinate both charging-discharging of EVs and intermittent renewable energy generation using certainty equivalent adaptive control (CEAC) principle. The economics of integrating wind, EVs and mixtures of Level 1/Level 2 charger infrastructures was addressed in [25] considering wholesale electric energy market. Grouping of EVs into fleets based on daily driving patterns was carried out using fuzzy c-means (FCM) clustering, followed by optimization done by genetic algorithm (GA) in combination with a Monte Carlo simulation (MCS). Artificial bee colony (ABC) algorithm was applied in [26] to minimize overall cost of power system consists of offshore wind farm-thermal units-EVs power system connected through HVDC link.

5 EVs Role for Active Power Balancing and Frequency Regulation

The power generated by all the generating resources in the system must balance the electric load in order to operate the system with desired nominal frequency. The V2G concept is one of the most promising solutions for providing faster and efficient power balancing service through faster charging and discharging of EV batteries. A significant amount of research has been carried out on the techniques and applications of V2G for frequency regulation [27] where focuses were given to EVs on their fast adjustments of V2G power. A fleet of thousands of EVs can be used as controllable energy storage devices to participate in power system operation [28]. The economic feasibility of V2G control performing frequency regulation service was investigated in [29, 30].

Area control error (ACE) and frequency characteristic of plug-in hybrid EV (PHEV) was suggested in [31] where load frequency control (LFC) signal was calculated based on the charging power of PHEV. Participation of EVs for secondary frequency control was reported in [32]. Frequency regulation issue in Danish power grid with EV and large penetration of wind power was investigated in [33] by modelling aggregated EV-based battery storage for the use in long-term dynamic power system simulations.

Smart charging with a droop control based on system frequency deviation was used to realize a fast and synchronized response among multiple vehicles for frequency regulation in [34]. EVs and the heat pump water heater (HPWHs) as controllable loads are modelled for LFC in [35] which can be helpful to reduce the capacity of battery storage systems. The dynamic PEV model considering dynamic battery storage capable battery discharging/charging characteristics and SOCconstraints was proposed in [36] based on distributed acquisition approach. A decentralized V2G control (DVC) method was proposed in [37] for EVs for primary frequency control.

Estimation of the EV charging load based on a statistical analysis of EV type, maximum travel range, battery capacity and battery state of charge was carried out in [38] to observe the contribution of EVs in primary frequency control of Great Britain (GB) power system. The comparison of "dumb" charging, "off-peak" charging, and "smart" charging of EVs were compared to show the impact of EVs to stabilize the grid frequency in the GB system. The coordinated V2G control and conventional frequency controller for robust LFC in the smart grid with large wind farms was proposed in [39]. The battery SOC was controlled by optimized SOC deviation using the particle swarm optimization.

In [40], control strategies for EVs to participate in supplementary frequency regulation (SFR) was proposed by framing a systematic framework including an EV aggregator, with many individual EVs and EV charging stations. A detailed model of a four-area power system with AC/HVDC links with smart charging of EVs was formulated in [41]. Fuzzy control of PV systems along with V2G for frequency control was proposed in [42, 43] where grid frequency deviation signal and SOC of batteries were used to control EVs charging.

V2G technologies are able to provide frequency regulation of a power grid with various types of interconnected systems, frequency controller structures and methods adopted for frequency control. The voltage violations in distribution network due to penetration of EVs and wind turbine have been quantified in [44] with time series approach considering time-dependent behaviour of wind speed, daily electrical load and EVs charging load.

6 EVs and Demand Side Management

In demand-side management (DSM), demand response of end-consumers who responds to price signal by voluntary changes their normal pattern of energy consumption [45–47]. DSM is adopted in smart grid for peak shaving, reduction in electricity bills, adequate usage of generation resources, energy loss minimization and for flattening the load profile [46]. In smart grid, EVs can be connected to network and shifted to different nodes based on applicable charging requirement and its charging price. In [47, 48], EVs are included in DSM and its impact is analyzed on demand profile. The problems of peak shaving and valley filling have been solved in [49] by proposing game theory approach for scheduling EVs charging whereas in [50] similar approach has been implemented by considering V2G and load profile is matched to target load curve. Coordination mechanism for allocating efficient EVs charging is proposed in [51] considering renewable energy generation. The problems such as congestion is solved in [52] by changing charging patterns for EVs. The issues of loss minimization and voltage violations are solved in [53] without including electricity market issues by presenting smart load management applicable to EVs. The maximization of profile for all agents is obtained in [54] by formulating DSM based on optimization approach on hourly available load-generation data. In this work, agents in smart grid are modelled in two types (a) EVs which can be shifted among the nodes of distribution network and (b) the agents which cannot be shifted and remain connected on same load such as loads, batteries, dispatchable and non-dispatchable generators and EVs.

The loads are modelled as the sum of fixed demand and shiftable demand depending on time. Non-renewable generator is modelled by its operational cost which is the sum of fixed, variable, start-up and shut-down cost. Renewable generators such as PV and wind turbine are modelled based on scenario tree and priority. A bank of electric batteries are considered as fixed storage elements and considers following aspects: (a) charging of battery (draws energy from the grid) or discharging of battery (delivers energy to the grid), (b) considering limits of power drawn or supplied by a battery, and (c) tracking of energy contained in the battery based on its state of charge (SOC). EVs are modelled as mobile storage device with some characteristics in addition to that of fixed storage elements such as batteries. In DSM, EVs can be modelled either in uncontrolled mode or in controlled mode by aggregator. For EVs, three time periods of operations are important (a) transition period when EVs are in transit state and consume energy from its batteries itself (b) charging period when EVs takes energy from network to charge its battery again (c) resting period when EVs neither consume energy from its own batteries nor from the network. An uncontrolled mode of operation of EVs follows a fixed pattern for all three periods. In controlled mode of operation, the decision of charging and resting will be taken by aggregator. Okeanos, a fundamental, game theoretic, Java-based, multi-agent software framework for DR simulation is proposed in [55] which can now modelled plug-in electric vehicles (PEVs). Flattening of load curve with controlled charging of PHEV at low-voltage transformer is reported in [56] by formulating DSM problem as convex optimization problem and decentralized water-filling-based algorithm is used to solve it. Scalable approach following three steps such as aggregation, optimization, and control are proposed for DSM including PHEV in [57].

7 Conclusion

This work reviews the V2G schemes to assess their impacts on the electrical power systems. The coordinated operation of EVs with renewable energy sources in the various electricity markets and the EVs' capability in providing ancillary services, in particular the frequency control, were investigated.

EVs have been participating in various electricity markets, such as flexible electricity ramp, ancillary services, electricity buying bidding, and social welfare. Moreover, a significant cost saving in EV charging is able to be made when the EV charging methods are in response to the time-of-use (TOU) electricity prices. Coordination between EV charging and discharging and the distribute energy resources (DERs) has been carried out to mitigate the adverse system impacts resulted from the DERs, to facilitate the supply and demand balancing, and to bring economic benefit for the system operation. V2G technologies are able to provide frequency regulation of a power grid with various types of interconnected systems, frequency controller structures and methods adopted for frequency control.

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References

1. Lopes JAP, Soares FJ, Almeida PMR (2011) Integration of electric vehicles in the electric power system. Proc IEEE 99(1):168–183
2. Yilmaz M, Krein PT (2013) Review of the impact of vehicle-to-grid technologies on distribution systems and utility interfaces. IEEE Trans Power Electron 28(12):5673–5689
3. Yilmaz M, Krein PT (2013) Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles. IEEE Trans Power Electron 28(5):2151–2169

4. Habib S, Kamran M, Rashid U (2015) Impact analysis of vehicle-to-grid technology and charging strategies of electric vehicles on distribution networks—a review. J Power Sources 277:205–214
5. de Hoog J, Alpcan T, Brazil M, Thomas DA, Mareels I (2016) A market mechanism for electric vehicle charging under network constraints. IEEE Trans Smart Grid 7(2):827–836
6. Zhang B, Kezunovic M (2016) Impact on power system flexibility by electric vehicle participation in ramp market. IEEE Trans Smart Grid 7(3):1285–1294
7. Ansari M, Al-Awami AT, Sortomme E, Abido MA (2015) Coordinated bidding of ancillary services for vehicle-to-grid using fuzzy optimization. IEEE Trans Smart Grid 6(1):261–270
8. Bessa RJ, Matos MA (2013) Global against divided optimization for the participation of an EV aggregator in the day-ahead electricity market. part I: theory. Electr Power Syst Res 95:309–318
9. Bessa RJ, Matos MA (2013) Global against divided optimization for the participation of an EV aggregator in the day-ahead electricity market. part II: numerical analysis. Electr Power Syst Res 95:319–329
10. Bessa RJ, Matos MA, Soares FJ, Lopes JAP (2012) Optimized bidding of a EV aggregation agent in the electricity market. IEEE Trans Smart Grid 3(1):443–452
11. Yang H, Yang S, Xu Y, Cao E, Dong Z (2015) Electric vehicle route optimization considering time-of-use electricity price by learnable partheno-genetic algorithm. IEEE Trans Smart Grid 6(2):657–666
12. Cao Y et al (2012) An optimized EV charging model considering TOU price and SOC curve. IEEE Trans Smart Grid 3(1):388–393
13. Davis BM, Bradley TH (2012) The efficacy of electric vehicle time-of-use rates in guiding plug-in hybrid electric vehicle charging behavior. IEEE Trans Smart Grid 3(4):1679–1686
14. Pantos M (2012) Exploitation of electric-drive vehicles in electricity markets. IEEE Trans Power Syst 27(2):682–694
15. Marra F et al (2013) EV charging facilities and their application in LV feeders with photovoltaics. IEEE Trans Smart Grid 4(3):1533–1540
16. Marra F et al (2013) Improvement of local voltage in feeders with photovoltaic using electric vehicles. IEEE Trans Power Syst 28(3):3515–3516
17. Alam MJE, Muttaqi KM, Sutanto D (2013) Mitigation of rooftop solar PV impacts and evening peak support by managing available capacity of distributed energy storage systems. IEEE Trans Power Syst 28(4):3874–3884
18. Alam MJE et al (2016) Effective utilization of available PEV battery capacity for mitigation of Solar PV impact and grid support with integrated V2G functionality. IEEE Trans Smart Grid 7(3):1562–1571
19. Wu T, Yang Q, Bao Z, Yan W (2013) Coordinated energy dispatching in microgrid with wind power generation and plug-in electric vehicles. IEEE Trans Smart Grid 4(3):1453–1463
20. Leterme W, Ruelens F, Claessens B, Belmans R (2014) A Flexible stochastic optimization method for wind power balancing With PHEVs. IEEE Trans Smart Grid 5(3):1238–1245
21. Zhang N et al (2015) A fuzzy chance-constrained program for unit commitment problem considering demand response, electric vehicle and wind power. Int J Electr Power Energy Syst 65:201–209
22. Liao YT, Lu CN (2015) Dispatch of EV charging station energy resources for sustainable mobility. IEEE Trans Transp Electr 1(1):86–93
23. Wang G, Zhao J, Wen F, Xue Y, Ledwich G (2015) Dispatch strategy of PHEVs to mitigate selected patterns of seasonally varying outputs from renewable generation. IEEE Trans Smart Grid 6(2):627–639
24. Nguyen HNT, Zhang C, Mahmud MA (2015) Optimal coordination of G2V and V2G to support power grids with high penetration of renewable energy. IEEE Trans Transp Electr 1(2):188–195
25. Valentine K et al (2016) Relationship between wind power, electric vehicles and charger infrastructure in a two-settlement energy market. Int J Electr Power Energy Syst 82:225–232
26. Jadhav HT, Ranjit R (2015) Stochastic optimal power flow incorporating offshore wind farm and electric vehicles. Int J Electr Power Energy Syst 69:173–187

27. Sekyung H, Soohee H, Sezaki K (2010) Development of an optimal vehicle-to-grid aggregator for frequency regulation. IEEE Trans Smart Grid 1(1):65–72
28. Guille C, Gross G (2009) A conceptual framework for the vehicle-to-grid (V2G) implementation. Energy Policy 37(11):4379–4390
29. Sortomme E, El-Sharkawi MA (2012) Optimal scheduling of vehicle to-grid energy and ancillary services. IEEE Trans Smart Grid 3(1):351–359
30. Tomic J, Kempton W (2007) Using fleets of electric-drive vehicles for grid support. J Power Sources 168(2):459–468
31. Takagi M, Yamaji K, Yamamoto H (2009) Power system stabilization by charging power management of plug-in hybrid electric vehicles with LFC signal. In: Proceedings of vehicle power and propulsion conference, Dearborn, MI, pp 822–826
32. Galus MD, Koch S, Andersson G (2011) Provision of load frequency control by PHEVs, controllable loads, a cogeneration unit. IEEE Trans Ind Electron 58(10):4568–4582
33. Pillai JR, Bak-Jensen B (2011) Integration of vehicle-to-grid in the western Danish power system. IEEE Trans Sustain Energy 2(1):12–19
34. Ota Y et al (2012) Autonomous distributed V2G (vehicle-to-grid) satisfying scheduled charging. IEEE Trans Smart Grid 3(1):559–564
35. Masuta T, Yokoyama A (2012) Supplementary load frequency control by use of a number of both electric vehicles and heat pump water heaters. IEEE Trans Smart Grid 3(3):1253–1262
36. Yang H, Chung CY, Zhao J (2013) Application of plug-in electric vehicles to frequency regulation based on distributed signal acquisition via limited communication. IEEE Trans Power Syst 28(2):1017–1026
37. Liu H, Hu Z, Song Y, Lin J (2013) Decentralized vehicle-to-grid control for primary frequency regulation considering charging demands. IEEE Trans Power Syst 28(3):3480–3489
38. Mu Y, Wu J, Ekanayake J, Jenkins N, Jia H (2013) Primary frequency response from electric vehicles in the Great Britain power system. IEEE Trans Smart Grid 4(2):1142–1150
39. Vachirasricirikul S, Ngamroo I (2014) Robust LFC in a smart grid with wind power penetration by coordinated V2G control and frequency controller. IEEE Trans Smart Grid 5(1):371–380
40. Liu H, Hu Z, Song Y, Wang J, Xie X (2015) Vehicle-to-grid control for supplementary frequency regulation considering charging demands. IEEE Trans Power Syst 30(6):3110–3119
41. Pham TN, Trinh H, Hien LV (2016) Load frequency control of power systems with electric vehicles and diverse transmission links using distributed functional observers. IEEE Trans Smart Grid 7(1):238–252
42. Datta M, Senjyu T (2013) Fuzzy control of distributed PV inverters/energy storage systems/electric vehicles for frequency regulation in a large power system. IEEE Trans Smart Grid 1(4)
43. Falahati S, Taher SA, Shahidehpour M (2016) A new smart charging method for EVs for frequency control of smart grid. Int J Electr Power Energy Syst 83:458–469
44. Long C, Farrag MEA, Zhou C, Hepburn DM (2013) Statistical quantification of voltage violations in distribution networks penetrated by small wind turbines and battery electric vehicles. IEEE Trans Power Syst 28(3):2403–2410
45. Gellings C (2009) The smart grid: enabling energy efficiency and demand response. Fairmont Press
46. Albadi M, El-Saadany E (2007) Demand response in electricity markets: an overview. In: IEEE power engineering society general meeting, p 1–5
47. Jenkins N, Long C, Wu J (2015) An overview of the smart grid in great Britain. Engineering 1(4):413–421
48. Strbac G (2008) Demand side management: benefits and challenges. Energy Policy 36:4419–4426
49. Darabi Z, Ferdowsi M (2011) Aggregated impact of plug-in hybrid electric vehicles on electricity demand profile. IEEE Trans Sustain Energy 2:501–508
50. Shao S, Pipattanasomporn M, Rahman S (2012) Grid integration of electric vehicles and demand response with customer choice. IEEE Trans Smart Grid 3:543–550

51. Sheikhi A, Bahrami S, Ranjbar A, Oraee H (2013) Strategic charging method for plugged in hybrid electric vehicles in smart grids; a game theoretic approach. Int J Electric Power Energy Syst 53:499–506
52. Wang Z, Wang S (2013) Grid power peak shaving and valley filling using vehicle-to-grid systems. IEEE Trans Power Deliv 28:1822–1829
53. Oviedo RM, Fan Z, Gormus S, Kulkarni P (2014) A residential PHEV load coordination mechanism with renewable sources in smart grids. Int J Electr Power Energy Syst 55:511–521
54. López M, Martín S, Aguado J, de la Torre S (2013) V2G strategies for congestion management in microgrids with high penetration of electric vehicles. Electr Power Syst Res 104:28–34
55. Masoum A, Deilami S, Moses P, Masoum M, Abu-Siada A (2011) Smart load management of plug-in electric vehicles in distribution and residential networks with charging stations for peak shaving and loss minimization considering voltage regulation. IET Gener Transm Distrib 5:877–888
56. López MA, de la Torre S, Martín S, Aguado JA (2015) Demand-side management in smart grid operation considering electric vehicles load shifting and vehicle-to-grid support. Int J Electr Power Energy Syst 64:689–698
57. Lausenhammer W, Engel D, Green R (2016) Utilizing capabilities of plug in electric vehicles with a new demand response optimization software framework: Okeanos. Int J Electr Power Energy Syst 75:1–7
58. Mou Y, Xing H, Lin Z, Fu M (2015) Decentralized optimal demand-side management for PHEV charging in a smart grid. IEEE Trans Smart Grid 6(2)
59. Vandael S, Claessens B, Hommelberg M, Holvoet T, Deconinck G (2013) A scalable three-step approach for demand side management of plug-in hybrid vehicles. IEEE Trans Smart Grid 4(2)