PHEVs as Dynamically Configurable Dispersed Energy Storage

*Final Project Report*

*Power Systems Engineering Research Center*

*Empowering Minds to Engineer the Future Electric Energy System*
PHEVs as Dynamically Configurable Dispersed Energy Storage

Final Project Report

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Power Systems Engineering Research Center

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Executive Summary

Studying the impact of Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs) is complex because these technologies provide dispersed and yet mobile energy storage that can be aggregated at different scales. This report focuses on how PHEVs/BEVs, as dynamically configurable, dispersed energy storage, can create multiple benefits in electricity networks while playing a major role in transportation networks.

PHEVs/BEVs provide multiple benefits by serving in two modes: Grid-to-Vehicle (G2V) or “smart charging,” and Vehicle-to-Grid (V2G) or “smart discharging.” G2V charging mode can be used when demand is low and there is ample, low cost electric energy supply available. V2G discharging mode can be used as a supply source when demand is high or supply is lost.

Communications is essential to enable smart control in either mode. Controlled charging/discharging of PHEVs/BEVs in public parking spaces or parking garages in business districts would facilitate aggregation to provide ancillary services. There would be cost advantages arising from the high density of Electric Vehicle Supply Equipment in such parking areas, such as from the ability to spread communications equipment costs over a large number of vehicles. In contrast, aggregation of multiple home garage charging stations may be cost prohibitive because of the need to meter and communicate with individual vehicles at different locations.

There are various requirements for and challenges in providing ancillary services, such as the minimum threshold capacity requirements for battery charging, telemetry measurements requirements, and the representation of PHEVs/BEVs in power network models. A case study of benefits in several ISO regions shows that these benefits will vary significantly over time, between different ancillary services, and from locality to locality. The net benefits to the PHEV/BEV owner and the electricity system could be significant to the extent that the communications and telemetry costs are fairly small, and the effect of providing ancillary services on battery lifetime is negligible.

Two important issues addressed in this study for the development of PHEV/BEV infrastructure were the “smart garage location problem” and “charging station installation problem”. The first problem is determining the optimal location of the garage facility and the type of profit incentives to maximize profit. In this research, the smart grid location problem is formulated as a bi-level optimization program and solved using a genetic algorithm. The results of sensitivity analysis show that poor walkability or low incentive parameters will increase the influence of vehicle trip rates on parking.

The second problem is determining the optimal number of charging/discharging stations to be installed in an existing parking garage. This problem is formulated as a stochastic program with a simple recourse. The problem includes uncertain parameters, such as the PHEV/BEV penetration rate in the vehicle fleet and the PHEV/BEV charging rate. The problem is solved using a Monte Carlo sampling-based algorithm. Sensitivity analysis shows that the mean value of PHEV/BEV penetration rate and charging rate are important factors in making investment decisions.
A model was developed to investigate the impact of aggregated PHEV/BEV on electricity power networks and on the parking garage developer’s decisions. The results show that high penetration of PHEVs/BEVs could affect power system operating conditions and locational marginal prices (LMP). Comparisons among the three cases, ‘V2G with uniform price’, ‘V2G with LMP’, and ‘G2V with LMP’, show that the business model of ‘V2G with LMP’ maximizes profit for a parking garage developer, thereby providing a relatively greater incentive for investment.

Future analyses could be advanced in several ways. Analysis of the impact of PHEVs/BEVs on electricity power networks and on a parking garage developer’s decisions would benefit from more accurate estimates of market penetration rates of PHEVs/BEVs over time. The models of the dispersed energy storage system and smart garage used in this study could be expanded to account for uncertainty, modification of the model parameters from survey results, and addition of other potential revenue and cost components.

**Project Publications**


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