



A review of computer tools for modeling electric vehicle energy requirements and their impact on power distribution networks



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HIGHLIGHTS

- 125 simulation tools for modeling electric vehicles and associated infrastructure are reviewed.
- The tools' capabilities are summarized and tabulated by source, availability, and application.
- Applications considered include modeling of vehicles, traffic, and power distribution systems.
- The advantages and limitations of particular tools in each application are summarized.

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ABSTRACT

This paper presents a review of the many simulation tools that have been reported for modeling and managing the impact of electric vehicles on power distribution networks, and associated applications. One hundred and twenty-five simulation tools have been identified and among them sixty-seven tools have been summarized to facilitate selection of the most appropriate tools for specific tasks. Typical applications of the tools include vehicle system analysis and control, renewable energy and vehicle-to-grid integration and impact analysis, energy market behavior and charge scheduling, vehicle energy management, and traffic system simulation. No single tool covers all areas of these applications, however sufficient information is provided to enable researchers to select the most appropriate combination of tools to meet specific research objectives.

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1. Introduction

Electric vehicles (EVs) are propelled by one or more electric motors powered by electric energy which is either stored in batteries and/or converted from chemical energy [1]. EVs may be grouped into plug-in (PEV) and plug-in hybrid (PHEV) types, and into fuel cell (FCV) and other hybrid vehicles, however all are potentially powered by renewable energy, and hence may reduce environmental damage caused by carbon dioxide emissions. The energy density of batteries commonly used in EVs is much lower than hydrocarbon-based fuels, which presents challenges for performance and operational range. As a result, EVs need to utilize their stored charge carefully; good energy management includes efficient use of energy within each vehicle, and also management of the energy flows between the vehicle and the electricity grid.

Research into EVs and PEV/PHEVs must therefore consider the design, analysis, and control of energy management systems to enhance energy economy and efficiency, and storage lifetime, whilst providing availability and reliability for both short and long-distance journeys in the context of real-time traffic flows and geography. Interest has also been growing in the potential impact of PHEV/PEVs on electric power distribution networks, e.g. in coordinated versus uncoordinated charging scenarios. The bidirectional characteristics of EVs pose particular challenges and opportunities; in addition to consuming energy, they have the ability to provide power to grid for finite periods, i.e. in vehicle-to-grid (V2G), home (V2H) or other (V2X) systems.

Consequently EVs are likely to play a significant role integrating renewable energy sources into the electricity distribution grid, e.g.

storing energy in times of excess generation, and providing energy back to the network during times of peak load. Conversely, inadequate or poor management of EVs could result in negative impacts on power quality and grid reliability. The collective impact of EVs on the electricity distribution grid will depend on a variety of factors, including power ratings, charging time (off-peak or on-peak), charging rate and pattern, the geographic distribution of EVs and their state of charge, etc. The negative impacts could include voltage instability, harmonic distortions, load imbalance and overload of the electricity distribution grid [1].

Grid impact analysis of many EVs with distributed renewable energy sources and emerging domestic battery storage options [2] requires the use of specialized simulation tools. Through the use of such tools one may attempt to optimize the performance and economic benefit of EVs in what is becoming an increasingly flexible and complex electricity supply system and market.

There have been many reports of specific computational tools for energy market analysis, EV design, traffic modeling, power network analysis, renewable and/or EV integration in distributed energy systems, etc. For example, to name a few, the Vehicle-to-Grid Simulator (V2G-Sim) [3], the power system analysis toolkit (PSAT) [4], the transport emissions modeling tool GREET [5], the AVL CRUISE vehicle simulation platform [6], the CarMaker tools incorporated with the Simulink environment to analyze integrated car functionality [7], the ANSYS Simplorer for multi-domain systems modeling [8], the MORPHEE tools for modeling vehicle integration [9], the Simpow power systems simulation tool [10], and the CANoe tool for distributed system design [11]. However, most of the latter tools are designed for a limited range of

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