Plug-in Hybrid Electric Vehicles Can Be Clean and Economical in Dirty Power Systems☆

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Abstract

Plug-in hybrid electric vehicles (PHEVs) that are driven and charged in 'dirty' power systems, with high penetrations of coal and other polluting generation fuels, may yield higher net emissions than conventional vehicles (CVs). We examine the implications of imposing a constraint on PHEV recharging that forces emissions from PHEVs to be no greater than those from a comparable CV. We use the Texas power system, which has a mix of coal- and natural gas-fired generation and has been shown to yield higher emissions from PHEVs than CVs, as a case study. Our results show that imposing the emissions constraint results in most of the PHEV charging loads being shifted from coal- to cleaner natural gas-fired generators. There is, however, virtually no increase in generation or PHEV driving costs due to e□ciency benefits that are possible through coordination of unit commitment and PHEV charging decisions.

Keywords: Plug-in hybrid electric vehicle (PHEV), emissions, unit commitment

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1. Introduction

Plug-in hybrid electric vehicles (PHEVs) have been offered as alternatives that can reduce driving costs relative to conventional and hybrid electric vehicles (CVs and HEVs). These savings stem from the fact that PHEVs have larger batteries than HEVs that can be charged from the electric power system, and give the vehicles a limited 'electric-only' driving range. Due to the abundance of low-cost generating capacity, especially overnight, electricity can be a less costly transportation fuel than gasoline, when the relative driving e□ciencies of electric motors and internal combustion engines are taken into account. The actual cost savings from PHEV use will depend on the generation mix in the power system. This is because of di□erences in the cost of generating fuels, for instance between coal and natural gas. Diurnal PHEV charging patterns will also affect charging costs, because di□erent generation fuels are marginal and would serve the charging loads at di□erent times of day. PHEV economics in a number of power systems in the United States has been examined, including by Parks et al. (2007), who model the Xcel service territory

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sions in Texas, and show that while CO_2 and NO_x emissions will be lower than a CV, net SO_2 emissions would be more than 50 times higher than a CV due to the use of coal-fired generation for PHEV charging. Sioshansi et al. (2010) model PHEVs in Ohio, which has a coal-dominated to generator startups and differences in generator efficiencies when operated at part load. We estimate emissions rates using continuous emissions monitoring systems data obtained from the United States Environmental Protection Agency (EPA).

We model a case in which 1% of the light duty vehicle fleet in ERCOT are PHEVs. This amounts to 75,750 PHEVs, based on vehicle registration data reported by the United States Department of Transportation's Federal

$$L_{v,t} = \overline{e} \text{ if } \varphi_{v,t} = 1, \qquad \forall\, v \in V, t \in T; \quad (14)$$

$$0 \leq ch_t \leq \begin{cases} 0, & \text{if } dist_{v,t} > 0 \\ \overline{p}, & \text{otherwise} \end{cases}, \qquad \forall\, v \in V, t \in T; \quad (15)$$

$$0 \leq cd_{v,t}, cs_{v,t}, \qquad \forall\, v \in V, t \in T; \quad (16)$$

$$\widetilde{cd}_{v,t} \in \{0, 1\}, \qquad \forall\, v \in V, t \in T. \quad (17)$$

Adding either constraint set (18) or (19) to the model couples the 365 days of the year together, making the model intractable to solve. We apply Lagrangian relaxation, which is described by Wolsey (1981), to relax these will be lower than the costs in table 3. This is because the incremental generation cost when PHEVs are added to the system will be socialized across PHEV and non-PHEV loads.

Table 3

Table 5: Net change in annual total generation and fuel consumed,

average NO_x

Table 9