Electrification of Bus Networks in Provo, Utah (DRAFT)

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Introduction

Recently, electric vehicles (EVs) have gained significant public awareness and various levels of support. Generally the adoption of EVs is seen as a good thing, as there are many clear benefits over internal combustion engine (ICE) vehicles. Perhaps the most obvious is that EVs have no emissions, since they are driven entirely by electric motors. Another important advantage is efficiency: while an ICE vehicle will convert around 20% of the fuel's stored energy into motion (Department of Energy 2022), EVs are around 90% efficient (U.S. Department of Energy 2022). Electric motors are also efficient over a large range of rotational speeds, whereas ICEs are only efficient at a much narrower range of speeds.

However, EVs are not always universally superior to ICE vehicles. One major consideration is that the range of EVs is lower than may be practical in certain applications. Though EVs are more efficient at converting stored energy into motion, gasoline and diesel are more energy-dense than batteries, and so that energy becomes harder to store in an EV by comparison. What truly makes this a concern is the time required to recharge an EV's battery compared to the time to refuel an ICE vehicle's tank. Though there are relatively fast charging standards available, as of now none of them are nearly as fast as filling up a car at a gas station (Environmental Protection Agency 2022).

This charging problem, though, is not generally a concern for personal vehicles. Even the slowest of charging standards are able to charge at up to 1.9kW, which if charged either overnight or at a workplace for 8 hours could easily offset a daily commute of 40 miles or more (Environmental Protection Agency 2022). However, for one major part of the transportation industry, namely commercial transportation, EV charging becomes a major consideration. Long-haul trucks, bus rapid transit (BRT), and even local bus networks may not be as well-suited for EV adoption. But despite the difficulty of solving the charging problem, electrification of these systems can still be a worthwhile goal, due to the many advantages of EVs. In fact, many transit agencies are using electric bus fleets XXXXXXXX, and others are in the process of transitioning to EVs XXXXXXX.

Charging Solutions

Developing charging infrastructure is the most significant prerequisite to deploying a fleet of EV buses. There are currently several options available for EV charging. Level 1 and 2 charging as well as DC fast charging use a plug-in connector to transfer power (Environmental Protection Agency 2022), and other options such as wireless inductive charging exist and are being developed upon (Klontz et al. 1993; Panchal, Stegen, and Lu 2018). Perhaps somewhat unique to buses are <><><><>, where a rail on the bus extends to make contact with an overhead power supply at a bus stop.

While the level 1 and level 2 EV charging standards work well for personal vehicles, which sit idle for large parts of the day, these are relatively slow standards. A personal vehicle can expect about 25 miles of range per hour of level 2 charging (Environmental Protection Agency 2022). A bus, which weighs several times that of a personal vehicle (Nealon and Kempken 2022), would get a fraction of that range (since work/energy is proportional to mass). Many bus routes run for most of the day, and even with an 8-hour daily level 2 charge a bus may only gain about 50 miles of daily range. A city bus running for 12 hours per day with an average speed of 12mph would need more than double that. Exclusively using level 2 charging would in many cases necessitate at least a doubling of fleet size to maintain those routes, which is impractical.

DC fast charging can charge vehicles on the order of 10 times as fast as level 2 charging (Environmental Protection Agency 2022). Depending on the implementation, this standard can charge as fast as 350kW. This is certainly fast enough to fully recharge an electric bus overnight, so seems to be a viable way to solve the charging problem. However, standard plug-in DC fast charging overnight may not be enough on its own due to battery sizes.

EV range is directly a function of battery pack size, and so a larger pack will provide more range. A typical electric bus with a battery pack size of 350kWh and energy consumption of about 3kWh per mile would have around 100 miles of range (Schabert 2022). This may be sufficient for many routes much of the year, but electric heating in the winter months can drastically reduce EV range. Assuming a worst-case scenario of 4-6kWh per mile, this reduces the range of a 350kWh bus to around 70 miles. While some buses are being developed with larger battery packs (Day 2022), these are currently not commonly available.

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