Integration of Electric Buses into the Power Grid

Challenges and Opportunities

KEY MESSAGES

- Integration of EBs into the power grid requires enhanced cooperation among different stakeholders, including ICT, mobility, and electricity service providers. An effective governance strategy is important to success.
- Extracting the electricity consumption profile of EBs and studying their impact on the power grid are crucial for a secure EB integration, and can be done using data from trial projects.
- Charging stations, for on-route, in bus stops to depots, should be optimally sized and located to maximise clean energy saving using flexibility in the buses operation.
- Optimal design of trials considering topographic features of the city, specifications of routes and location of chargers is important in achieving expandable results.
- Optimal charging and discharging schedules are required to maximised clean energy saving using flexibility of the bus operation.

BACKGROUND

Among the different sectors which contribute in the gas emissions, transportation contributes 14% of the global and 18% of Australia's total carbon emission. Meeting Australia's goal to reach net zero emissions by 2050 depends in part on the uptake of Electric Vehicles (EVs). Bus electrification can provide significant benefits towards this goal. There are currently 100,473 buses (mostly ICE) operating in the public and private sectors (Electric Vehicle Council, 2020), with bus trips accounting for 5% of public transport journeys.

Approximately 1,300 new heavy buses are registered each year in Australia. Electric buses are being trialled in NSW, VIC, WA, ACT, and QLD, with several governments and private sector operators committed to bus electrification. A comprehensive summary of recent electric bus trials and commitments is provided by the Electric Vehicle Council (2020). Victorian and New South Wales Governments, for example, have major plans in place for significant expansion in electrification of the bus network (e.g., T4NSW, 2020).

However, bus electrification brings new issues to conventional bus transportation systems.

ELECTRIC BUSES AND THE POWER GRID

A shift to electric buses (EBs) requires planning to account for specific characteristics of an EB system and its interaction with the power grid. A cornerstone of any public transport system is reliability. The energy and fleet requirements of a reliable EB system need to be determined by analysing the mobility demand. For example, considering a 300kWh battery for a typical EB, full electrification of the Victorian bus transport system leads to an additional load of at least 1.2GWh to the electricity demand. The problem becomes more complicated when fast charging systems of 175-500 kW power are required to meet the tight schedule of buses.

Currently, there are significant knowledge gaps in optimal solutions for the placement of charging stations, intelligent scheduling of EB deployment, and smart coordinated scheduling of EB recharging. For example, the negative impacts of unpredictable, intermittent, and large scale EB charging/discharging are of concern to electricity Distribution Network Service Providers (DNSPs). The impact of EBs could result in heightening peak power consumption or lead to local peak-hour undervoltage in the grid. On the other hand, optimal charging of EBs during daytime could helpful spread the load.

A number of industry-led projects are currently investigating EVs and Distributed Energy Resources (DERs) more broadly, including transitioning from "passive" DER to "active" DER (AusNet); enabling clean mobility (AusNet); accommodating future EV load (PowerCor), control of DER hosting capacity (Jemena), supporting EV uptake (Victorian DELWP), and accommodating EVs (AEMO).

CHALLENGES

Governance

One of the key enablers underpinning a successful integration of EBs into the grid is enhanced cooperation among different stakeholders, including ICT and mobility service providers, transport and urban planning authorities, electricity market aggregators and operators, EB and charging stations operators, and power grid operators. In a recent position paper, ENTSO-E, the European Network of Transmission System Operators for Electricity, calls on Transmission System Operators (TSOs) to play a key role in supporting the optimal integration between the transport and the energy sectors. This means that TSOs must look beyond the boundaries of their traditional activities to adapt and support the wider energy system integration and prepare system operations ready for the challenges ahead. Regardless of this European solution, the governance strategy of EB integration integration to grids is a new challenge for governments.

Impact on the grid

Analysis for the NSW Government has indicated that grid upgrade costs are only a small fraction of the total transition costs to fully electrified buses because of the very high investment required in the vehicles (T4NSW, 2020). However, there are several technical issues which can result in failure of the transition if not addressed.

Optimal size and location of EB charging and parking

Traditional bus routes are based on transport demand instead of the location of fuelling/recharging stations. The location of charging stations along EB routes presents a barrier for their uptake, as suitable locations for required charging infrastructure do not always correlate to the areas of transport demand. This indeed requires a load forecasting tools that can forecast demand profile of EBs.

Grid infrastructure to support EBs

EB battery capacities can vary from around 60kWh to more than 500 kWh, with larger sizes needed to service long routes or long charging intervals (Gao, Lin and Franzese, 2017). EBs generally require very high-capaity chargers (up to 500kW), which invariably requires upgrades to electricity networks (Gao et al., 2017). An optimal upgrade pathway, in the scale of adding new transformers, substations or feeders, may be required in both depot and on-route charging stations and considering limitations of the distribution grid where EBs normally connect. Facilities for bi-directional charging should be also considered to enable using the Vehicle-to-Grid (V2G) technology for supporting the grid. Detailed specifications, including the location and size of these upgrades, rely on detailed knowledge of the grid and relevant bus routes.

Operational strategies

Depot charging is currently concentrated into hubs and primarily required at night, away from solar generation times and often aligned with network peaks. Charging strategies that maximise the renewable energy storage are required. Opportunities for en-route charging can align with solar generation, but are expensive. The energy capacity of battery storage systems is currently around 18 times less than that of fossil fuels [1]. Although technological solutions are expected to emerge in the future, EBs today need large and heavy storage systems, which can limit operation in challenging conditions, such as long or hilly routes, without on-route fast charging stations. Coordination between EB aggregation and demand response programs facilitate optimal grid support using EBs. Revisiting bus routes not yet EB capable may also assist in some cases.

OPPORTUNITIES

Compensation for the minimum demand reduction

A recent fact sheet from AEMO shows that the minimum operational demand, i.e. the lowest level of total daily demand from the grid, has been significantly reduced during recent years and is expected to reduce further. This is mainly due to high penetration of photovoltaics and other new bi-directional technologies in the power distribution grid. Lowering minimum operational demand presents challenges to grid security and reliability. AEMO's action plan includes storage systems to "soak" extra solar generation, as well as photovoltaic curtailment in emergency conditions. Charging EBs during daytime can be another strategy, for example during midday when mobility demand is low. At scale, this will help to raise minimum operational demand as well as ensuring EBs are charging from clean energy, mainly solar.

Grid support during evening peak time

EB aggregators can provide different ancillary services to support the grid, including voltage stability, frequency support, load following services, and peak shaving. Some EBs may come back to the depot well-charged and could contribute to the early evening peak thanks to V2G technology. A depot with 50 EBs can work as an storage system with almost 7.5MWh energy, providing niche opportunities for night-time V2G without orchestration overheads required for distributed vehicle fleets. Proper integration and coordination processes are required to use this ESS efficiently in supporting the grid.

Flexibility of the bus operation

The peak time of the mobility demand is often different from that of electricity demand. For example, in the early evening electricity peak demand, the operation of buses slows, with some returning to the depot. The opposite may happen in peak daytime mobility demand when the grid operational demand is lower. This brings a flexibility in integrating EBs into the grid, aligning the fleet's electricity demand with the daily electricity demand profile. Another source of flexibility arises with dynamic bus-to-route assignment, adjusting the recharging schedule EBs in response to demand. Dynamic route assignment also offers potential for reducing the cost of fleet purchase and increased utilisation of purchased vehicles. Together, optimal organisation can help ensure a smooth integration of EBs into the grid.

The electrification road map

The EB network expansion can begin with a sizeable portion (e.g., 20%) of diesel or CNG buses, replacing them with EBs using only a limited number of en-route charging stations [2]. Routes passing through locations with larger population and job density, such as the CBD, are more desired at the beginning of the transition, since they are serviced by a high-density transit network and charging stations can be shared between routes. Systematic step-by-step integration of EBs into a transportation system is a matter for study, but examples already exist, such as the one implemented onto the network operated by the Utah Transit Authority, US [3].

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REFERENCES

[1] International Energy Agency (IEA), "CO2 Emissions from Fuel Combustion, in Secure Sustainable Together". 2015, IEA: Paris. 152pp.

[2] RACE for 2030, "Electric vehicles and the grid, N1 opportunity assessment". 2021, RACE for 2030, 173pp.

[3] R. Wei, X. Liu, Y. Ou, and S. K. Fayyaz, "Optimizing the spatio-temporal deployment of battery electric bus system". *Journal of Transport Geography*, vol. 68, pp. 160–168, 2018.

[4] Australian Energy Market Operator (AEMO), "Minimum operational demand". 2021 https://aemo.com.au/en/learn/energy-explained/energy-101/energy-explained-minimum-operational-demand

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