Will Flipping the Fleet F**k the Grid?

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Overview

High penetration of EVs could a substantial increase in total electricity load in car-dominated transport systems countries such as New Zealand (Transpower 2018) and it has been predicted that if all current light private vehicles were electric, annual New Zealand residential electricity consumption would increase by ~30% (Concept Consulting 2018). In part this assumes concurrent charging, especially in the early evening when many motorists return home (Speidel and Bräunl 2014; Langbroek, Franklin, and Susilo 2017). This in turn could negatively impact the operation of a low-carbon renewables-based grid by increasing peak loads (Azadfar, Sreeram, and Harries 2015) at a time when they are usually met through hydro generation running at close to full capacity (Khan, Jack, and Stephenson 2018). On the other hand, recent analysis of has suggested that comuting patterns may be more temporally heterogensous than usually assumed (Mattioli, Anable, and Goodwin 2019) and in addition, EVs could also be used to feed electricity into the grid at times of peak demand. This could offer a form of demand response (Kempton and Tomić 2005) that may even reduce the need for expensive peaking generation and local network capacity investment (Strbac et al. 2016). Unfortunately modelling of the potential impact of future EV uptake is hampered by a lack of real world data on EV users' charging behaviour (Rezvani, Jansson, and Bodin 2015).

In response, this paper utilises EV charging data collected from a sample of ~ 50 electric vehicles over an extended period of time to provide further insight into the potential effects of a dramatic increase in domestic EVs on the New Zealand electricity grid. In doing so we focus on two key research questions: 1) how much EV charging tends to occur in (evening) peak demand periods and 2) to what extent could pre-charged EVs be used to feed electricity into the system during peak demand periods?

Methods

Anonymous data on the battery health, power demand, charging rate, speed and other performance information was collected from 19 24kWh Nissan Leafs, 21 30kWh Leafs and 7 eNV200 vans monitored from 2018-04-05 to 2019-03-01 by Flip The Fleet, a New Zealand based EV community project. The data reported here consisted of 1,882,040 1 minute interval observations of timestamped measurements of charging power (kW) and battery charge state (% charged). The data received contained all available observations but charging was set to 0 kW if the vehicle was non-stationary (speed > 0 km/h) prior to analysis. This enabled the exclusion of charging through regenerative braking from the analysis. Further we defined standard charging as a charing rate of < 7kW and 'rapid charging' as a charging rate of > 7kW based on current New Zealand domestic electricity installation capacity.

Results

Our results show that rapid charging events were comparatively rare in this sample and tended to occur durng the day begining at 08:30 on weekdays and peaking around 11:30 before declining towards early evening. Standard charging events dominated and occurred with the greatest frequency between 20:00 and 08:00, with much lower occurrences of charging during the morning peak demand period (07:00 – 09:00). Standard charging steadily increased from this morning low through the afternoon but did not to substantially increase until 21:00. Standard charging sequences were longer with a median duration of 210 minutes compared to rapid charging events (14 minutes). As a consequence, 54% of the total energy drawn during charging was overnight off-peak standard charging. Day time standard charging was 19% of the total and day-time rapid only 8%, while evening peak standard charging was 12% of total energy while evening peak rapid charging was only 2%.

Analysis of the vehicles' state of battery charge confirmed other research (Speidel and Bräunl 2014) suggesting that half of standard charge sequences begin with battery state of charge (SoC) at ~50% and this is roughly constant across time periods. In contrast, half of rapid charging sequences started with SoC of 43% and a higher proportion of rapid charging events start with relatively low SoC, presumably reflecting use of rapid chargers on longer distance travel. SoC of 5% or less was observed in just 1 rapid charging event out of 455, presumably when a traveller only just made it to the next rapid charger during a long-distance journey.

Conclusions

Overall, these patterns suggest that whilst this sample added some additional consumption to the evening peak period, their energy draw tends to be concentrated in the off-peak over-night and day-time periods. It seems that many drivers appear to already minimise charging during peak electricity demand periods, presumably through the use timers to take advantage of off-peak electricity. In future larger batteries may lead to prolonged charging events and less 'range anxiety' so that even gresater flexibility of home charging may be possible. Rapid charging is currently much less frequent than standard charging but could have significant future network effects during the day and in the late evening and overnight if residential systems are upgraded as expected (KPMG 2019). However, if the reported temporal patterns of charging at home are maintained, even where larger batteries are available, this may not significantly impact existing periods of peak demand.

The state of charge analysis demonstrate the potential for Vehicle-to-Grid' (V2G) and 'Vehicle-to-House' (V2H) power flows during peak demand periods, as many vehicles are beginning to charge with substantial available stored energy on most days. If V2G and V2H technology can be established, and larger batteries become more prevalent, there is ample scope for EVs to contribute their stored energy to other uses and release pressure on the local electricity network in particular.

In summary, if these patterns of behaviour are maintained the results suggest that there appears to be a relatively low risk that EVs will substantially increase evening peak electricity demand with it's pontential to disrupt a future renewables-based electricity system. In contrast, vehicle to grid energy flows could make substantial contributions to actively reducing peak demand and enabling more efficient incorporation of non-dispatchable renewables into a low-carbon electricity system.

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