Making way for
ultra-low-emission vehicles

Colin Herron and Shirley Coleman look at how to determine the number of rapid chargers for a given volume of electric vehicles.

Within the UK there is a transition from internal combustion engines to ultra-low-emission vehicles (ULEV) with an expectance that by 2040 these will be the only vehicles sold. The UK's Office for Low Emission Vehicles (OLEV) defines ULEV as: *Cars/vans emitting less than 75g of CO_2 from the tailpipe per km driven, based on the current European type approval test*. An electric vehicle (EV) owner has the choice of charging at home, at work or at a public charge point. This article provides a figure of power delivered from a given rapid charger (a rapid), in the space of one hour, over a 24-hour period with a nominal 10-minute change over time.

Findings

Using the Nissan Leaf (24kWh and 30kWh,) this article shows the power flow is not linear. The power curves were measured on a DBT 50kW charger at one-minute intervals. Figure 1 illustrates the origin of the 80% state of charge (SoC) in 30 minutes norm in many manufacturers' statements. This curve provides reference data to calculate power delivery over one hour and also shows that an extra 15% of charge takes a further 25 minutes. A vehicle changeover of 10 minutes has been allowed. Therefore there is a 50-minute delivery window each hour.

The observed power delivery curve shows a clear trend to 65% SoC over 20 minutes, then a further smaller change to 85% over 10 minutes. A 30-minute charge has therefore been taken as 20 plus 10 minutes.

Trials

Every minute of the volts, amps and SoC was collected. The power (kW) was then calculated (volts x amps). Figure 2 shows power (W) on vertical axis and SoC (%) on horizontal axis. The different points reflect ambient temperature. It is clear that the 30kWh Leaf is taking a higher current for longer. The key intersections on Figure 2 are:

- SoC of 65% (20 minutes)
- SoC of 85% (30 minutes)
- SoC of 90% (45 minutes)
- Maximum of 95% SoC (55 minutes)

The 30kWh Leaf maintains high power, taking around 380 volts and 106 amps (40kW) until a SoC of 65% then it tails off. The power drop-off gradient for the 24kWh and 30kWh batteries follows a similar trajectory after the 65% SoC. The 85% point was reached after 30 minutes.
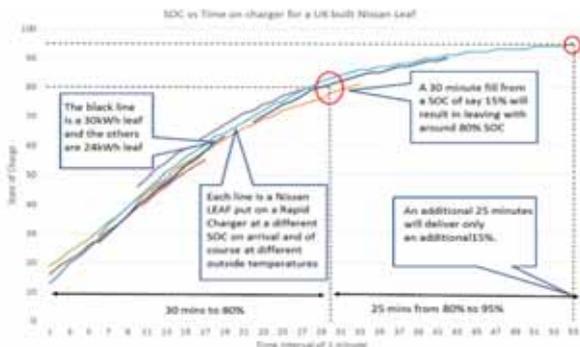
Operational performance

Assuming back-to-back charging 26.49kWh has been selected. The derived equation is based on the industry measure of overall operational effectiveness. This is made up of availability x speed against design x quality of product. To measure the performance of a charger, the operational performance (OP) will be determined as: utilisation x power (delivery vs design) x availability or hours used/24.

We assume that power (delivery vs design) is 26.49/43 (43 is the maximum delivery from a DBT charger). For a charger delivering for six hours per day and an
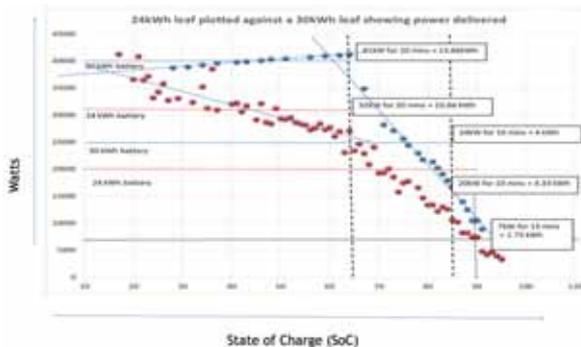
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State of Charge (SoC) vs Time for a UK manufactured Nissan Leaf
Figure 1

Power delivery as state of charge increases, using averages within intersections for 24Kwh (red dots) and 30kWh Leaf (blue dots)
Figure 2

availability of 97% we get 6/24 x 26.49/43 x 0.97 = 0.25 x 0.61 x 0.97 = 15%.

- The utilisation is set by need and price
- Power delivery is set by battery design
- Availability is due to design and maintenance

Energy required for a year's driving in the UK, if we assume 100% EV

In the UK, 30 million cars drive 311 billion miles a year. The average EV delivers five miles per kWh. Therefore energy required for 311 billion miles is 62,200GWh or 62TWh, which is 170.4GWh of energy per day – see Table 1.

Current delivery capacity using Nissan Leaf as a datum

A 50kW rapid charger can deliver on average 27kW for 24 hours, which is 648kWh of energy. Therefore to supply 170.4GWh of energy, we need (170.4GWh/ 648kWh) chargers = 263,000.

If we follow a logic that 90% of charging will be at home or work, then 10% of the national mileage per day requires rapids; for a full EV population (30 million) we currently need 10% of 263,000 = 26,300.

Energy required to do a year's driving in the UK now

In the UK we have 90,000 EV, which will drive 90,000 x 26 miles x 365 = 0.85 billion

More than 283,000 Leaf cars have been sold since the Japanese firm launched the brand in 2010

miles per year requiring 17.1GWh of energy at five miles per kWh. Daily requirement is 468,000kWh of energy.

Current delivery capacity using a Nissan Leaf

A 50Kw rapid can deliver currently 27kW per hour for 24 hours, which is 648kWh of energy. So to supply 468,000Wh of energy we need (468,000Wh / 648kWh) = 722 chargers.

How many chargers do we actually need now?

If 10% of EV mileage per day requires rapids, we currently need chargers for 9,000 cars. If these 9,000 cars cover the average mileage, we require 46,800kWh of energy to be available. This 46,800kWh divided by the average power available by

a 50kWh battery gives us 46,800kWh /648kWh = 72 chargers.

The calculation to deliver OP would suggest a current level of 15% for the network. This means that an estate of 500 chargers operating at 15% would deliver the same as 75 at 100% utilisation. If we build in the current spread and utilisation, this roughly equates to the current UK estate requirement of 72 chargers. Therefore, we currently have sufficient chargers and our calculations can be used to determine how many will be needed as more EV are used.

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Variable	Data	Provenance	Source
UK volume of cars and light vans	30 million	Derived	RAC Foundation*
Daily average distance driven per car	26 miles	Derived	RAC Foundation
Total UK miles driven per year	311 billion	Derived	RAC Foundation
Miles available per kWh	5 miles	Derived	Actual performance of a 30kWh Leaf
Average power delivery from 50kW charger	27kW	Calculated	Experimental, as described in this article
Percentage charge at home/work	90%	Assumed	Accepted prediction
Charge time	30 minutes	Set	Using 80% rule in 30 minutes
Current UK EV volume	90,000	Derived	OLEV

Input data
Table 1

*www.racfoundation.org