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Our energy insights

Forecourt thoughts: Mass fast charging of electric vehicles

This is the first in a series of Thought Pieces which aims to stimulate discussion on electric vehicles (EV) and how their adoption may influence the evolution of the electricity system.

> This article was written in April 2017. A follow up Thought Piece, based on new information and feedback, will be released this autumn. You can receive a copy of the coming Thought Piece by signing up to our Insights Newsletter by emailing ukfes@nationalgrid.com.
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> 18 Sept 2017

If the government is to reach its 2050 decarbonisation target it is probable that by that date all cars will have to be electric as is outlined in our Future Energy Scenarios.

But if all cars were electric and they were to have the range of today's petrol and diesel cars (internal combustion engines, ICE) they will need to have large capacity batteries installed. Residential charging is the norm now but is it going to be a viable solution for the future? What about those without off-street parking? What about multiple EV households? Can our domestic electricity supply take the extra demand?

There are a number of solutions to these challenges, one of which could be to establish a network of recharging stations, which has the potential to benefit the consumer.

What is today's situation?

Today a top of the range EV will travel about 300 miles on a single charge. For instance the 2018 Jaguar iPace will have a range of 310 miles. To cover this distance it requires a battery capacity of 90 kWh. This, or similar, is likely to be a standard size battery in the future as prices drop and greater ranges are a 'must have'.

If you assume you have an average size battery charger; it is a 3.5 kW device (equivalent to a fast boiling domestic kettle's electricity usage) . It would take about 19 hours to charge one of these batteries from being 25% full to 100% charged.

This time could be halved to 10 hours with a 7 kW charger. This size of charger is already available and will soon become more prevalent than the 3.5 kW versions.

However, these batteries can accept a 50 kW input and it would take about 80 minutes to charge if you could plug into that level of power. A home charger will not support this level of power requirement, but commercial sites do. Table 1 illustrates the charging times required for various battery and charger sizes.

Table 1 Approximate times it takes to 75% charge EV batteries by charger size

Charger size	Large battery 90 kWh	Average battery 28 kWh
3.5 kW	19:20	06:00
7 kW	09:40	03:00
11 kW	06:10	02:00
50 kW	01:20	00:30

Why may rapid charging at home be a challenge?

There are two potential areas why fast home charging will be a problem. The first is for those with on street parking and the second is network connectivity issues.

Not all vehicles have a permanent parking spot which could accommodate a connector to the network – or at least one that would be safe (see Figure 1 and Figure 2).

In a survey[1] 57% of households had access to off street parking and it is assumed that 43% did not. With 20 million EVs on the road that means that there will be 8.6 million vehicles without the necessary facilities to charge from home. So these consumers will require alternative charging facilities.

Figure 1 On street charging may present issues for some at home…

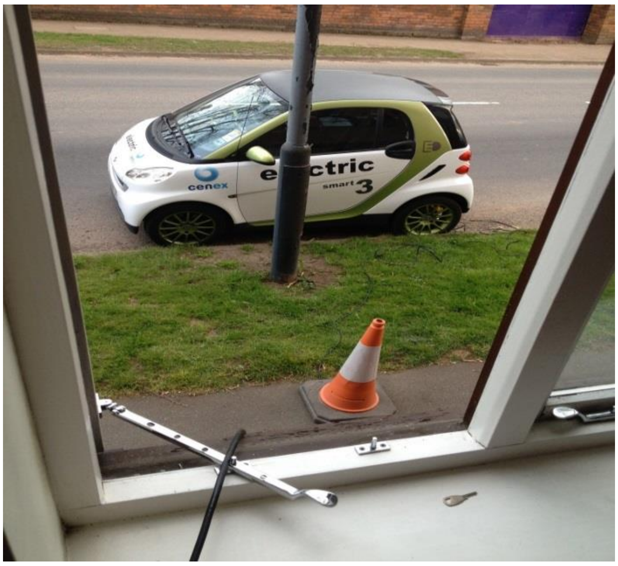

Figure 2 …or at work

The amount of power that can be drawn from the electricity network is limited. These limitations will obviously differ at various points across the grid, from household through distribution networks to the transmission system. For this insight we will only consider, in detail, the ability of a household to charge a domestic vehicle.

The average household is supplied with single phase electricity and is fitted with a main fuse of 60 to 80 amps. Using a 3.5 kW battery charger requires 16 amps. If one were to use an above average power charger, say 11 kW, this would require 48 amps. When using such a charger it would mean that you could not use other high demand electrical items (such as kettles, oven, and immersion heaters) without tripping the house's

[1] http://webarchive.nationalarchives.gov.uk/20111006052633/http://dft.gov.uk/pgr/statistics/datatablespublications/trsnstatsatt/parking.html

main fuse. Using an 11 kW charger would take 6 hours to fully charge a Tesla Model S, which also has a 90 kWh battery, from the 25% full state.

If your house had fitted the maximum 100 amp main fuse then a more powerful 22 kW charger could be used. It would take only 3 hours to charge the battery (or 5 hours if the battery was completely flat); but all the other electrical equipment in the house would have to be turned off as the charger requires 96 amps. In reality an 11 kW charger, with an above average main fuse, is likely to be a good compromise. So the house electricity capability is one 'pinch point'; unless the car is not used too much so the battery just needs 'topping up' and one is happy to trickle feed it each and every night.

Smart chargers are becoming common place and they will be the norm in the near future. These will help with spreading the demand away from peak times. When large numbers of EVs need charging they will be one important part of the solution jigsaw.

Another 'pinch point' would be the substation and the peripheral routes and branches within a local distribution network. Pilot projects, such as My Electric Avenue, were reporting potential issues at the distribution level. In one more extreme example they were identifying voltage issues when five 3.5 kW chargers were connected to a network cluster (with 134 dwellings) and were charging at the same time. The project concluded that across Britain 32% of low voltage circuits (312,000) will require reinforcing when 40% – 70% of customers have EV's based on 3.5 kW chargers[2]. These problems will only be exacerbated when 7 kW chargers are used.
with a 90 kW battery to three-quarters charge.

What sort of fast chargers are available at the moment?

Currently there are a number of fast charging national suppliers such as Ecotricity, Charge Your Car, Polar Network, Tesla, etc. Their fastest chargers are, typically, 50 kW. Such chargers take about 30 minutes to charge an average EV on the road today. It would still take over an hour for one of our desired long distance EVs Recent announcements by VW, Ford, Daimler and BMW have indicated that they plan to build a network of at least 400 rapid EV chargers across Europe. These are likely to be 150 kW units and may be capable of supporting 350 kW chargers in the future[3].

What might 2050 look like?

In the first place most, if not all, cars will be pure electric vehicles (EV). There will be no place for the ICE and the motoring infra-structure will be geared towards the EV. This EV dominance will have been driven by a number of factors such as:

- the national desire to meet the 2050 carbon reduction targets
- the desire for cleaner air
- the desirability of these newer products
- the probable relative cheapness of EVs.

There are approximately 32 million cars on the road today. In our Future Energy Scenarios we anticipate half this number will be EVs in our greenest scenario by 2033 and in our less green but prosperous scenario by 2042.

By this time these EVs will match the range of current ICEs and it will be normal for them to travel 400 plus miles on a single charge. The current recharging times are not going to be acceptable in the future unless there are other activities that could be undertaken at the same time (shopping, café, etc.). These delays will be even longer if there is a queue on the forecourt.

Consequently the approach we explore here is a system that can deliver these single charges within the order of minutes; similar to the experience of filling up at a petrol station forecourt of today.

What sort of charger would take minutes?

A 350 kW charger would take less than 4 minutes to three-quarters charge an average EV of today, with a 22 kWh battery. It would take about 12 minutes to charge a longer distance EV battery.

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2 http://myelectricavenue.info/sites/default/files/Summary%20report.pdf

3 Bloomberg, *European automakers charge into EV infrastructure*, 1 December 2016

This size charger is approaching the quick fill up time we currently experienced at the garage forecourt. So bigger would be better for the consumer.

There is one snag and that is current batteries cannot support this level of charging. However, in this article it is assumed that well before EVs become the norm, technology will have resolved this issue.

How many charging stations would be required?

The number of petrol stations has been steadily declining this century, although the rate of decline has slowed in recent years as the smaller stations get squeezed out by larger supermarket ones. It is estimated that there are about 8,500 petrol stations in the UK[4] today. If the historic rate of change is extended out to 2050 there could be just under 7,000 stations (see Figure 4).

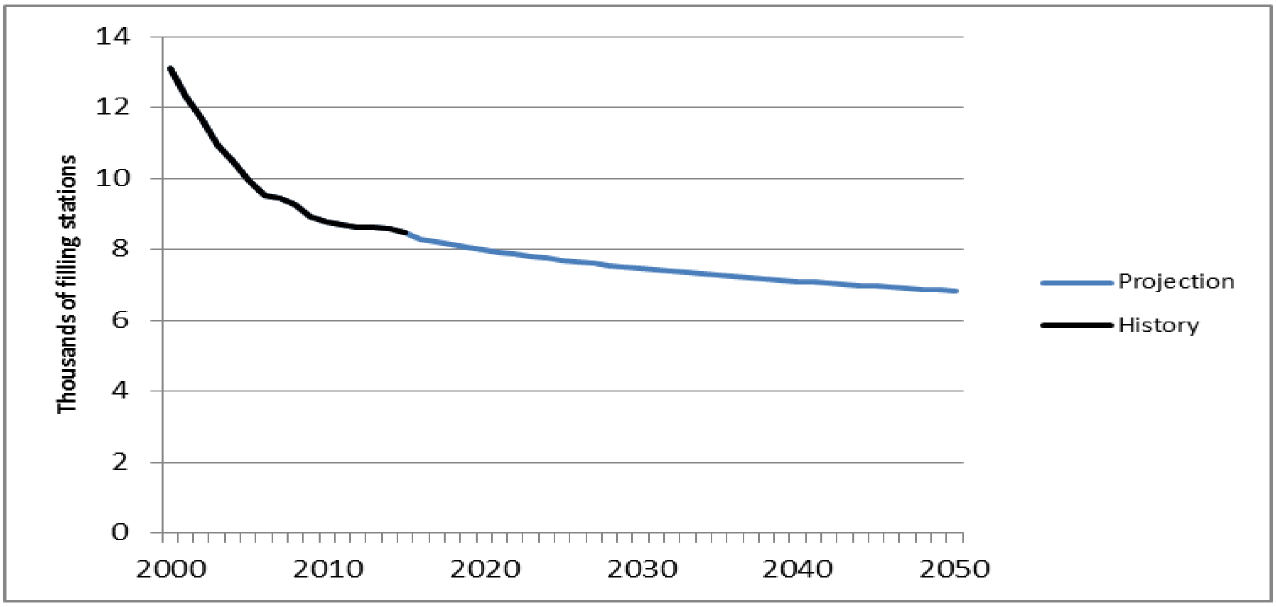
Seven thousand charging stations should be sufficient to cater for the needs of motorists. In reality fewer may be required as some element of home charging may occur.

What has also been apparent in the recent past is the growing dominance of the supermarket forecourt and the amount of fuel they sell per site[5]. This consolidation of services may well have advantages in a future environment where filling up times may take longer than today's.

The average number of pumps per forecourt was 7.3 in 2011[6] and this has been rising as the larger petrol stations predominate. The average number could be around 9 in 2050.

By applying these numbers to charging points, nine pumps of 350 kW capabilities would require an infrastructure capable of handling 3.1 MW. This is enough power to supply 1,000 average households[7]. In current forecourts, having 20 pumps is not unknown. Such EV charging stations would require a 7 MW infrastructure to support them. All these megawatt sites will be significant

Figure 3 The potential decline of petrol filling station



4 http://www.racfoundation.org/assets/rac_foundation/content/downloadables/racf_deloitte-fuel_retail-jan13.pdf

5 http://www.ukpia.com/docs/default-source/default-document-library/ukpia-2015-statistical-reviewf72b5c889f1367d7a07bff0000a71495.pdf?sfvrsn=0

6 ibid

7 https://www.ofgem.gov.uk/gas/retail-market/monitoring-data-and-statistics/typical-domestic-consumption-values

connections and would warrant a direct connection to the distribution network which would be above the domestic 240 volts.

How could we get these forecourts?

To achieve a national network of high powered EV charging stations will require the chicken and egg cycle to be cracked. Large battery EVs will not become common-place unless there are sufficient charging stations to service them. However there will be little appetite to build such service stations unless there are enough cars to be serviced.

Ultimately a network of forecourts may grow organically, as it did when cars were first introduced; but perhaps in this modern world someone may need to take the lead.

A few car manufacturers are constructing their own Europe wide networks. However, some analysts believe this has been undertaken primarily to sell vehicles[8] - and the quantities are small.

Supermarkets and their success in petrol forecourts may be other possible players. At their sites customers tend to be occupied for some time anyway so perhaps charging could be integrated into the shopping experience. Another option could be network owners and electricity suppliers working in tandem, one to reduce their infrastructure reinforcement costs by having alternative approaches to upgrading the residential network, and the other to sell retail electricity?

If we want long range vehicles that can be charged in minutes, home is not going to be the place to do it. And it certainly won't be for nearly half of householders who do not have access to off street parking.

In summary

In a world where almost all cars will be electric:

- 43% of car owners will not have access to off street parking
- too many domestic charging points will cause network stress.

So perhaps one potential solution would be to build a few thousand super-fast charging forecourts of over 3 MW capacity rather than carry out a large scale rebuild of the domestic electricity infrastructure. It may well be that the charging from home option may not be in the long term interest of the consumers even with smart chargers.

If you have any questions or comments we would like to hear from you.

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[8] Bloomberg, *European automakers charge into EV infrastructure*, 1 December 2016