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Going electric

How to incentivise the efficient deployment of electric vehicles

Ofgem has recently unveiled its new 'strategy for regulating the future energy system'. One of its objectives is to ensure an efficient locational management of the energy system, such that networks allow the transfer of energy from areas of surplus generation to areas of surplus demand. Ofgem also wants to incentivise the efficient development of energy networks in the longer term, taking account of the fact that it is yet unknown how exactly energy networks will be used in the future. In this paper, we examine how the regulatory framework implied by Ofgem's strategy would affect one of the main drivers of the change: electric vehicles (EVs). In particular, we ask how EV users would respond to the incentives embedded in the current and future regulatory frameworks.

Context

The fundamental change we witness in our energy system today is largely driven by decarbonisation policies and technological innovation. Decarbonisation policies have radically increased the share of renewable generation, much of it small-scale, such as rooftop solar PVs connected at the distribution level. Innovation provides low-carbon technologies to meet policy objectives—by, for example, lowering the cost of PV panels—but also creates opportunities for consumers that were not possible in the past, such as producing their own electricity or responding to market signals in real time.

The future development of each of the drivers of change, as well as their impact on the energy system is somewhat uncertain. Importantly, the regulatory framework and the incentives it provides will shape that development. To achieve Ofgem's stated objectives, the regulatory framework should offer a set of incentives to each participant of the energy system to behave efficiently.

It seems almost inevitable that EVs will be going mainstream in the near future, significantly changing electricity usage patterns within the distribution grid, but also creating opportunities for using their batteries as energy storage devices.

We examine how the proposed solutions under Ofgem's strategy would affect the user of an electric vehicle (EV). This includes whether EV users would have the right incentives to charge their vehicles in an efficient manner, and whether the strength of incentives would be sufficient to discourage inefficient behaviour. Where and when EVs are connected to the grid and how they are charged will have important implications for network investment. It is clear that the current electricity distribution networks are not configured for large-scale deployment of EVs. For example, it has been reported that charging just six EVs in close proximity to each other could lead to local outages at peak times.[1]

[1] http://www.green-alliance.org.uk/resources/People_power_how_consumer_choice_is_changing_UK_energy_system.pdf

INCENTIVISING EFFICIENT BEHAVIOUR

From a whole-system cost perspective, EV users should receive sufficient signals to connect and charge their EVs at locations and at times where they impose the least cost on the system while also meeting their own transport needs. What EV usage will look like in the future is still unclear, with current deployment still limited to early adopters. However, current evidence[2] suggests that most EV users prefer to recharge their EV at their home; most use charging points that can be accommodated by the typical household connection capacity available today; most start charging their EV before the battery is less than half full; and owners of EVs tend to be geographically clustered. Furthermore, dynamic pricing or smart tariffs are not yet common for domestic customers. While characteristics of EV usage may change in the future—for example, with autonomous driving, consumers may no longer want to charge their EVs at home or even own a car themselves—it is easy to see how the current adoption and usage patterns cause headaches to the distribution network operators (DNOs). Thus, regulatory and market incentives are critical to incentivise efficient behaviour.

CURRENT REGULATORY FRAMEWORK

In general, the regulatory framework incentivising domestic customers, which we think of as typical EV users, consists of three main elements:

- Network access regime;
- Network access charges; and
- Electricity tariffs.

These three elements provide incentives through price signals. Ofgem has suggested that it prefers the market to respond to such signals, potentially reducing the need for the System Operator (SO) and the DNOs to directly procure flexibility to manage the system. However, if the price signals do not elicit the desired response from consumers, then the SO, or perhaps more likely DNOs could engage in a direct procurement of flexibility. For example, DNOs could contract with EV users to stop charging their vehicles when the network is congested.

NETWORK ACCESS REGIME

The network access regime is a set of arrangements that establishes the connected customer's access rights to the distribution network. These access rights are currently offered on first-come-first-served basis. Whenever connection capacity is limited (which will likely be the case with a mass adoption of EVs), the first-come-first-served arrangement is clearly inefficient and inconsistent with Ofgem's guiding principle of relying on market-based mechanisms. Furthermore, any changes to the access regime may have a limited impact on households that are already connected, since the typical household connected today has a connection capacity that significantly exceeds its peak consumption. Any household that can accommodate a new EV within its currently available connection capacity will not be liable for any reinforcements. Consequently, the price signals sent by the access regime are limited.[3]

[2] https://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20B2%20-%20Impact%20of%20Electric%20Vehicles%20and%20Heat%20Pump%20loads%20on%20network%20demand%20profiles.pdf

[3] Note that to address delays with new connections, some distribution network operators now offer flexible connections using active network management that allow customers to connect more quickly and at a lower cost.

The fundamental problem is that too many access rights have already been allocated for the current access regime to give the right incentives to EV users. Ofgem is now seeking to explore mechanisms through which firm access can be more efficiently allocated, also providing a better signal for the DNOs on where to upgrade their networks.

Auctions are a common market-based mechanism to efficiently (re-)allocate capacity. These could potentially be applied to already allocated network connection capacity, as long as the transferability of access rights is made possible. For example, households with excess connection capacity (e.g. those not intending to purchase an EV in the near future), could offer their excess capacity in these auctions to those requesting new connections, benefiting both. In addition, high clearing prices would signal to the DNO in which parts of the network capacity upgrades would bring the highest benefit.

Ofgem refers to auctions for gas entry capacity, through which existing capacity products of different durations are re-allocated, as a potentially useful model to consider. They envisage an arrangement where capacity is priced by the market in primary auctions and through secondary trading, with access re-allocated in all timeframes to those who value it most.

While a potentially useful idea to re-allocate the current excess connection capacity, we note that there are significant differences between gas and electricity markets that may limit the direct transferability of these mechanisms.

First, gas does not require the near-instantaneous balancing that electricity does, and therefore there is time to hold explicit auctions for capacity allocation ahead of the capacity being needed. This also explains why in the EU electricity market coupling mechanisms network capacity is allocated implicitly, not through explicit auctions. Second, the kind of liquid secondary capacity trading close to real time that Ofgem envisages does not exist even for gas capacity. When the locational nature of expected capacity constraints are considered, liquidity availability may be even more problematic. Third, capacity trading in gas markets is performed by sophisticated traders. To expect similar trading by domestic customers would require unprecedented levels of engagement or new automated services provided by aggregators and technology providers. Lastly, if the purpose of connection capacity auctions is to re-allocate excess capacity, the supply of such capacity will dry up as more and more households adopt EVs.

In sum, while relying on market-based mechanisms, such as auctions, to re-allocate the current excess network capacity may work well in the transition to mass EV deployment, it is unlikely to be an enduring mechanism to efficiently allocate or re-allocate network access rights of EV users.

Network access charges

The current network access charging regime consists of forward-looking charges for connecting to and using the distribution network. As discussed above, most households with existing connections are not likely to incur new connection charges if they purchase an EV. Therefore, the main price signals they would face are the ongoing usage charges. Importantly, current distribution network access charges provide limited locational and time-varying signals to end users at lower voltages[4], and therefore do not convey to EV users where and when to charge their EVs.

[4] Locational price signals are provided at higher voltages of the distribution network, but those would not apply to EVs operated by households.

Ofgem has noted that there are significant differences in approaches to transmission and distribution networks charging which may lead to distortions, and therefore wants to explore whether there is a need for harmonisation. It also wants to introduce market-based mechanisms, although does not elaborate on how that would be done with charges that are inherently not market-based.

While transmission access charges do not affect EV users, with the interactions between transmission and distribution networks growing, there is certainly a merit in reviewing whether network access charges need to be aligned to ensure that overall energy system costs are minimised. One option could be to introduce the types of locational signals embedded in transmission network into distribution network access charges at all voltage levels. We note, however, that price signals provided by network access charges are static and may not sufficiently reflect changing system conditions that would be necessary to incentivise efficient EV charging in more operational timescales. The type of price signal that may be needed would be best provided through smart or dynamic pricing tariffs that have a locational element.

ELECTRICITY TARIFFS

Ofgem argues that the roll out of smart meters and mandating half-hourly settlement will incentivise suppliers to offer smart tariffs to their customers because they would want to pass on the costs associated with the customers' half-hourly consumption pattern. While this may be the case, half-hourly settlement will not further the objective of 'efficient locational management' unless suppliers face not just time-varying but also locational price signals.

The theoretically most efficient form of time-varying and locational price signals would be through locational marginal pricing, already implemented in a number of wholesale electricity market around the world. Under this pricing regime, the price signal that consumers face in each settlement period reflects the marginal cost of supplying electricity at the consumer's location at that time.

To our knowledge, such locational and time-varying tariffs have not yet been implemented at the distribution level anywhere in the world. However, academic literature has already explored whether distribution locational marginal pricing (DLMP) could alleviate congestion induced by EV loads in future power systems.[5] It has been found that in a system where the distribution system operator (DSO) determines DLMPs by performing a social welfare optimisation problem—similar to that performed by transmission system operators where locational marginal pricing is already in place—it can successfully alleviate the congestion caused by EV loads.

However, implementing locational marginal pricing at the distribution level would require a widespread deployment of enabling technologies, such as smart meters, smart charging and automation. Since this is not the case today, locational marginal pricing at the distribution level does not seem implementable in the near term.

CONCLUSIONS

The current regulatory and market frameworks are not appropriate to efficiently incentivise EV users. On the other hand, the theoretically most optimal solution, dynamic locational pricing, cannot be implemented in the near term in the absence of a sufficient deployment of enabling technologies. Its implementation may also create

[5] Li et al (2014), Distribution Locational Marginal Pricing for Optimal Electric Vehicle Charging Management, IEEE Transactions on Power Systems, Volume: 29, Issue: 1, Jan. 2014.

a significant number of winners and losers. To mitigate these distributional impacts would likely require a gradual transition.

Therefore, in the transition to a mass deployment of EVs, the most viable regulatory response appears to be incremental changes to the current network access and charging regimes, while preparing the groundwork for implementation of more dynamic, market-based price signals further into the future.

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