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V2X User Perception, Business Models and Regulatory Framework

Conference report

Workshop organised by the Armand Peugeot Chair and the Catalonia Institute for Energy Research, in cooperation with the Governace and Regulation Chair

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DEBATE

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Welcome address

Task 28 of the International Energy Agency (IEA) Hybrid Electric Vehicle Technology Programme explores the technologies, regulatory gaps and business issues associated with applying electric storage from plug-in electric vehicles (PEVs) to other purposes. Analysis of the technical and economic viability of potential V2X modes and functionalities via models, expert workshops, laboratory and field research and demonstration projects are being used to develop V2X policy and regulatory recommendations and a technology roadmap. Key priorities include the business case for V2X technology, battery degradation, standardisation and harmonisation, dissemination and engagement, marketing and regulation.

Manuel Sanmarti
Co-operating Agent (IREC)

1st panel: Business Models

Business models for V2X: A framework analysis and identification of industry challengers

Claire Weiller
Directeur général d'HSBC France

Value of V2H for home users

Vehicle-to-home (V2H) is a straightforward model: the individual needs a suitable vehicle, a charging/discharging cable, and suitable smartphone applications but they do not need a contract with a utility or retail supplier. V2H enables people to optimise their electricity costs, use energy they generate, and reduce their vehicle operating costs. Compared to vehicle-to-grid (V2G), V2H is relatively simple and easy to access. It is likely to appear on the market at an earlier stage, subject to consumer demand for e-mobility and dedicated stationary storage.

The return on investment for V2H varies significantly depending on the solution chosen. It could take sixteen years to recoup the investment for a Tesla PowerWall; with the addition of solar panels and optimised charge/discharge cycles, that period can be reduced to three years. If V2H cycling was optimised throughout the day, it could be possible to generate around £900 per year.

V2G: a more complex proposition

V2G benefits the grid as a whole rather than the individual and, as such, requires the involvement of aggregators to contract and manage the relationship between the vehicle owner, the grid and the distribution network and ensure effective operations. V2G services offer fast ramping, high and low power and any level of volume and can be provided from any location as long as the user can be identified. Business models need to manage operational and contractual complexities but also compensate vehicle owners for the inconveniences associated with participation.

A number of small-scale research projects are underway in the UK to test particular services or aspects of V2G provision. These tend to be funded as individual programmes; the self-sustaining revenue streams and private sector investment required to explore functioning business models are not yet in place. It should become possible to test business cases with a new wave of projects that are currently going through government funding reviews, such as a project to use solar panels and integrated chargers to transform car parks into V2G-enabled power stations.

Framework analyses

V2X could be a very low capital expenditure model because customers pay for vehicle infrastructure up front. Customer acquisition, however, is a significant cost to V2G providers and providers must also invest in software platforms and equipment to control distributed vehicles. Grid services, fast frequency response (FFR) and various types of ancillary services all offer revenue-generation potential but are limited by energy markets and grid investment regulations. For example, FFR contracts are for four years only, which limits the potential for start-up aggregators to secure private-sector funding. V2G could enable grid operators to reduce capital investment and obtain low-cost service balancing, but this will depend on other parties creating vehicles that are V2G-compatible and opening their systems to grid operators.

V2G is unlike other sustainable manufacturing models. It maximises energy efficiency, delivers functionality rather than ownership, encourages sufficiency, and develops scale-up solutions. This places it within technological, social and organisational categories. It also uses a platform business model, with an aggregator mediating the grid and end-user relationship and sharing some of the savings and revenues with car owners to compensate them for transaction costs.

End users can be compensated through upfront discounts on car prices or a share of revenues. Research indicates that consumers are only willing to give up about 33% of any savings or benefits that they gain from adopting services, which makes it difficult for aggregators to develop a profitable business model. End users tend to prioritise upfront discounts on the vehicle or a pay-as-you-go contract that offers proportionate compensation for services but does not involve obligations that limit their flexibility. Compensation levels have been estimated in some cases at twenty times expected aggregator revenue, indicating that these models are not sustainable.

Furthermore, customers require certainty on the benefits they will accrue; guaranteed performance of the energy savings model is a necessary condition for commercial success. Companies require long-term visibility on fixed cash flows to attract private sector investors. If the cost of batteries falls and demand for frequency response services rises, V2G could become commercially viable and offer competitive advantages.

Is aggregator revenue expected to be 20 times lower than compensation demand?

Yes. Based on current consumer compensation preferences, aggregator revenues would need to be twenty times higher than current revenue projections to meet customers’ expectations.

Could you provide more detail on consumer expectations for costs and savings?

Research into different types of user contract that utilities can offer customers indicated that end users are willing to give up some control over appliances in their home to enable utilities to optimise their energy consumption. However, users are only willing to pay £0.33 to the utility for every £1 reduction in their energy bill that they obtain through this service.

Business cases vary depending on the contract frameworks, compensation and revenues that are available to aggregators in different countries. How can this be managed?

I am most familiar with the UK. In environments with a small market and no revenue certainty, an aggregator might be unable to find a business model that adequately compensated car users.

Could you discuss the relationship between your energy savings model and regulatory energy efficiency requirements?

I am not able to discuss this at present but it is a valid point.

It will be interesting to see how future business models balance the enormous potential for savings on the grid side and the need for V2G to be commercially viable.

Do your business models include fixed costs and variable costs? Is it possible to assess the size of the market and the likely number of players for each model?

The electric vehicle (EV) market is constantly changing and is set to grow rapidly in the coming years. Due to innovation diffusion, it is likely that a sizeable number of people will have all of this kit in their homes within the next five years or so.

Have you analysed the role of the spot, capacity and primary and secondary markets?

The UK and Germany contract balancing services in different ways. It is unlikely that bidding into regular energy markets will be profitable. At present, enhanced frequency response bids and the capacity markets or a combination thereof are most profitable.

There is potential for V2G concepts to offer savings on re-enforcement and modify the flow of the transmission network. Do you agree?

This touches on broader questions about the impact of distributed energy resources on central grids. An impact on transmission networks might be avoided with small-scale local deployment.

There are significant regional differences in terms of business models, operating costs, aggregator activities and network reinforcement. The current focus on frequency response markets is driven by access to easy value, but new value chains in distribution services should open up in the future. Regulators will play a key role in any changes.

Effects of battery degradation on economic analyses of V2X service provision

Andrew W. Thomson
Vedecom

V2X is a potential source of energy storage and grid services, including the lucrative ancillary services known as frequency reserves. EV batteries can provide fast, technically reliable service provision as well as mobility. They can be connected to a building to offset consumption or to an aggregator who sells energy to the grid to offset unplanned grid losses or perform arbitrage. Frequency regulation is the most lucrative market due its lower net energy transfer requirement.

Market-specific capacity requirements are a very large barrier to entry for new storage technologies. Performance standardisation requirements can also limit new entrants. To ensure efficient service delivery and minimise battery degradation, battery systems need to maintain a state of charge (SoC) of 50%, namely a net energy that is as close to zero as possible.

Li-ion Batteries

The degradation mechanisms acting on the anode and cathode of lithium-ion batteries are increasingly well understood. All ageing mechanisms result in either increased internal impedance or fading capacity. Over time, battery quality degrades naturally through cycling fade and, more importantly, calendar fade. These intertwined relationships are heavily dependent on temperature, charging power and SoC. Driver behaviour also influences battery degradation.

Battery Lifetime Models and Economic Evaluations

Models of battery lifetime tend to be built entirely on theoretical equations or entirely on data. No existing model is sufficiently sensitive to capture the minute effects of quick charging and discharging on battery degradation or the effects of cycling at different depths of discharge. Most models reflect lab tests of full cycles and do not capture quick cycling behaviours. Accelerated cycling tends to over-estimate battery life. Models also tend to be limited in their ability to analyse the impact of different Li-ion chemistries on the ageing profile.

The total amount of energy that a battery can provide over its life, known as total battery energy throughput, is strongly influenced by usage and SoC. Economic evaluations tend to examine the total lifetime and energy of the battery and the number of cycles that can be obtained, but fail to account for battery degradation caused by calendar fade. The net present value of battery throughput is a first attempt to take this factor into account in an economic evaluation.

Optimised charging that reduces the time the battery spends at high SoC could help to balance the costs of electricity and battery degradation. In a hypothetical situation with near-perfect temperature stability, lowering SoC would justify power exportation due to calendar fade alone.

Conclusions

Economic valuations of V2X must not ignore physical realities. The time, temperature and SoC at which at battery sits are the most prominent factors in battery degradation. Battery models are a best estimation due to the difficulty of obtaining long-term empirical data. V2X may be more valuable than previously thought, particularly if battery life can be prolonged.

What are the next steps in battery research? How do the different variables in economic and technical evaluations of battery degradation relate to each other?

The next step is to develop a battery model with sufficient time resolution to capture the effects of frequency regulation. Projects are underway. The aim is to conduct economic analyses of energy degradation on the basis of annual battery throughput. Energy costs, operating costs and battery degradation costs are all relevant to V2G.

What are the likely implications for grid operation, distribution and aggregation?

There is a lot of debate about the relationship between aggregation and distribution systems operators (DSOs) and transmission system operators (TSOs). The overall impact of batteries will depend on their final output. This is already the case with generators.

As batteries get larger, it may be easier to hit the 50% mark. Is this just a happy accident?

My current focus is entirely on battery degradation and how the smallest impact can be obtained. My contention is that V2G can be used as a methodology to optimise charging algorithms so the effects of battery degradation are taken into account during service provision.

Value propositions for disruptive technologies: Reconfiguration tactics in the case of electric vehicles

Prof. Dr. Jonatan Pinkse
Manchester Business School

Disruptive technologies reinvent a market by introducing new attributes that deliver competitive advantage. When they are first introduced, these technologies tend to under-perform in areas that are viewed as key attributes of the incumbent technologies; improvement can be time consuming and uncertain and limits customer recruitment. Business model innovation can help to compensate for technological inferiorities and create a more attractive value proposition to enhance customer engagement. EV is a classic example of a disruptive technology: it is set to change the market but a several barriers must be overcome before its potential can be realised.

Value proposition: comparing attributes

Value propositions can be used to explore the relationship between incumbent and disruptive technologies. At first, customers value the incumbent technology more highly than they value the potential of the disruptive technology. Nevertheless, there are points of parity where the technologies are similar, points of opportunity that are desirable but not supplied by either technology, and points of untapped value that are offered by the disruptive technology but are not yet recognised by customers. For EVs, untapped value includes discharge technologies.

Value proposition reconfiguration

By reconfiguring certain aspects of the value proposition, companies can compensate for unattractive features of their technology and make the product more appealing to customers. EV manufacturers are currently focusing their tactics on addressing three key problems: driving range, price, and charging time and infrastructure. For example, mobility services such as roadside assistance and dashboard software help to address range anxiety while initial price reductions, extremely long warranties and 'smart home' lease deals address price concerns.

Value proposition tactics

Value proposition range from basic steps to compensate for points of inferiority to enhanced techniques that create points of opportunity. Manufacturers that innovate and work with other companies to deliver coupled value tend to perform better than those that simply compensate. Manufacturers start by disaggregating the existing value proposition to explore how customers perceive and value different product attributes, then identify ways to change customers' perceptions, preferably without making expensive technological changes. The value proposition can then be reconfigured in a way that is more attractive to customers.

Applying the framework: the opportunity for V2X technology

V2X technologies have the potential to reshape the EV value proposition. Customers value compensating tactics, such as a larger driving range, and enhancing tactics, such as advanced software and rich communications. Coupling tactics that enable firms to build a new customer ecosystem offer the greatest potential. Success will be determined by how far manufacturers are able to go and how much control they are able to maintain.

Do you think that any OEMs will develop strategies based on exclusivity to avoid cannibalising their existing business? Have you taken these factors into account?

Many car firms are hesitant about adopting radical business models and prefer to refine models used for existing vehicles, even though they could go further and in new directions. This is a real problem. Of the companies we have observed, only BMW and Tesla are truly innovative. The companies are prepared to be more radical are more successful at present.

Are coupling strategies always successful? Some customers view them as additional complication. Could they act as a barrier instead of an opportunity?

The customers are often the most conservative actors in this equation. This kind of insight is crucial for understanding and overcoming the various technologies and challenges of EV.

Car companies are working to reduce the total cost of ownership for customers and demonstrate that EVs are nice cars. How can we share the value of EVs with end users?

It is important to be clear about the value that we are actually offering to the customer.

It would help if the price of an EV was equivalent to the price of a similar car. We need regulators and energy companies to help end users access the value that EVs offer.

Persuading utilities and regulators to recognise the value of V2G is an ongoing challenge. We hope that the recommendations of this group will help to move the process forward.

The value proposition also needs to be looked at from the perspective of consumers, not just regulators and utilities. Regular users want things to work, they do not care about transmission and distribution. Customer interfaces need to be as simple as possible.

Electric vehicles and ancillary services markets

Rao Konidena
MISO

The form and regulatory structure of grid operator networks influences the regional potential for EV uptake. In US states with Independent System Operators (ISOs), aggregation must be undertaken in partnership with local utilities.

V2G and its associated distribution and transmission infrastructure opportunities could be a great resource for aggregation, generation and demand/response programmes in wholesale markets. Retail penetration could generate further wholesale opportunities. Transactive energy, namely transactions between players who are consuming and supplying energy in peer-to-peer exchanges, is driving grid architecture by enabling specific marginal prices to be generated at individual locations at wholesale and distribution system levels.

Aggregated EV Resource

Aggregated EVs could contribute to that market. At the same time, plug-in hybrids increase the existing challenges of transmission planning and energy storage devices such as EVs could further complicate the situation. Grid operators care about large generating volumes that could affect grid reliability and transmission. EVs change that equation: as individual resource they are small, but as aggregated assets they are a sizeable market of distributed generating resource. It is hard to make the case that EV could increase or displace a transmission-level network upgrade, but they could defer a distribution-level upgrade.

There is a healthy tension between market participants and stakeholders around aggregation thresholds. ISO markets tend to have conservative thresholds of 1-5 MW depending on the resources in question; other markets can go as high as 100 MW. Lowering these thresholds would help to make EV aggregation a viable prospect. Resources and cycle charging/discharging behaviours should be modelled in preparation for a time when the EV market takes off.

At present, locational marginal pricing is a transparent way of exploring the cost of serving the next marginal megawatt and incentivising the future resource mix in different areas. Different ISOs have different models, but all of them explore the price at the commercial pricing node (CP node). The CP node is composed of elemental pricing nodes which are an aggregation of transmission buses. As EV grows and its resources are aggregated, the impact will be felt in the buses and filter up the chain, making it possible to integrate EVs into pricing frameworks.

Wholesale Energy and Ancillary Services Market Opportunities

Different resources have different relationships to different markets. For example, demand resource responses do not respond quickly enough to operate as regulating resources. Capacity markets also place certain obligations on operators. With an aggregated EV resource and some adaptations to current market obligations, it would be possible for EV to act in all wholesale markets, including capacity markets. If energy storage capacity is considered as a resource, utilities will be able to integrate that resource into capacity and defer the need for upgrades.

A certain amount of aggregation is required to become visible on the network. What is the minimum level? What are the considerations? Is the individual EV level desirable?

Individual EVs and storage devices are at kilowatt level, which is substantially below the scale at which wholesale energy markets operate. Market software cannot cope with anything smaller than a megawatt. Aggregation is probably the best way to create a useful platform.

Have you done any business modelling of revenue schemes for aggregated CP nodes?

I do not believe MISO is doing any. It is likely that PJM are doing some but I would need to check.

Very detailed information is collected from autonomous vehicles. Are grid operators developing the capacity to work with that level of detail for individual vehicles?

Grid operators are technologically agnostic and work on the basis of price and load, not individual resources. They face with a range of new resources and opportunities and are required by regulators to work in the same way with different providers.

Electric vehicle deployment scenarios used in France to estimate grid development

Florent Chiappini
ENEDIS

In June 2016, France had almost 90,000 EVs and PEVs and more than 14,000 public charging points. Activity is concentrated in the Paris region due to car-sharing schemes but private ownership is increasing quickly and now outpaces the growth in company car ownership.

Charging capacity and consequences for distribution network

The 2015 Energy Transition Law sets an ambitious target of 1 million points by 2020 and 7 million charging points by 2030. There is rapid growth in installed capacity, particularly in quick public charging points, which could have a tremendous, disruptive impact on distribution networks. Different types of charging points have different impacts on grid reinforcement and development costs. A single normal charging point takes 7 to 8 hours and consumes 3 to 7 kVA while a quick charging point takes an hour but consumes 22 kVA. Fast and ultra-fast charging points have even higher demands. Charging methods, locations and management approaches all influence how infrastructure is used. It is vital that long-term scenarios are developed to manage this transition.

Main drivers of EV and PEV development

EV and PEV development is driven by local factors such as vehicle renewal rates and household purchasing power, and national factors such as regulation, vehicle ranges, and changes in consumer attitudes. Access to public charging infrastructure is expected to play an important role.

The impact of these changes to 2035 is being modelled on the basis of four national development scenarios. The most negative scenario predicts low economic and demographic growth and slow deployment of EV and PEV while the most optimistic predicts strong economic and demographic growth, massive transport electrification, and strong growth in EV and PEV. Estimated annual sales of EVs and PEVs in 2035 range from around 3.2 million in the depressed scenario to 9.6 million in the most optimistic. Even so, market share is not expected to exceed 33% by 2035.

It is expected that urban areas will experience faster EV and PEV development because more households experience pendulum migration and appreciate the environmental benefits that these technologies offer. High-density areas will also experience more uptake due to higher vehicle renewal rates and higher household purchasing power. Other areas will experience slower growth rates. Models are also being used to estimate EV network and infrastructure requirements.

Conclusion

Enedis is developing forecasting tools to assess the long term deployment of EV and PEV in order to estimate the cost of its impact on the network. These tools are also being used to build a shared vision with different stakeholders at a local scale. Massive deployment of EV and PEV could represent between 1.5% and 4.5% of current electric consumption. Power requirements will be more significant and will strongly depend on charging methods, locations and management tactics. The efficient development of EV will require interoperability between different charging infrastructures, a national director scheme for charging infrastructure to ensure geographical and technical coherence and minimise the social cost of deployment, and the creation of incentive tariff signals and leveraging smart technologies.

What steps are being taken to reach the government's challenging charging point targets?

Enedis is using its own EV fleet to evaluate different charging methods and incentives and obtain insights into charging behaviours. It is also exploring EV behaviours in urban areas. A GPS location tool is available to help people understand the costs and locations of charging points.

What is being done to promote access for low-income and disadvantaged populations?

A national director scheme would reduce the cost of deploying infrastructure and expand access.

Are you considering price modulation to incentivise people to charge at night time?

France already has lower night-time domestic tariffs. Regulatory changes could be implemented for EVs to help to reduce peak power demand from EVs.

There is a move towards larger batteries, yet your models show that you expect the number of fast charging points to decrease in the future. Why is that?

The numbers shown represent identified infrastructure projects. They are not projections.

Does your model take account of the fact that smart management of EVs could make it possible to postpone or even decrease grid investments?

That is the next step of the study. Once the potential costs of the technology have been estimated, aspects like the impact of smart charging will be modelled.

Demand-side factors are important, but so is supply. Do your scenarios take account of sudden peaks in demand that are likely to arise as EV becomes fashionable?

We take this parameter into account but it is difficult to model and the overall impact is not expected to be significantly different. The deployment curve is expected to be an S curve.

It would be interesting to see a 2035 scenario that models 100% EV sales to take account of predictions around fuel costs, decarbonisation goals and wider adoption of EV.

This will be modelled, but modelling a major disruptive scenario like this was not our first step.

2nd panel: V2X Challenges for field implementation

Introduction by the Chair

EVs are expected to account for 20% of global vehicle sales by 2020. This will have significant consequences for energy demand and systems. In France alone, the additional demand could be equivalent to two to four nuclear reactors. Demand management and charging infrastructure will be central to meeting this challenge. The storage capacity and flexibility of V2G could enable it to play a key role, subject to the availability of efficient two-way batteries, innovative energy boxes, home energy management functionalities, and a well-adapted regulatory framework. At the same time that new technologies are being rolled out that enable suppliers to offer more creative pricing structures, regulators are working to develop the next generation of network tariffs.

Integration of new technologies in the energy system

Christina Plum
Energinet.dk

Denmark is highly integrated with the rest of the European energy system. Around 42% of energy consumption was wind-generated in 2015; by 2018, the proportion of wind should rise further and production from conventional sources should fall. Nevertheless, the system's flexibility currently depends on decentralised power plants and cross-border inter-connectors. Energy consumption from heat pumps and EVs is expected to increase in the future.

Flexibility in the electric system

Attempts to introduce more flexibility into the Danish energy network are focused on the ancillary services market and balancing services. The framework and the rules for a new aggregator role are being reviewed and a shared Nordic TSO project has begun to harmonise market rules and enable cross-border aggregation. A project is also underway with the Danish Energy Association.

Four pilot projects are exploring how market roles can evolve to overcome barriers that limit participation and reduce supply and competition. The pilot projects aim to test market rule adaptations for batteries, EVs, heat pumps and industries. They are exploring areas including online measurement, verification and third-party aggregation and should help to identify areas where regulations and market practices could be usefully modified to overcome barriers.

Other projects

The NIKOLA/DTU project, which is exploring the extent to which EVs can participate in frequency regulation services, has made good progress and is providing variable inputs to the grid using codes intended for small wind turbines. The EVs can deliver both up and down regulation, which facilitates integration with other resources.

A heat pump project is exploring the potential to expand flexibility by installing larger heat pumps at schools and institutions. It is also examining how aggregators deliver measurement data from sub-meters to the hub. EnergyCool and EConGrid are exploring the potential for recycling and reusing batteries that are still functional but no longer adequate for use in EVs. EnergiDanmark are examining the aggregator role and its role in demand/response.

Denmark aims to be fossil fuel independent in 2050, in part by incorporating ancillary service from new technologies.

You expect more flexible pricing in the ancillary services market in the future. What is that likely to mean in a context of increasingly flexible loads and generation in the market?

It is difficult to say what the price will be in the future. However, at some point, a new balance will emerge between flexible resources and higher demand. We expect to buy the same amount of reserves in the coming years but use of the balancing reserve might increase.

How do you see the relationship between stationary storage and V2G?

TSOs are technology neutral: we just look at the price. It is possible that batteries and EVs will compete in the future. At present, this is simply a question of price.

Service provision, market rules and tariffs should all be technology neutral. Do you expect to have separate signals or services designed for specific technologies?

The short answer is no. We cannot change the frequencies in the Nordics.

PJM have split the Frequency Containment Reserve signal into net zero energy fast-acting provision and an additional signal. Do you do this?

No. If we do anything, we might develop a synthetic inertia product in the distant future.

Are you using individual cars to bid into the system or an aggregated approach?

We use aggregation, but we currently operate at a very small scale with just ten cars. We will explore larger scale aggregation in the future.

Electric vehicles: A problem or an opportunity for utilities

Senan McGrath
Eurelectric

Policymakers and utilities do not have a consistent attitude to EVs. There is no consistent answer within or across utilities about whether EVs represent a problem or an opportunity, as this depends on whether they are being viewed from a perspective of energy efficiency or distribution system planning and connection. In general, utilities that have already engaged extensively with renewables tend to see EVs as an opportunity and vice versa.

Driving an average distance of around 16,000 km/year consumes around 2,500-3,000 kWh of electricity, equal to the consumption of an average resident in southern Europe. Battery size and charging rates are increasing at faster rates than anticipated and costs are also falling faster than expected. Private cars everywhere are typically parked for over 90% of their life. EVs are unique in terms of residential load management as short-term supply interruptions are acceptable.

Latest trends: low-carbon generation is leading, capacity goes green

In 2013, for the second year running, more than half the energy generated in Europe came from low-carbon sources. More than 70% of new capacity installed since 2013 is renewable. European electricity utilities are committed to the idea of full decarbonisation by 2050. However, petroleum lobbyists are fuelling concern that emissions are simply being transferred from the tailpipe to the power station. Research indicates that the average European mix for 2010 is 66g/km, allowing for network losses. This falls to around 58g/km in 2015 and expected to be 28g/km by 2035.

EV range is also increasing. For example, the Nissan Leaf / Renault Zoe had a range of 160km (24 kWh) in 2010 and should reach 400 km by 2018. A 24 kWh battery offers twice the range required by the average driver; spare capacity will continue to rise as battery sizes increase. As such, it should be possible to operate in a 30-80% charge situation and still offer spare capacity.

Charging systems are developing rapidly. At present, five minutes charging with a standard 16 amp domestic charger offers 2.1 km of range while a fast 50 kW charger provides 27.8 km. Car companies are pushing to have vehicles with a 500 km range and a 350 kW charge on the road by 2020. The aim is to have a suitable 350 kW network in place by 2018.

EV in the United States and Europe

Research indicates that if 100% of US vehicles were EVs, consumer energy spending would shift US $500 million per day from the petroleum industry to the electricity industry. If charged overnight, 73% of the current light-duty car fleet could be supported as PEVs without adding a single power plant. The situation is even better in Europe. A Californian utility proposal to invest in charging infrastructure with 60,000 points has been approved.

In Ireland, the TSO is interested in reintroducing automatic inertia as a huge amount of inertia has been lost from the system in the last three years. The Irish power system faces significant challenges, including a growing need for advanced systems and distribution improvements.

There is no common approach to EV charging across Europe. Germany, France, Scandinavia and the Czech Republic view EV charging and grid services as the responsibility of a supply company or an unregulated sub-company. In Italy, Luxembourg and Flemish Belgium, charge points are installed and operated by the DSO. In the UK, market forces are expected to solve the problem. Spain, Portugal and the Netherlands have a mixed approach that involves all options.

Can the European electricity system cope with EVs?

If all cars in Europe were electric, total electricity demand would rise by 24%. However, if all charging occurred outside peak periods, this demand could be met without any increase in generation or transmission. Clustering may result in investment in distribution systems but can be limited with smart charging. Improved asset utilisation will tend to reduce electricity prices for everyone, including those who do not own an EV.

How do DSOs view the goal of a Europe-wide 350 kW charging infrastructure by 2018?

The DSOs will apply the rules and have already coped with Tesla's 120 kW demands. The 350 kW network is likely to installed as banks of chargers with a minimum demand of 1.2 MW.

This would place substantial demands on the network and the whole electrical system.

The Irish utility installed an extensive charging network with minimal grid upgrades because it was careful to leverage existing distribution capacity. European utilities are likely to meet this challenge by putting copper in the ground, because regulators are not encouraging uptake of smarter distribution solutions such as V2G. It will take time, but we will get there.

A methodology for interoperability testing of V2X technologies

Miguel Olariaga
Joint Research Center, European Commission Science & Knowledge Service

By 2014, €3.15 billion had been invested in European smart grid projects, most of which related to smart network management, EV and V2G, and smart customer/home projects. The IEA expects a further €600 billion of smart grid investment in Europe from 2014 to 2035. These projects have shown that technical barriers are less important than social and regulatory issues when it comes to upscaling pilot projects. An analysis of market and regulatory forces highlights a clear link between incentive-based regulatory schemes and investments in smart grids.

SG-EV Interoperability

Interoperability tends to lower production and operational costs, which encourages regulators to expand incentive schemes and encourage additional investments, and should also encourage market penetration of smart grids.

The EU-funded COTEVOS project proposed a reference architecture for information and energy exchanges between DSOs, TSOs and other electro-mobility actors that need to work together to balance capacity and demand and manage energy pricing and mix accordingly. These roles can be distributed across different entities which have to exchange information, deploy technologies, and respect multiple standards and regulations in real time if the system as a whole is to function.

The energy management system sits at the core of the home but there are questions around its role and the extent to which different components are able to take independent action. Again, multiple actors are involved and there is a need for multi-level interoperability. At present, there is no coherent response to this challenge.

JRC Interoperability Center

Standards are not sufficient to ensure interoperability: technologies, functions and regulatory issues can all impede interaction. Component interoperability for various activities and outputs must be tested in line with a reference architecture and multiple use cases in order to identify how the component deals with diverse regulations, multiple communication paths and standards, and different stress conditions. The testing process identifies parameters affecting interoperability and also facilitates the exchange of information and integration of new technologies.

Have you tested a V2X charger?

Not specifically. We have worked on power quality, which is relevant to data transmission for V2X, but we are still building the test bed infrastructure required to conduct specific projects.

Are you undertaking any projects on energy storage and grid services?

We are testing disconnection and frequency stability in a micro-lab with 450 kWh of capacity. We are also testing a household scenario.

Are you collaborating with the US, for example on regulatory standards?

There is a cooperation agreement between the US Department of Energy and the EU Commission to work on EVs and smart grid interoperability. We are conducting phased testing of products according to local standards with a view to facilitating trans-Atlantic market cooperation. Next year, there will be projects focusing on smart homes.

Interoperability is of the utmost importance for EVs. Is it likely that there will be any EU norms or standards in the near future?

There are three mandates. The mandate on smart grids is complete and work is continuing on mandates for gap identification and testing, for example on V2G, e-mobility service providers and markets. We are contributing to ongoing cyber-security work.

Discussion

Manuel Sanmarti (IREC)

Compared to business models and regulation, to what extent are standards and interoperability a barrier for car manufacturers?

B. Carroll (ESB)

DSOs are technology neutral as long as the technology meets their grid requirements. Their primary function is to secure the electricity supply. As such, they are unlikely to compromise their requirements to facilitate the entry of a new technology to the market.

Andrew Thomson (Vedecom)

Current requirements are based on established technologies. If the technical requirements do not evolve, that will create an implicit barrier to entry.

B. Carroll (ESB)

TSO markets are designed for traditional technologies but they are starting to change. There are very few standards on the DSO side. Some German standards are starting to filter through, for example for connection standards, but they do not exist fully.

From the floor

Additional regulation are required for EVs to be seen as an element of the grid. A dedicated standard would be useful. Technical interoperability issues will be solved with time.

Introduction by the Chair

The liberalisation and deregulation of distribution and transmission networks has been going on for many years. In the last ten years, the potential of non-traditional resources on demand-response and demand-side management has been increasingly recognised and steps have been taken to improve energy efficiency and reduce barriers to demand-side balancing and consumer participation. Nevertheless, Europe does not have a consistent approach and there are technology biases and limitations. Meeting the challenges posed by new technologies will require a shift away from traditional regulatory approaches and operational solutions.

Economic regulation issues regarding V2G in the US

Ramteen Sioshansi
Integrated Systems Engineering, Ohio State University

Economic regulation issues in the United States affect V2G and distributed resources and storage more generally. New market designs may make it possible to overcome some of these issues.

V2G Applications

PEVs can provide V2G services via unidirectional services, whereby the charging rate is controlled to provide a demand-response type of service, or via bidirectional services, whereby the capacity to discharge the batteries enables the provision of additional services. Bidirectional services raise degradation issues, which act as disincentives for original equipment manufacturers (OEMs). In both cases, the PEV behaves like a distributed energy storage device and gives rise to many potential applications, including energy arbitrage/generation shifting, ancillary services, capacity deferral, end-user applications, and renewable curtailment.

These potential applications need to be combined in ways that maximise the social and private value of PEVs. For example, distribution relief may be most valuable at particular times of day. However, there are important regulatory barriers to achieving this goal, primarily because restructured electricity markets are, in practice, a hybrid between market-based and regulated designs. There are usually transparent, market-generated price signals for services, such as energy, ancillary services and generated capacity. Services such as power quality, transmission capacity and service reliability, however, do not generate meaningful price signals.

Hybrid Regulation

Hybrid market design means there are differing regulatory treatments of generation, transmission and distribution assets. For example, electricity generation is generally priced in the market on the basis that generators recover costs through wholesale prices. Distribution and transmission are usually regulated, with the costs recovered from customers through the regulatory ratebase.

V2G/storage can cross these boundaries. For example, energy arbitrage is priced on the market, while distribution capacity services are not. In two recent cases, the US federal regulator has treated storage products as providing either regulated or market-based services only, with cost recovery determined on that basis. In the case of a 500 MW pumped hydro storage (PHS) plant with an adjoining transmission corridor to relieve transmission congestion, the regulator determined that the transmission corridor could be ratebased but that the PHS services would be priced in the wholesale market. In another case, the regulator agreed to ratebase the construction of a set of batteries to provide voltage support and other transmission services.

These regulatory decisions indicate that the costs of V2G or other distributed assets for distribution relief could be recovered from customers through the ratebase. However, this is likely to be conditional on services not being provided to the market if there was a high energy price or frequency regulation price. As such, a V2G project developer has to choose between providing regulated services with guaranteed costrecovery or providing market-based services with greater risk and some services that are not remunerated. As a result, only a sub-set of the potential services that a project could provide will be delivered.

Proposal: Storage-Capacity Rights

An auction-based business model for aggregating different value streams of energy storage could overcome the challenge of co-mingling priced and unpriced services by separating out contingent rights to use storage capacity. Aggregators could define storage rights for a given asset then auction the rights to different storage users. These users would make payments to the V2G aggregator and recover the costs through wholesale market transactions or the regulatory ratebase, in line with final use. An efficient and incentive-compatible pricing rule could be established in this way. Revenues earned through the auction by the V2G aggregator are equal to the imputed marginal social value of storage capacity, which sends the right signal for long-term investment. Rights and pricing rules behave in a similar way to financial transmission rights and locational marginal pricing. In addition, the spot market for storage capacity rights could enable the aggregator and third parties to bilaterally contract on a long-term basis.

Conclusions

PEVs have great potential to provide a low-cost source of energy storage. However, the current regulatory design is not conductive to capturing the value of energy storage or V2G services, especially at the distribution level. Storage capacity rights can address this issue by disentangling the cost recovery of different uses from storage or V2G ownership and investment.

Federal and state ratebases and regulations are not the same.

That is correct. I chose not to explore or highlight those differences on this occasion.

Do you expect practical implementation soon? Are there legal or regulatory obstacles?

Oncor, a T&D utility in Texas that is proposing to build 5 GW of distributed batteries but is locked in a legal impasse, is an interesting test case. It is not clear if their case will be resolved in the next legislative session or if they will need to implement a contracting arrangement.

Is there any regulatory agreement about a market design to resolve these issues?

The concept presented here is my proposal. The federal regulator is taking steps to resolve the inconsistency around ratebased and market-based cost recovery. As the number of distributed storage projects grows, utilities and regulators need to resolve these challenges to open this capacity to the wholesale market and ensure it is not underused or funded solely by customers.

Barriers to entry in frequency regulation services markets

Olivier Borne
Armand Peugeot Chair

Deviations in system frequency indicate an imbalance between electricity generation and consumption. An imbalance lasting more than a few seconds can destabilise the entire network. To obtain stable frequencies, TSOs require other actors to be able to change their consumption or production output rapidly at short notice. Historically, frequency regulation reserve (FRR) services were provided by large centralised generators; with smart grid technology, other actors including consumers, distributed generators and EVs can perform this role. However, markets will need to be redesigned to enable these changes.

The increasing share of renewables is driving change in electricity systems. Balancing issues will become increasingly frequent given the difficulty of forecasting production by renewables and a decrease in system inertia. Redesigning the market to enable distributed sources to participate would help to resolve these challenges, but TSOs face learning costs and transaction costs to do so. The change process would also generate flexibility risks that could affect supply security.

Presentation of a modular framework for EVs

EVs are basically flexible batteries that are idle 94% of the time. As FRR provision is a remunerated service, the total cost of ownership could be reduced by using this idle capacity to contribute to energy provision. The costs of providing this service include battery degradation, data sharing equipment, and upgrading of supply equipment to allow reverse flows. In addition, the charge must be managed to maintain mobility, the primary function of an EV.

A modular framework has been developed to identify and rank barriers to entry for aggregators. It analyses the technology neutrality of TSOs, the range of flexibility that can be exploited by aggregators, and the way in which aggregators are remunerated. The resulting model establishes optimal rules for the aggregation of distributed resources, the definition of products sold on the market, and the payment scheme for grid services.

The primary and secondary reserve markets in France, Germany, Denmark and the UK were assessed for barriers. Results varied significantly with Denmark offering the strongest model for primary reserve management on the basis of short products, pay-as-cleared remuneration and low minimum bids. Secondary reserves are based on long-term contracts that restrict entry.

Conclusion

As generation from renewables grows, reserves must also increase to ensure flexibility. Well-functioning market designs are required to ensure these reserves are procured at least cost and to mitigate flexibility issues. A benchmark review did not identify any suitable models in action but highlighted that all markets are trying to adapt their markets to enable distributed energy sources to participate. No country is currently using distributed resources to deliver large regulation reserves but some exploratory projects are underway.

France and Belgium are joining a four-country platform in 2017. Increased cooperation should make it easier to optimise the shift towards a market-based system. Nevertheless, regulated tariffs are simple and predictable for end users. A market-based approach might make it possible to extract more value but it creates price risks for end users.

The cost of natural gas is important for the development of storage and EV. If gas prices rise, these options will become more economically attractive.

New directives and regulations give priority to renewable resources. The market is not completely free in most countries. Gas sets the marginal price but renewables come on to the system first. Flexibility is a bigger issue.

It would be interesting to look at these questions through the lens of the energy price. To what extent could European directives promote flexibility in individual countries?

The grid codes for frequency reserves are intended to establish a common framework.

B. Carroll (ESB)

DSOs need to open markets and regulated services need to evolve into market platforms. At distribution level, natural localised monopolies tend to emerge; this is likely to be the most significant challenge that an open market would face on the distribution system.

It has taken more than eighty years to get to this stage. The precise coding and management of demand resources at local level will not happen tomorrow.

Standardisation trends in V2G

François COLET
Vedecom

The Vedecom institute is a recent public-private partnership focused on vehicle electrification, autonomous vehicles, and infrastructure and services.

There are two views of standardisation. The bottom-up vision develops standards for everything from plugs and outlets to data security and safety. Each series defines a number of potential solutions and relates them to relevant standards. The top-down approach is relatively recent. It relates the smart grid architecture model of IEC 62913 to the needs of EV recharging and aims to define the roles, actors and use cases for charging services as well as their primary interactions. It should be noted that distributed energy resources are treated separately from the electric transportation domain and V2G. Although the grid connection rules might be similar, the number of actors is completely different and the primary function of an EV is mobility.

On-going standard up-dates

Business and system use cases dedicated to Reverse Power Transfer, also known as reserve charging, have been reintroduced into CD4 standard recommendations. A clearer approach will separate the type of charge from the charging location, given that a single location can integrate various charging options. A reverse charging use case will focus on ancillary services offered to a TSO. The CD4 standard, which provides a technical specification, will be published as soon as possible to encourage the different parties to discuss options.

The IEC Technical Committee 57 (TC57) dedicated to Charging Energy Management will be transferred to TC69, which covers EV charging and discharging structures. The new proposal will manage energy transfers, asset management of the EV supply, authentication authorisation payment of charging and discharging, and provisions for other e-mobility services.

There is also a proposition to revise ISO 17409, which relates to vehicle safety management and charging. Bidirectional power flow was introduced to charging could be managed in AC and DC mode. Reversibility is a complex area with many potential use cases and it is not possible to manage everything at once.

Working Group 15118 is currently reviewing communication standard ISO/IEC 15118 with a focus on wireless power transfer, reverse power transfer, and generic automatic connection systems.

Vedecom

Vedecom is working on two V2X service projects, the first covering technical issues including chargers, electrical safety and protocols and the second covering services and business models. Three new protocols are being evaluated: two relate to charge spots and the third is a private protocol connecting the EV to the energy management system. The results will be used to identify advantages and disadvantages in terms of cyber-security, trans-coding and synchronisation.

Conclusion

Work on V2X standards is ongoing. These standards are not purely dedicated to industry and broad participation is welcomed. Aspects that require more attention include the potential to separate EV charge and discharge from distributed energy resources and stationary batteries, compatibility between paid grid services and mandatory grid codes, and the performance values and requirements for different services.

Sometimes the problem is not a lack of standards but an excess of standards and a lack of agreement over their application. Is there a risk of creating a catalogue of standards but still not achieving interoperability?

Each country or region is promoting its own solution. It is difficult to know the minimum level of harmonisation we should be targeting or to decide which reference should be implemented.

The Commission cannot usefully produce a mandate if the standards cover all of the options. That is a major barrier to interoperability.

Standards are technologically agnostic. They are not responsible for choosing the best solution.

From the floor Part of the problem is that not everyone in the Commission understands that.

Do you expect that services will be able to support more kinds of applications? Will new services such as synthetic inertia and reactive power compensation be supported?

We are interested in this and your input would be welcome.

It is difficult to define these applications in use cases. This creates the risk of a permanent lag between standards and new concepts.

We understand this concern but it is very difficult to find a single solution that responds to the requirements of different countries and regions. We are trying to define the minimum requirement.

What about standards and time delays for frequency ancillary services?

From the floor **The newest version of the CHAdeMo protocol is used for DC charging because it enables a very fast response between**

the charger and the BMS system in the car.

From the floor Are the five-second delays caused by communication gateways?

From the floor

We are trying to identify the cause; communication software is a likely source.

Discussion

From the floor

Will it be possible to pre-emptively monitor the grid for voltage sags or frequency changes? A US company has a patent for this. Is this being considered in Europe?

Christina Plum (energinet.dk)

We are already doing this. Frequency reserves are activated by a local signal.

From the floor

If frequency-response is the only variable and the signal is not conditioned, this could be a very technology-specific signal. The PJM market has a dual response to any imbalance based on a fast-acting net energy zero response and an additional slower response. It is possible the vehicle monitor and respond directly to the grid rather than waiting for a signal.

3rd panel: V2G Experiments & International Diffusion

V2G HUBs

S. Cascante
Enel

Enel is a multinational utility active in Italy, Spain and Latin America offering different vehicle charging infrastructures, ranging from 3.7 kW home boxes to 400 kW solutions for charging e-buses. Smart grid capabilities are used to manage the infrastructure and charging process to offer demand-response services and advanced V2G grid services. Enel's V2G development activities began with a 2012 pilot project in AC and DC bidirectional chargers. In 2015, the commercial V2G charger was presented at the Geneva motor show.

Enel's V2G activity focuses on the benefits for DSOs, including reactive compensation, frequency regulation and constraint management. Most benefits for DSOs are derived from regulation; to generate revenues from these benefits, the market needs to evolve.

Enel is running a number of pilot projects with real users in real environments. Energinet and Enel are running a successful ancillary services pilot in Denmark based on real V2G services. The transition from theory to practice was complicated, particularly with regard to sub-metering and charge-based metering requirements, the physical production of suitable chargers, and aggregation testing.

The August 2016 tender for enhanced frequency response services in the UK had an interesting outcome. Batteries have emerged as the main pricing mechanism, which implies that V2G is a key component in pricing. Enel has installed nine V2G chargers in the UK and is testing them. There are similar projects in Germany, Italy and France with more expected in the future. In Spain, the focus is on V2H due to regulatory limitations on feeding energy back into the grid.

Enhanced frequency response requires a sub-2-second response. How are you dealing with this given that we have previously heard about 5-second response delays?

We are working on a number of possible solutions to optimise the speed of the response. We are targeting the sub-2-second target as it is the most profitable.

Were you surprised at the £7-12/kWh prices obtained in the UK tender?

Yes. We knew that the UK price would be low and that is what we saw.

How did you manage the grid code differences between Denmark and the UK, especially with regard to over- and under-frequency behaviours? Which type of code do you use?

We use PEV rules because they were the only codes available on these markets and because this was requested by the DSOs.

What is Enel's position on chargers?

Our position depends on business models rather than technical preferences. Specific chargers will be required for TSO-DSO V2G activities. I have no preference regarding AC or DC. Infrastructure costs will be lower for utilities if bidirectional chargers are installed in EVs, but utilities will adapt as required.

What is the maximum power return to the grid for the DC chargers in your project?

The current pilots use 10 kWh charge and discharge to comply with CHAdeMO, but we are also exploring higher power rates as these would have the potential to deliver higher revenues.

From the floor - Above the defined micro-generation limits the generator must meet an additional set of technical requirements. This complicates implementation.

Parker and V2X – V2G and V2L pilots in Denmark

Peter Bach
DTU

The Danish NIKOLA project is exploring the potential for intelligent EV integration to support and provide services to an energy system fuelled by a high proportion of renewable sources. Any element that had a positive impact on the timing, rate or direction of the power and energy exchange between the EV battery and the grid was considered to be a service. A technical and economic evaluation was conducted to explore the potential applications of each service and the maturity of relevant standards. The project trialled advanced, state-of-the-art EVs and chargers thanks to effective partnerships with OEMs.

A study of frequency regulation and revenues indicated that the revenue potential of bidirectional vehicles can be up to thirteen times higher than that of unidirectional vehicles. The initial analysis showed that the market would release up to €120/month/vehicle in availability payments. This highlights the potential of this type of application in Denmark.

Car manufacturers are already pursuing some of these opportunities through functional, profitable, vehicle-to-load projects. For example, AFA JC Decaux is using Nissan EVs equipped with a separate 1 kWh in-car battery to travel between advertising hoardings and power a low-pressure washer to keep the hoardings clean.

As projects increasingly move out of the lab and into the real world, it becomes necessary to ask at what point integration will have been achieved. The widespread adoption and integration of V2G is likely to occur around 2025, but some projects, such as the third-generation PARKER project, are already showing what is possible in terms of advanced, vertically-integrated smart grid services that can respond to both local and national needs. The project focuses on grid applications, replicability, scalability and grid-readiness certification. It is exploring the technical and economic limits of grid applications and services in the current environment and provide new ways of identifying technical and regulatory barriers and validating business cases. The concept of grid readiness reflects the degree to which an EV is ready to support and respond to the power system. Grid enabling keys map the capability of different EVs to perform a range of services and the speed and precision of their responses. These keys will help to understand the extent to which grid integration has been achieved.

The next step is to push towards 360-degree grid support that provides a seamless transition between system-wide services and local distribution and enables EVs to perform a wide array of services. V2G capabilities will be an important component and benefit of any grid-integrated car.

Multi-tasking appears to have replaced vertical integration as a desirable concept.

How would you overcome the regulatory issues associated with providing system-wide and local distribution services through a market?

We have not tested this concept in practice. The NIKOLA project explored frequency regulation and different ways of protecting the local distribution system but considered them separately. We now have an opportunity to test these ideas and harmonise these different objectives.

When an EV leaves a charging point, what volume of energy is stored and how is this calculated? Is it based on 100% SoC? How does this affect business models?

Algorithms ensure that the vehicle has sufficient mileage to cover the driver's needs for the day. Network and frequency regulation requirements are secondary; the primary function is mobility.

The system operates when the EV is not in use. Does EV availability and usage present challenges in terms of system micro-regulation and frequency regulation?

It depends, but in general the more the vehicle is connected, the better. Shared cars are assets in the sharing economy. The aim is to maximise sharing during the day and maximum grid connection time during the night.

Vehicle-to-device and vehicle-to-load need to be treated separately. The former refers to connections to a domestic plug and the latter refers to connections to a type 2 plug.

Nissan Europe: Innovation, V2G, 2nd life batteries, RES and EMS

Nicolas Joubaud
Nissan

Renault Nissan is the world's 4th largest automaker, producing one in every ten cars in the world. It has sold 335,000 EVs thus far with the number increasing year on year. Nissan views batteries as a means to mobility and a way to contribute energy, stability and efficiency to the grid. Nissan intends to use V2G, stationary storage and photovoltaic panels to build virtual power plants.

In Nissan's model, EVs are connected to the grid via bidirectional chargers and aggregators. The aim is the complete integration of EVs into the grid, changing both the energy landscape and energy markets. The three primary applications for EVs are smart charging, V2H and V2G. TSOs would regulate the grid using stored energy from EV batteries, with aggregators passing part of the revenues back to the owners of the EV to reduce the lower total cost of EV ownership. Models indicate that each bidirectional EV could generate almost €1,000 per year in revenues. Unidirectional systems could generate €100-150 and smart sourcing around €50/year.

New, game-changing V2G-capable, bidirectional EVs and charging stations are expected to come to market in 2017-2020.

Energy storage system (ESS)

Reliable, affordable EV batteries should accelerate the deployment of distributed stationary storage systems in homes, offices and industrial batteries. After five years, the global capacity of EV batteries is around 80%, at which point they can be given a second life as stationary storage. The stationary storage market is expected to be worth US $34 billion by 2023, 30-40% of which will be in Europe. Installed capacity is expected to reach 15 GW by 2020, split between grid ancillary services, renewable integration and other community and residential storage applications. Nissan is working to develop low-voltage, all-in-one distributed energy storage services for the home based on blocks of 12 second-life modules generating around 5.4 kW. A grid-connected energy management system would monitor and control home consumption.

Hajime Project (Nissan HQ France)

Hajime is a showcase and living laboratory for Nissan's zero emission technologies. It will seamlessly integrate 900 22 kW photovoltaic panels, 50 V2G chargers and 60 second-life battery packs and connect them to the grid to demonstrate the technical and economic potential of optimised energy systems and stationary storage scenarios. The devices will be managed by a central energy management system (EMS) with real-time reporting and piloting of all parameters.

Who is building the EMS?

At present this information is confidential. Discussions with suppliers are still in progress.

Will the next generation of EVs will have AC/DC converters on board?

Yes, in future they will have converters that enable them to return AC energy to the grid.

How do utilities feel about hosting this service from an EV rather than a stationary source, such as a CHAdeMO charger?

From the floor Safety is the key concern. The main technical issues relate to ICT: the car needs to recognise where it is and communicate effectively. On-board chargers benefit from reduced costs but off-board chargers are less complex.

What is the price differential between bidirectional and unidirectional charging stations? How much are residential customers expected to pay? What is the payback period?

People are more likely to make the shift to V2G if they receive something in return. I do not have answers to all of your questions at present.

Narcis Vidal (Enel)

In Denmark, revenues are around €1,000/vehicle/year. The cost of the chargers is currently confidential and varies depending on the project and the partners. These are commercial ventures and we are confident we can obtain payback within three or four years.

Peter Bach (DTU)

DC chargers are more expensive because they enable faster charging. Fleet operators might be willing to pay more to charge 3 times faster; V2G is a bonus.

Senan McGrath (Eurelectric)

Generally speaking, the cost of chargers is significant. V2G is unlikely to be a successful commercial proposition if energy sales are the source of revenue. There is a market based on TSO grid services, but the market is limited and could be cannibalised as the number of cars rises. Success is likely to come from services to DSOs rather than TSOs, but that market does not yet exist. If regulations, systems and markets are developed to enable DSOs to access V2G, then I believe that DSOs will use this service.

What revenues would you expect to derive from low-voltage stationary storage?

Nicolas Joubaud (Nissan)

I do not know the target price. Ideally the house would generate revenues of around €500/year.

From the floor

V2G is an element in a platform economy, not a traditional regulated industry. The business model for EVs will require a similar revolution in payments models, services and interfaces. Nissan is positioning itself as a platform player, like Google.

Introduction by the Chair

Enedis serves 35 million customers and invests €4 billion per year in the electric system. It is deploying the Linky smart meter in French households to make the grid as smart as possible, as quickly as possible. The development of EVs, renewable energy sources, and changes in consumer behaviour present challenges but also opportunities. As technical barriers fall, it is increasingly important that regulators keep pace with the changing environment.

Towards sector integration? Challenges and opportunities for e-mobility in Germany

Sebastian Strunz
UFZ

Germany's energy transition policies aim to deliver an 80-95% reduction in greenhouse gas emissions by 2050. Reductions are being sought in multiple sectors, including heating, transport and energy. The electricity sector is focusing on reliability, economic efficiency and environmental protection. Renewable sources produced 6% of Germany's energy in 2000 and 32.5% in 2015 but efforts are being made to slow the rate of growth as TSOs are struggling to manage the technical impact. EV ownership remains stubbornly low. This has a direct negative impact on GHG emissions and also limits the potential to use EVs to increase grid flexibility.

<u>E-mobility in Germany</u>

Only 20,000 of Germany's 53 million cars are EVs. An ambitious strategy is aiming to have one million EVs on the road by 2020 and 6 million by 2030, but even when advanced local EV strategies are available, ownership levels remain low. Financial incentives, such as a scheme to offer €4,000 to purchases of battery-only EVs and €3,000 for PEVs, are encountering limited success. Between July and October 2016 there were only 4,500 applications for the scheme, compared to 150,000 for a similar but non-electric premium that was offered in 2009.

<u>Why has progress been slow?</u>

Although €1.2 billion has been made available for the EV/PEV incentive scheme, there is limited politico-economic support due to the importance of the traditional car industry to the Germany economy. German car manufacturers are not among the world's top manufacturers of EVs and there are fears that strong EV targets could undermine this vital industry.

Technology is important for e-mobility but social perceptions and consumption patterns are also vital. Renewables were once viewed as unrealistic 'green' concepts but the introduction of feed-in tariffs and social pressures helped the public to perceive them as functional, financially-viable technologies. This shift has yet to happen for e-mobility. Utilities vastly underestimated the potential market share that renewables could deliver, which is part of the reason they are now struggling to integrate them into their business models. The 2020 e-mobility goals will not be reached, but it is possible that the 2030 goals will be exceeded if social perceptions shift.

Security of supply

Germany has a portfolio of options for securing energy supply, including demand-side management, strong European market policies, and investments to improve the reliability and predictability of renewables. E-mobility has to compete with these other options. It is not yet clear how different capacity and storage elements will interact.

Although the installed capacity of wind and solar in Germany has tripled since 2008, balancing reserves and balancing costs have both decreased due to extended cooperation agreements between TSOs. This indicates that balancing demands will not necessary rise in future. Model-based analysis indicates that the capacity of V2G to make an effective contribution to reserve energy in Germany by 2035 will depend on significant improvements in battery quality.

Increasing V2G uptake in Germany

Traditional policy instruments to increase EV uptake are encountering limited success in Germany. Uptake increased substantially in Norway when EVs were made exempt from toll payments and allowed use bus lanes. Radical alternatives, such as cap-and-trade systems based on car sharing, are also being discussed. E-mobility could have a catalytic function and disruptively transform existing relationships between actors in different sectors.

For V2G to succeed in Germany, a number of elements need to be in place. The market needs to take off, reserve provision needs to increase, regulations need to enable EVs to access the balancing market, and battery technologies need to improve. There is no guarantee that these improvements will occur. The potential to use second-life batteries as stationary storage could complement other areas in the energy system. Future shifts in international cooperation and transnational renewable deployment could reduce demand for other sources of flexibility.

Psychological and social dimensions should also be considered in the shift to a more sustainable transport sector. EVs are a replacement for conventional vehicles, not an addition, and should be marketed in ways that support public transport and individual mobility options such as cycling.

Conclusions

Social, political and economic factors have, thus far, limited the uptake of EVs in Germany but significant growth may well occur in the future. Sector coupling is required to meet emissions reduction goals but this depends on a sizeable EV fleet and changes to the regulatory framework. Battery technology needs to evolve to enable V2G and complement other forms of grid provision.

What is the single most important factor limiting EV market development?

Psychological factors are the most challenging. It is easy to underestimate them and they are not easily solved with minor policy instruments and financial incentives.

Financial subsidies are not always sufficient, as your presentation showed.

Range anxiety is an issue: people do not know how far they might have to drive. The price of EVs is also offered as a reason but this can serve as a cover for deeper psychological concerns.

Franziska Schmalfuß (Chemnitz University of Technology)

Charging infrastructure and price are significant barriers, as are psychological factors. Nevertheless, EV numbers are growing.

Sebastian Strunz

Leipzig is an interesting test case. Innovative projects like free-floating car sharing could help to tip the social balance and substantially increase uptake.

Could second-life batteries help to resolve car manufacturers' concerns?

They reduce competition between stationary storage and e-mobility, which is a positive for car manufacturers, but they then have to compete with other options that provide similar services.

Is Germany's large base of domestic photovoltaic panels an opportunity for V2G?

I do not have experience in this area.

Franziska Schmalfuß (Chemnitz University of Technology)

There are some V2H projects in Germany. This is being discussed in academic circles.

Could EVs help to resolve the significant transmission grid constraints that exist between north and south Germany?

Sebastian Strunz

This is one of the factors that will determine the ultimate role of EVs in German grid flexibility. We are following efforts to mitigate this bottleneck with interest.

The weak offer from German manufacturers is slowing uptake. Car makers have a responsibility to make vehicles that consumers want to buy.

François Colet (Vedecom)

In 2003, Germany invested about €2 billion to deploy infrastructure for natural gas stations and had a full range of natural gas vehicles. This could explain why German

OEMs are reluctant to invest heavily in EVs. Some solutions work and others struggle.

There has been a lot of talk about EVs in Germany in recent years but little action on the part of institutions and car makers. This has fuelled consumer doubt. Furthermore, there are not the same social pressures that boosted to photovoltaic panel uptake. Cars are a status symbol and people are particularly sensitive to the judgement of others regarding their vehicles.

Forbes has reported that the German Bundesrat is aiming to phase out internal combustion engines by 2030. Is this true? Will it be enforced?

It is an opinion and a long-term goal but it is not legally binding.

With this goal, there would only be another two or three generations of conventional cars. Fifteen years is a long time for the automotive industry.

Practical V2G experiences in Amsterdam, European initiatives and networks

Hugo Niesing
Amsterdam University of Applied Science (AUAS)

AUAS focuses on practical innovation. It conducts extensive research into e-mobility, for example by analysing, modelling and monitoring charging profiles and infrastructure data from across the Netherlands, modelling and demonstrating V2G technologies and their impact on the grid, researching aggregation platforms, and analysing smart incentives for electric taxis.

Since March 2014, AUAS has been conducting a V2G project to explore the relationship between the grid, the household and an electric pleasure boat. Energy autonomy based on photovoltaic panels has grown from 34% to 65% over the duration of the project. Energy independence from the grid has been achieved during the summer months. In September and March, production closely matches consumption and energy is fed back to the grid during the height of summer. Overall, energy exchange with the grid has fallen by 45%. The project has challenged consumer behaviours by highlighting consumption fluctuations.

SEEV4-City is a large-scale applied project to demonstrate the potential for vehicles to act as the cornerstone of a sustainable city with positive impacts on the integration of renewable energies. Seven cities around the North Sea have been challenged to identify ways to use EVs to consume energy locally, reduce dependency on external resources, increase zero-emissions driving times, and use EVs and second-life batteries to smooth peaks in demand. Different partners in the consortium are exploring different aspects and scales of V2X implementation, such as vehicle-to-business and vehicle-to-street. The pilots should be operational by March 2017.

A new project to explore people's perceptions of EVs and other innovations is also being considered in order to understand why people are quick to adopt some technologies and slow to relate to others. AUAS is currently seeking a research institute partner, preferably in France.

With the right data, it will be possible to show the benefits that V2X offers and its potential to help resolve many energy and environmental challenges.

What battery degradation have you experienced with the electric boat?

Six to seven percent degradation over two years, based on 500 cycles.

How could the winter production deficit be managed In the future?

We installed a small windmill but it had to be removed after four weeks due to noise complaints from the neighbours. An affordable, silent windmill for city use would be very welcome.

What would be required for the house in your study to be totally off grid?

We have a storage capacity of 10 kWh, of which we tend to use 8 kWh per day. It would not make sense to install a larger battery but another generator could be helpful. There is significant over-production during two months of high summer. The grid is not a bad thing; we will always need it. The aim is to make it intelligent and make more effective use of it.

Your data is based on an optimised house. Realistically, how many houses can be optimised?

Hugo Niesing (AUAS)

Last year, there was 45% growth in installed photovoltaic capacity in the Netherlands. The most expensive element is the batteries. The cost of the panels has dropped by a factor of four. The right regulatory and financial frameworks would encourage people to fuel their cars with this technology.

Christophe Bonnery (ENEDIS)

As an economist, I trust the signal price but it appears that the current tariffs are not a good match. The tariff system is based on capacity subscription and kWh consumption. Consumers value access to the grid, the right amount of power, the right volume of energy, and reliability. The value of these four services is not currently reflected in tariffs.

Hugo Niesing (AUAS)

The origin of the energy could also be valued. Local, clean, zero-emission energy and remote, polluting energy could be valued in different ways.

Lyon conducted a large-scale experiment based on Japanese smart communities that incorporate many of the technologies highlighted here. There are extensive data that we are happy to share if you are interested in a large-scale study with real consumers.

The US casino industry is investigating the use of renewables and storage to generate their own power. Do you think this could be relevant to Europe?

I do not know, but I could imagine there could be demand from large institutions.

4th panel: User engagement

JuiceNet (demand flexibility platform) overview and case studies

Alan White
eMotorWerks, UFZ

EVs offer better load capacity, target storage and flexibility than conventional storage options. The JuiceNet software platform manages shiftable, flexible loads to avoid the need for peak generation and grid upgrades, enhance reliability, and generate revenues for EV owners. The JuiceNet portfolio includes a market-leading 10 kW portable charging station, a 5 kW in-vehicle extender and a smart charging adapter. The adapter integrates a revenue-grade meter and a communication module that enables any charging station to participate in the revenue platform.

EV Load Access

eMotorWerks is working with OEMs to integrate its JuiceNet platform into vehicles, enabling them to access grid service revenues via any charging station. The platform core includes a predictive grid model, a predictive resource model, and a dispatch engine that indicates which resources are available at any given time. The platform can also be integrated into competitors' charging stations and the data systems of system operators and utilities. This capacity will support V2G services and will also enable greater vehicle ranges.

Standalone and integrated apps provide reassurance, information, and choices around charging and the use of excess capacity. The charging station delivers precise load control with latency as low as three seconds. It enables instant local grid response and can be controlled remotely. Demand flexibility could help to reduce the US $9 billion annual cost of grid investment.

Driver experience

The industry as a whole is aiming to provide a satisfying, low-stress, financially attractive EV experience from start to finish. By default, the platform decides when and how to charge the parked EV to optimise grid services. Customers can use an app to override the platform. The system is very popular due to ease of use and because customers are paid for charging.

Case studies

The CPUC sub-metering pilot enables a revenue-grade sub-meter in each charging station to participate as a grid resource. This enables the EV owner to optimise their charging behaviours and reduce their operating costs. Supply-side and excess-supply pilots are aggregating vehicles into sub-load aggregation points to foster participation in demand response markets, increase understanding of market-based bidding and settlement, and provide behind-the-meter flexibility. Around 100 customers are currently earning revenues from participating in this pilot.

The CA DRAM (Demand Response Auction Mechanism) pilot is a auction-based, pay-as-you-go, resource adequacy market using demand response from investor-owned utilities. eMotorWerks was the only company to bid into the DRAM based on EV resource rather than building-based resources. This pilot enables revenue generation through low-effort vehicle charging.

V2G is an important element in the EV story. eMotorWerks intends to enter the European market when the policy and regulatory conditions and market conditions are ripe.

When you are aggregating EVs and modulating the charge, are you making money by providing services to the grid? What contracts do you have in place to manage the impact of battery degradation caused by charge modulation?

Consumers have to opt in to the programme. There are two value propositions: the potential to use their EV to help balance the grid and the potential to generate cash for themselves. Most of the leases are three years and no particular problems have been identified thus far. It has not been a barrier to entry on the resource side. On the grid side, the revenues we generate for customers are based on the demand-response auction mechanism, energy markets and ancillary services such as up and down regulation.

Do you have visibility on the SoC of the battery? What happens when it is fully charged? Do consumers make more money if they plug in with an empty battery?

We have access to SoC information when the JuiceNet API is integrated into OEM software. If not, the data is acquired in arrears and we manage our position accordingly.

How many people did you have to approach in order to recruit 100 participants? Did you trial an opt-out mechanism to capitalise on customer inertia?

People tend to have limited understanding of the grid, which can make it difficult to communicate effectively with them. We are working with utilities to scale up adoption of these technologies.

How do you manage conflicts between the charging behaviour that suits your system and the standards that are built into cars?

It has been a very painful process. Nevertheless, utilities are recognising that time-of-use rates are sub-optimal and that it might be possible to move away from those rates for EVs. We need to persuade customers to shift to our system even when there is a short-time financial impact.

It is possible to connect your metered plug to any charger?

It fits any J17-72 charger and enables the EV to connect directly to our platform.

When you control the charge of the vehicles, what exactly are you doing? How do you account for the loss of assets when an EV moves from one balancing region to another?

We modulate charge by 1 kW at a time. 85-90% of charging occurs residentially. We usually perform two to three hours of charging within a twelve-hour window and programme it to match what we expect to happen on the market. With regard to ancillary services, we anticipate cross-streams and assign vehicles to the most relevant market and revenue opportunity.

Engaging the consumer in V2G

Michael Nicholas
UC Davis

The energy price differential is an important element in consumer motivation. With low fossil fuel prices, savings from running an EV rather than an efficient conventional vehicle can be minimal or non-existent. Transaction costs such as environmental benefits or convenience dis-benefits, also feature in consumer decisions about whether or not to plug in.

Research shows that the likelihood of people plugging in is directly related to the benefit that they can obtain. With free workplace charging, PEVs with longer range batteries are highly likely to plug in. However, PEVs with small capacity batteries can only ever generate small financial returns and plugging in tends to fade away over time. Plug in rates are determined by miles recovered per event cost versus benefits. Benefits climb as maximum battery size climbs, fossil fuel costs rise or as the transaction cost falls. Linear regression models indicate that every mile recovered during a charging event increases the likelihood of plugging in by 1.4%. Equally, every dollar saved increases the likelihood of plugging in by 12%.

Transaction costs can be reduced through policy and infrastructure. For example, people are more likely to plug in when charging stations are less congested and do not have timing restrictions. Some measures disproportionately affect certain battery sizes.

<u>Duck curve scenario: technical potential of V2G</u>

Modelling indicates a risk of solar over-generation in California by 2020. Based on a dataset of 46,000 households and in a scenario where everyone commutes in an EV, a shift to daytime workplace charging could be absorbed simply through excess solar capacity.

If plugging in behaviour is determined by the avoided cost per event, a PEV 40 getting half price electricity is just as motivated to plug in as a PEV 20 getting free electricity. A larger transaction per event is required to persuade people to shift their behaviour. Smaller capacity vehicles require an additional incentive, such as a per-transaction fee, and the removal of barriers such as parking limits. Pricing mechanisms and motivational games to engage customers have the potential to shift people's charging locations and behaviours and create a better match with grid capacity.

Did you explore the cost impacts of workplace charging on the building owner?

I assumed that there would be a desire to dump excess solar during the time periods modelled. Workplace charging of this type would require extra infrastructure. The cost implications of this additional infrastructure investment have not been modelled yet.

Would incentivising night-time charging be an easier way to address the 'duck curve' issue and smooth demand?

Not necessarily. The problem is that solar resources ramp down at dusk when evening demand is ramping up. Adding EV demand further increases this peak. Charging during the day makes effective use of intermittent renewable resources.

Convenience can be a positive transaction cost. In Copenhagen, there are very attractive parking spots that can only be used by EVs and where plugging in is a requirement of use.

That is an effective way of lowering the transaction cost and incentivising positive behaviour.

Would it be possible to benefit from consumers' laziness and cost aversion? Have you tried a system whereby consumers forfeit inco-me if they do not plug in?

It is true that people tend to have a stronger response to losing money than to gaining money but we have not explored this yet. Routine and simplicity are also powerful factors.

A recent project in San Francisco gave people money to charge and removed a dollar per day for poor charging behaviour. It is difficult to implement this kind of model in Germany.

Project Gesteuertes Laden V3.0

Franziska Schmalfuß
Chemnitz University of Technology

User engagement in smart charging systems

The Gesteuertes Laden V3.0 project focuses on user expectations, experiences and preferences in order to understand user motivations around charging. People often plug in less frequently than is required for successful V2G operations. The project aimed to develop a system that would encourage people to plug in when they arrived home. It asked them to provide information about their intended departure time, and range and flexibility requirements to enable smart charging to proceed without infringing the primary purpose of mobility. It tested a points-based reward system based on data obtained through laboratory studies, online surveys, focus groups and field tests.

Field study

Participants in Berlin obtained rewards when they charged their BMW ActiveE vehicle at home or via a public charging station between 8pm and 8am. A smartphone application enabled them to change their charging settings and a fortnightly email told them how much they had earned on a scale from €0-12. All 20 participants had a wallbox charging system at home and paid a monthly lease for the EV. Most had at least one other car at home. A separate study with ten participants focused on technical elements.

The system delivered rewards based on time spent connected to the charging station, flexibility demands, their range buffer, and their minimum range requirement on departure. Rewards were also distributed for feedback and were withheld in some cases, for example when the SoC was above 95%. Rewards were capped at €25 per month.

Pre-study testing indicated that users trusted the system and thought it would be suitable, effective, acceptable, and worth using. Their enthusiasm waned during the study but remained generally positive, although there were concerns that it would not be suitable for daily life. Participants initiated five to six charging events per week, many of which exceeded eight hours. Controlled charging was used for 80% of events and the average SoC was 73%. The average SoC safety buffer required was 33%.

An analysis of rewards behaviour indicated that some participants stopped using the system entirely while others were willing to forego points to gain flexibility. There was a lot of positive feedback about the concept but many participants felt that the range (around 100 km) was not sufficient and that reliability and flexibility was not adequate. Others felt that the financial payback did not adequately compensate for the inconveniences.

Subsequent focus groups with different participants explored charging behaviours in scenarios that would demand more or less consumer effort and differing levels of reward. Unsurprisingly, higher levels of effort reduced willingness to participate and increased demand for compensation. The focus groups showed no clear preference for the location of energy release. Reliability, flexibility, smarter systems and financial incentives emerged as key elements in user behaviour.

Was the decline in trust due to reliability problems during the pilot? Were rewards triggered simply by having the car connected to the grid?

Yes, participants felt the system was not entirely market ready. Rewards were influenced by the time and duration of connection. Charging during the day was not rewarded. Accepting a lower safety buffer or lower range buffer increased rewards and vice versa. The different reward attributes were weighted.

Did the incentive scheme compromise people's sense of freedom and create a conflict between the reward of using the car and the reward of earning points for grid connection?

We tried hard to address this point and meet the demands of the grid and the participants.

I strongly believe that usage adjustment should be automated using pattern prediction and data analysis.

Yes, I agree. However, it is difficult to do this well.

Do you think a basic 3 kW charger is sufficient for the average residential consumer?

This was discussed during focus groups. People need to understand the topic, the relationship between their behaviours and society, and have incentives for changing those behaviours.

What happens in the long term? How long did your study last? Consumers tend to become less interested in 'playing the game' over time, making automation important.

The research literature shows that all reward systems have a peak followed by a decline, but that behaviours rarely fall back to baseline levels. The studies lasted 21 weeks on average. It is important to look at long term effects. Automation and pattern recognition should be a goal, but it needs to be really good to make a positive difference.

What is the difference in charging time between controlled and uncontrolled systems? With controlled charging, are users anxious that their vehicle will not be ready?

Charging time depends on the SoC when the vehicle is plugged in. The application ensured that the minimum range would be delivered by the time the consumer needed their vehicle.

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