Connecting electric vehicles (EVs) to the power grid over mobile networks makes charging easy and efficient. **The controlled charging model** proposed here has numerous advantages.

**A controlled charging model** allows for time-shifting and the reduction of peak power on the grid. By building on existing infrastructure, there is no need to wait for the buildout of charging stations everywhere; instead charging can be carried out from any electrical outlet, and correctly billed to the car user.

The transport sector is a major contributor to the world’s increasing CO₂ emissions, and clear political goals have been set to improve this situation. Having more efficient vehicles and alternative fuels are important advances, but the ultimate solution is electrical propulsion using electricity generated by renewable sources.

The battery electric vehicle (BEV) is becoming increasingly popular as a means of personal transport and urban delivery. It is clean, quiet, and inexpensive to charge. While existing battery technologies are currently limiting the adoption of BEVs, research and industry efforts have led to numerous improvements to the technology, so that vehicle range is constantly improving, while battery cost is falling.

**Removing the hurdles**
Most car manufacturers have launched (or will soon launch) plug-in hybrid vehicles (which can be charged from the grid as well as having an internal combustion engine). The first generation of hybrid cars is being redesigned, so that more recent models have much increased battery capacity with the expectation that they will mostly be charged from the grid. As these cars are less dependent on dedicated charging stations, this is where the market will take off first.

Government incentives – like those
“The benefit to the utility is that the peak demand is managed, and little investment needs to be made in upgrading the grid to boost capacity.”

provided in Norway – can significantly boost the uptake of BEVs.

Predictions for the take-up of EVs vary from region to region around the world according to government policies, and owners’ sensitivities with regard to the price and range of cars. However, researchers producing credible studies anticipate that EVs will account for 20–25 percent of the private-owner car market by 2020–2025. In the time-scales used by utilities, this is very soon indeed.

There are, however, some major hurdles to overcome which – if left unaddressed – could dramatically slow the rollout of EVs or even prevent their mass adoption:

► For the driver, the issue is how and where to charge their battery easily, cheaply and as quickly as possible.
► For the electricity utilities, the issue is how to manage the simultaneous charging of thousands of EVs, without a massive peak energy demand or excessive local demand.

National, state and municipal governments around the world are engaged in trials to test the acceptance of these new vehicles and their charging mechanisms under real-world conditions. This has typically meant rolling out a sufficiently dense network of charging stations (charge poles) so drivers can access one easily. In many of these trials, the electricity is not paid for.

However, the establishment of such a network of charging stations is a costly process, and being reliant on one clearly limits the use of EVs to certain regions. An alternative model is possible by using the existing electricity network and public mobile networks. This would eliminate the dependence on networks of charge stations.

This model has been developed in a cross-industry project in Gothenburg, Sweden, by Ericsson, Volvo Cars, Göteborg Energi (the local energy utility) and the Viktoria Institute (an IT research organization based in the city).

CHARGING AT HOME

Charging-station technology has focused on fast charging (15 minutes to an hour). This will no doubt be useful in situations when the vehicle is away from “home”: during intercity journeys and at shopping centers, cinemas and so on.

However, charging at the most essential locations – at “home” (at the driver’s or owner’s residence), and at “work” – must be effective. After all, this will represent the most common form of charging, particularly overnight.

To charge a vehicle with today’s range and battery technology, around 10–20kWh is required to recharge the battery after driving approximately 50km on a particular day. This is similar to the typical daily energy consumption of a European household. In other words, charging just one EV at home effectively doubles the household energy demand, while charging two such cars triples it. Clearly, careful planning will be required for such a substantial increase in grid usage to be handled.

Today, all mainstream EVs can “slow charge” (over several hours) from a general-purpose 110V/240V household electrical outlet, avoiding the need for a complex and expensive charging station. Indeed, for the most basic slow charge (single-phase charging at less than 16A), all that is required is an adaptor cable to connect the car to the outlet.

This means while charging is possible at the home, there are problems if this approach is used extensively:

► As drivers return home from their workplace – typically around 6-7pm – and plug in, the demand for charging will add to the existing peak demand (typically at 6-7pm), making it even more extreme, and potentially requiring the distribution utility to invest in higher-capacity grid infrastructure.
► History has shown that EV uptake will not be uniform, with pockets of high density expected as people copy their neighbors, creating potentially extreme local demand, especially when EVs are new and exciting.
► It is highly desirable to have the vehicle charging...
metered separately, so that it can be billed separately too; this is particularly important when charging a vehicle at work or while visiting family or friends. (Consider the situation when the driver has selected one energy provider and the outlet owner has a contract with another energy provider.)

**TIME-SHIFTING THE CHARGING**

The model being tested by Ericsson and partners involves the following sequence of steps:

1. The owner connects the car to the electrical outlet and identifies it (QR code, GPS position and so on.)
2. The car enters ready-to-charge state.
3. The owner uses the car’s center console to identify their charging requirements (minimum charge required, time when the charge is due to be complete, location...)
4. The charge requirements are sent from the car to the electric vehicle charging system (EVCS) over a machine-to-machine communication link over the mobile-phone network.
5. The EVCS requests a charge schedule from the electricity utility.
6. The electricity utility assembles parameters for the charge schedule based on predicted electricity demand and forecast local demand, and sends it to the EVCS.
7. The EVCS computes the charge schedule and sends it to the car.
8. The car executes the charge schedule throughout the night, recording energy consumption on a meter in the car.

The charge schedule can thus be selected by the electricity utility to meet the owner’s or driver’s requirements, as well as spreading the demand over the course of the night.

Should the owner or driver find that a charge is required sooner than expected, they need not return to the car but can change the charge requirements remotely, from a smartphone or tablet, and easily and conveniently reset the car’s charge schedule.

Similarly, the utility can modify the schedule if necessary – for example, if lower-cost energy becomes available (from wind farms, for example), or should damage to the grid (from a storm, for example) reduce the ability of the grid to meet aggregate demand. Drivers are sent an SMS to warn them of such changes.

With this model the peak load on the grid can be “shaved” and “shifted” in time, so that the bulk of charging is done when demand is normally low.

The benefit to the user is that energy at “off-peak” times can be provided more cheaply. This will be especially important in the EU as new charging models are introduced that penalize high usage during the “peak hours.”

The benefit to the utility is that the peak demand is managed, and little investment needs to be made in upgrading the grid to boost capacity. (In a 2012 Australian Energy Market Commission study, it was calculated that with uncontrolled vehicle charging the Australian grid would have to have a massive capacity increase by 2030 costing AUD 8.6 billion (USD 9.2 billion), while the additional cost with a controlled charging approach is zero – basically arguing that the existing grid is adequate.)

Furthermore, having the “meter” in the car makes it possible to bill separately for each charging session, by taking the appropriate kWh reading from the metered outlet bill, and adding it to the specific bill for a particular vehicle. With all utilities using a common clearing house, it becomes simple for vehicle owners to “roam” from region to region, and potentially from country to country, charging their cars as they go.

**SMART GRIDS A NECESSITY**

While the proposed model should reduce the risk of excessive peak demand, and excessive local demand, it would be unwise to assume these issues have been addressed. The actual real-time

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**The electric vehicle charging system (EVCS)**

1. Charging adapter is connected to dumb outlet
2. Car state changes to ready to charge
3. Driver selects charging requirements
4. Charging schedule request from the car to EVCS
5. EVCS submits charge schedule to utility
6. Utility validates car and provides detailed charge schedule
7. EVCS sends detailed charging schedule to the car
8. Charging logic in the car executes charging schedule

Source: Ericsson
usage of the grid should be monitored and managed so that any problems (caused by unpredicted demand, accident or bad weather, for example) are identified immediately and addressed promptly.

Traditionally, utility distribution networks are not actively monitored, so there is the risk of localized problems causing excessive demand, with protective fuses being activated or (worse) transformers and feeder cables overheating.

The solution – which is already due to be adopted by many leading utilities – is to install sensors and control devices to manage the grid. This “smart grid” will allow monitoring of energy demand and flows in each part of the distribution network, so that EV “hot spots” can be identified and measures taken to enhance local grid capacity.

While smart meters and smart grids are already being deployed – for many other good reasons – the introduction of EVs will make these new ICT-equipped grids a necessity.

Wireless connectivity in cars is being widely introduced (EU regulation on automatic crash notification is expected from 2015) and the charging system described here simply adds another application to the various communications apps already in the car.

What is novel is having a meter in the car (this is actually implemented as firmware in the car rather than a separate physical meter). A “roaming” meter is not included in existing utility billing systems or in existing government legislation: all the more reason why separate billing systems for EVs are desirable.

numerous business models supported A controlled charging model for EVs is essential. Without it, the utilities would have no choice but to make massive capital investments to increase the capacity of the existing grid. The consequence would be greatly increased electricity bills as the utilities recover this investment from users. Meanwhile the utilization of the grid (peak to average use) would deteriorate and the grid would become highly inefficient infrastructure.

The model proposed in this article provides a way for utilities to benefit from a controlled charging model, while subscribers retain control of their car, and benefit from savings owing to “off-peak” charging rates. Furthermore, the model uses existing infrastructure – the power grid and mobile-phone networks – while minimizing the need for new infrastructure (charging stations).

It is a flexible model which can accommodate numerous business models.

For the ongoing research project, the partners involved have developed specially equipped cars to be used around the city of Gothenburg by “friendly” drivers, who report on how satisfactory this model is in practice. Further research results are planned for the end of 2012.

Sources


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In Japan, the car can double as your power plant

BY 2015, of the 3.5 million cars expected to be sold annually in Japan, 2 million are likely to be electric or hybrid. These are the predictions of the global market-research firm Forrester Research.

The main thing that has encouraged Japanese drivers to take a second look at electric cars is vehicle-to-grid – the idea that they can be connected as a source of power.

The Japanese government continues to promote the use of solar cells; new houses now regularly come equipped with them. Unfortunately, however, the people who rely on them for power have discovered one fundamental problem: they don’t work at night.

You need a way of storing the energy generated by a solar cell, so you can draw on your reserves when the sun is not shining. This means investing in a battery. And equipping your home with a battery is a substantial investment.

**HOUSEHOLD SUPPLY**

In Japan, new houses are built not only with solar cells on the roof, but with electric vehicle (EV) battery chargers in the parking spaces. The electronics are part of the solar cell inverters as a matter of course. But it is not only individual households that can get a boost from connecting cars to the grid. It is even possible for an electricity company to use charged car batteries to even out the peaks and troughs in its power production.

But the only practical way to manage both this and separate billing systems for hybrid cars as they roam is to use the mobile network – which will lead to a whole new type of mobile network traffic.

Most cars in Japan are on the road for only an hour or so per day, since they are generally used only for short distances. Stationary the rest of the time, they can be used to supply the household with energy. In a country where most people commonly travel by train anyway, and use the family car only while on holiday, this opportunity becomes even more attractive.

Japanese-car manufacturers – in particular Nissan – are hard at work making sure charging stations are established anywhere the hybrid-vehicle owner might need them.

The great earthquake and tsunami in northeastern Japan in March 2011 destroyed not only nuclear plants in Fukushima, but also large parts of the power grid in the area. In such areas of seismic activity, what do you do when you have no electricity? You use your car as a power source.

**Vehicle-to-grid fundamentals**


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ERICSSON RESEARCH is sponsoring a project at the University of Tokyo, to investigate the effects of EV charging on communications.