E-MOBILITY IN THE PARTICULAR CONTEXT OF THE FRENCH ISLAND TERRITORIES

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ABSTRACT

There are currently large public debates in France and political signals are being set to promote electrically driven mobility among future transport concepts. The central argument is that e-mobility is a key solution for sustainable transport development, the French electricity generation being characterized by a particularly low carbon emission.

This paper explores the related question to what extent e-mobility and transport concepts can be sustainable in the particular context of the French island territories: Corsica as well as the French overseas departments.

The paper highlights 2 experimental projects which are conducted by EDF IES, in Corsica and Reunion Island respectively, in the aim of optimizing the economic and environmental impact of the electric vehicles on the islands.

INTRODUCTION

As a fully integrated utility in the islands, EDF Insular Energy Systems Division (EDF IES) is in charge of the transmission- and distribution grid operation, responsible for the power system stability and electricity supply.

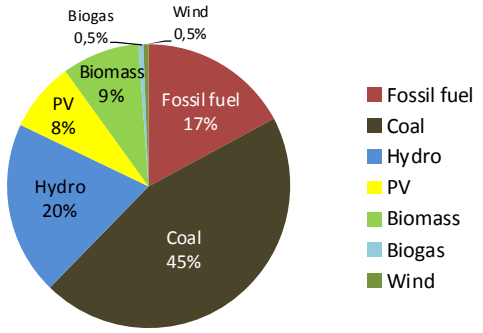

Figure 1: Fuel mix of power generation, Reunion Island (2013)

The specificity of the islands can be summarized as follows :

With a significant part of fossil fuelled electric power plants, $C0_2$ emissions are rather high.

The island's electric power systems are relatively small and without interconnection to larger continental grids. They're naturally fragile. Wind and solar power is abundant, whereas electric system stability criteria do not allow for the unlimited development of intermittent renewable energies.

Electricity generation costs are high compared to those in continental France, whereas the retail price for electricity in the French islands is regulated and bound to the one in mainland France. Indeed, retail prices are significantly below generation costs: residential end customers pay about 0,12 €/kWh. A tax called 'CSPE' paid by all electricity consumers all over France comes up for the difference.

CONTEXT AND APPROACH

The emerging use of electric vehicles (EVs) in the island territories has to be considered from an environmental, technical and economic point of view. In the French islands, e-mobility can potentially reach a growing significance with the contribution of private and public players. The present article shall underline the major considerations that relate to this new usage of electricity.

From a **technical** point of view, if we imagine that 10% of today's vehicles running on Corsica were replaced by EVs, we would observe an overall increase in the island's electricity consumption which would sum up to 40MW. As a result, additional electricity generation units would have to be set up, and grid infrastructures reinforced.

From an **environmental** point of view, due to the specific fuel mix of electricity generation in the islands, an electric vehicle that is being recharged during evening peak hours from the island's grid would generate greenhouse gas emissions in the order of 160 to 230 gCO_2/km, depending on the electricity source used to cover the peak demand. Such emission rates are beyond the average CO_2 emission of equivalent conventional vehicles that is about 100 gCO_2/km.

From an **economic** point of view, seen from the end user's perspective, the cost of electric driving is highly attractive with about 2€/100km, compared to approximately 12€/100km for a conventional diesel fuelled car. However, seen from the global market perspective, the additional electricity consumption of the EVs generates supplementary expenses which will have to be covered by a tax contribution (CSPE) paid by the overall population of electricity consumers. If we get once more back to our assumption of 10% of all vehicles in Corsica to be replaced by EVs we would generate an overall increase of the island's electricity consumption of about 6%. Such an increase would clearly go against the joint effort of industrial and public players during the last years in order to enhance energy efficiency and reduce the impact on the CSPE compensation fund.

DESCRIPTION OF THE TWO PROJECTS

The market development of electric vehicles in the French islands generates additional electric demand: the overall energy consumption as well as the peak load demand are likely to increase, generating additional constraints for the electric power system.
How can additional CO_2 emissions and power plant extensions be avoided?
2 projects shall be described in more detail in order to answer this question:

The VERT project– Reunion Island

The first project has been set up on Reunion Island. EVs have been charged using solar electricity from specific charging stations, without interconnection to the local distribution grid. In order to allow the recharge of the vehicles independently from the sunshine hours, the systems have been equipped with stationary buffer batteries.

The gathered operational data from this project has been used to simulate the economical and environmental impact of the EVs depending on various parameters such as:

- Energy demand (level of discharge)
- time of the day for battery recharge

while off-grid and on-grid recharging modes have been compared.

The VERT project has been launched on Reunion Island in mid-2012 following the French energy agency's initiative (ADEME) to test EV charging stations. Various industrial partners have collaborated in the project: Schneider Electric, Sunzil, the University of Reunion Island, EDF and Renault. The project came to an end in December 2013.

Image 1: VERT solar charging station on Reunion Island

VERT aimed at evaluating the recharge of EVs through autonomous solar charging stations that were equipped with stationary buffer storage batteries. The solar generators were operated in a strict off-grid mode, even though a grid connection allowed for emergency backup charges. The buffer batteries were foreseen in order to allow for EV charging independently of the sunshine hours.
Such an off-grid solar charging station can indeed provide an environmentally clean charging service independently from the specific constraints of the island's electric system.
The VERT Consortium has designed the project in order to minimize both the CO_2 emissions and the financial impact on the island's generation costs (CSPE).
Five charging stations have been installed in the frame of the project and placed at different locations on the island: the 3 solar carports have been set up at the company sites of the participating partners and 2 additional charging stations have been placed at two TOTAL gas stations, along major connecting roads. The latter were standard grid-tied charging stations associated to solar PV generators installed on the gas station's roof structures. They were designed as relay charging stations for the EVs running low on their batteries and to give end users the possibility to use the EVs for larger distances.

Six EVs have been run by the participating companies (EDF, Sunzil, GBH): different employees could reserve and use the electric pool cars in the same way they were used to handle conventional vehicles. Driving distances could therefore vary, and were nor predefined or known up front.

The project put a particular emphasis on exploring the battery charging level at the moment when the EVs were reaching or leaving the solar carports. We have observed that in the vast majority of cases the users would start a ride with a battery sufficiently charged to cover the planned trip with no risk to run out of charge. As a matter of fact, in 80% of the cases the battery was fully charged when leaving the carport. Furthermore, the EVs returned to the charging station with a generally comfortable energy reserve (80% of the EVs returned with a battery state of charge >50%) which translates the tendency of the drivers to use the EVs primarily for short distances.

More than 80% of the trips between two charging stops were inferior to 50 km. The average distance of the trips was about 25 km. However, the time-correlated analysis has shown that distances up to 75 km appeared towards the end of the project. It is likely that the increasing understanding of the EVs consumption properties has led the drivers to be more confident to use their vehicles also on longer distances.

Results

The VERT project has shown evidence that off-grid solar carports associated to buffer batteries may allow for a charging service compatible with the mobility needs of companies. In our case the covered distances were rather short and therefore the energy needed to refuel the EVs was naturally limited.
From a technical point of view, the VERT project has

shown the feasibility of off-grid solar carports to charge company pool cars and provide them with the required mobility reserves.

Two different user behaviors have been observed: some users have charged their EVs rather in the morning, others rather in the afternoon. The morning charge corresponds to users who will take the vehicle home in the evening for commuting. The EV is connected to the carport in the morning upon arrival to work. On the contrary, the afternoon recharge translates a user profile with trips only throughout the working day. In both cases, the charging process coincides at least partially with the sunshine hours, which limits the need for energy storage in the stationary batteries.

The consumption of the electric vehicle depends directly on the driver profile and the specificity of the trip. Charging an EV via an off-grid solar charging station minimizes the impact of the vehicle on the island's electric system, thereby reducing the environmental impact in terms of CO_2 emissions. On the contrary, the project has allowed to simulate and to determine the CO_2 emissions which would have been generated if the EVs were charged directly on the island grid: the emissions would have been superior to those of a conventional diesel fuelled car.

The VIASOLE project – Corsica

A second project has been initiated in Corsica. An analysis tool has been developed in order to determine at any moment in time the potential impact of an EV's power demand on the island's electric system. A simplified signal (red/yellow/green light) is displayed to the end user and gives him the opportunity to coordinate the battery charge according to the system constraints. Both environmental and economic criteria can be taken into account to define the signals.

Key elements of the project

VIASOLE is an experimental project launched in 2013 by EDF Corsica involving one EV based at the EDF headquarters in the city of Ajaccio. The main office building is equipped with a 15 kWp PV solar generator and stationary batteries (NiCd, 28,8 kWh, 2nd life batteries). The electric vehicle is used by the mail service of the headquarters. In the given context, VIASOLE aims at optimising mobility needs that are characterised by:

- known distances and duration,
- invariable time schedules,
- at least 4h of parking during midday when the sun is at its highest (i.e., much more favourable conditions than an EV used all daylong for professional needs but less favourable than an EV used for home/work commuting).

The only unknown impact factors arise from varying traffic conditions (traffic jams) or auxiliary electric consumptions (air conditioning or heating depending on seasonal needs).

Image 2: Predefined route planning for daily trips

The vehicle used in the frame if the VIASOLE project is a Peugeot full electric car, iOn type. This car develops a 47kW power and contains a 16,3 kWh energy storage. According to manufacturer specifications, the autonomy of the vehicle is 130 km. Experimentally collected data shows that the maximum autonomy of the car under our actual conditions of use would be close to 80 km, i.e., a consumption around 200 Wh/km. At this stage, we observe an average consumption of 9 kWh for 40km.

Characteristics of VIASOLE	
Vehicle type	Peugeot iOn 2 seats full electric
Charging station	1 regular domestic socket (mode 2) et 1 type 3 socket (mode 3)
Charging Type	Slow charging
Site	EDF Ajaccio headquarters
Type of sourcing	Rooftop 15 kWp PV generator at EDF Ajaccio headquarters, grid-connected backup, stationary 28,8 kWh NiCd buffer storage

Results

The tested use cases can be divided into several parts :

- A reference scenario which is used as a basis for comparisons with optimizations,
- Two optimization scenarios enhancing the reference scenario.

The reference scenario corresponds to the energy consumption for the EV recharge assuming that the charge is started as soon as the EV is connected to the charging station. This classical charging mode has been observed in all major French EV experiments where the

natural user behavior is to recharge the vehicle at the end of the day upon arrival to its parking lot.

Two complementary optimization strategies have been studied:

The first one aims at maximizing the use of solar energy thanks to self-consumption. Instead of charging the EV batteries from the grid, they are charged with solar energy. Moreover, the knowledge of the routes planned for the next day enable the tool to determine if a charge is needed or not, depending on the state of charge. If yes, the EV's battery is charged with the solar production of the day stored in the stationary batteries. If there was no production during the day, the EV batteries are charged from the electric grid as long as there is no constraint on the network which will be indicated using a specific signal (flag). In this case, the charge is limited to the energy exactly needed to cover the needs of the next day.

The second strategy aims at optimizing the charging period to avoid all periods during which the electric power system is constrained. In this case, the charge is not allowed during consumption peak hours which occur on the Corsican grid mainly in the evening between 6 and 9pm. In all cases, if the customer has an urgent need for charging, the charging process may be forced.

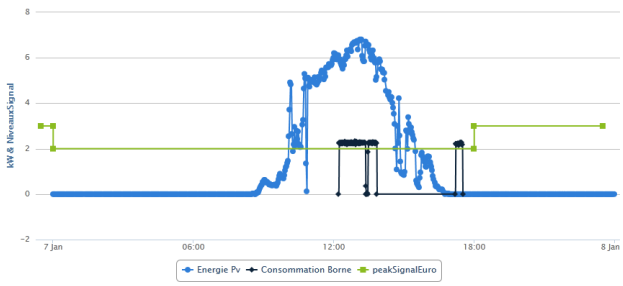

Figure 2: Charging sequence on January 7th, 2015. The solar coverage of the needs reaches 84 % thanks to the PV-based charge between 12:00 and 14:00. Only 30 minutes of supplementary charge from the power grid (17:00 – 17:30) were necessary to reach the full battery charge.

Results

VIASOLE has led to the development of an analysis tool which allows to raise various flags indicating to the end customer and EV user whenever it is preferable to charge the EV (level 1 – green flag), when a charge must not take place (level 3 – red flag) or during intermediary periods when a charge could take place but should rather be postponed, if compatible with the mobility need (level 2 – orange flag).

The flags are reflecting the analysis and vision of the operator of the island's electric system. The signal they represent may rely either on technical (network constraints), economical (CSPE impact) or environmental criteria (CO_2 emissions).

Mixed signals can also be generated, combining different criteria. For instance, it is possible to combine a technical signal with an environmental signal, a technical signal with a cost signal, a cost signal with an environmental signal, etc.

CONCLUSIONS

The two projects which have been described in this paper illustrate the economic and environmental impact of electric vehicles in the French islands.

The fuel mix of electricity generation on the islands and the resulting CO_2 emissions explain why electric vehicles in this specific context do not necessarily constitute an environmentally clean means of transport: the "plug-to-wheel" analysis is incomplete and neglects the specificities of the island's electric power generation systems.

Specific approaches are needed in order to minimize the EV's impact on the electric system: a complete "well-to-wheel" analysis is necessary and shows that specific charging stations based on renewable energy sources and stationary batteries or an optimized charge control from the grid possess a significant potential to reduce the CO_2 emissions.