Prospective study on the impact of electrical vehicles on the winter load peak in a village of East of France

Valérie Murin, Dominique Osso, M. Sarr, Hassan Bouia, C Bathany, J. Maire

21, rue d'Artois, F-75008 PARIS
http: //www.cigre.org

C6_204_2010

CIGRE 2010

Prospective study on the impact of electrical vehicles on the winter load peak in a village of East of France

V. MURIN D. OSSO M. SARR H.BOUIA C.BATHANY J. MAIRE

EDF-R&D
France

SUMMARY

Environmental concern and climate change, safety supply and control demand are the some of the main issues of this century. The challenge is important and development of renewable energies and dispersed generation are an answer.
Another issue is the transport and especially the transport of people because it represents 15% of the carbon dioxide emissions and also 15% of the energy consumption in France. And, with a context of the rapid rise of the value of oil and its scarcity in the future, electrical vehicles could be a solution: they are silent, non pollutant and energy sparing. Their development is ready and their commercialisation starts. But what will be their impact on the grids?
The first question to answer is: <u>what the impact of the electrical vehicles on the electricity demand?</u>
A first estimate shows that the transfer from thermal to electrical car fleet should not create tension on the supply-demand balance in electricity in a short to medium term.
For example, in France, if 15% of the car fleet change from thermal to electric, the annual demand in electricity wouldn't exceed 3%. But, thanks to the French energy mix the improve for the carbon dioxide balance compared to thermal vehicles would reach 90%.
<u>Is there any impact on the grids?</u>
At first sight, , the use of electrical cars wouldn't have any effect on the transmission grid for the next years because of the previous estimate..
But the situation on the distribution network could be different, especially if significant penetration levels are reached locally.

Originally, distribution networks have not been designed neither for dispersed generation nor for a drastic increase of the demand in electricity. The question to answer is what will be the

consequences for distribution electrical equipments of the change in residential way of electric use.
In a first approach, three uses seems to be able to have an effect on the load peaks: air conditioning, heat pumps and electrical cars.
This article will focus on the impact of electrical vehicles or plug-in hybrid vehicles on the distribution network at the local scale, with a 2020 temporal perspective.
For this purpose, a residential area has been chosen, in the countryside, where there is no possibility of easy and frequent public transport. Moreover, this residential area has been chosen not to far from several urban areas (less than 30 km). This large village is located in the East of France and it is representative of several other villages in France.
Thanks to public available data – like INSEE Statistics (French national statistic institute), residential knowledge, technology knowledge, technical data (equipment efficiency for example) and weather data from Météo France, a model of household called EPURE has been developed by EDF R&D.
this model is able to provide a dynamic calculation of load curve per end-uses at a national, regional or district level at hourly step and also an assessment of a demand side management or energy saving policy on the load curve and energy consumption. Its results can be:

- Hourly Load Curve by end uses
- Aggregated load curve
- Wattage.

With EPURE, the effects of electrical vehicle have been simulated with several penetration levels with charging periods on the network placed at different times of the day and with complete or fast recharging.
The study also addressing the impact of heat pumps' penetration in the same village on the winter consumption peak.

KEYWORDS

Load peak, electric vehicle, hybrid plug-in vehicle

INTRODUCTION

Keeping in mind, the main targets of European energy policies such as the security of energy supply and greenhouse gas mitigation, technologies using less fossil energy like electric vehicles (EV), Plug-in Hybrid vehicles (PHEV) and heat pumps (HP) are needed. However, the future impact of such technologies on the electric supply side should be studied from a generation, transport and distribution point of view.

The large expected development of electric vehicle in the long term (i.e. 2030) will impact the electric system both at national (production and transmission) and local (distribution) levels. Moreover, the growth of other electric end-uses like HP and appliances will continue modifying greatly the overall load curve of the system.
The main question remains: what will be the effect of the EVs (i.e. EV+PHEV) on the local load profile, especially the peak load ?

Studies on the impact of an EV and PHEV fleet both on supply and environmental sides are already available for some countries [1,2,3,4,5]. Some studies present the local consequences on the Distribution System Operator (DSO) grid [6] and show a large increase of the afternoon load peak on a typical household load curve [7] and the potential modification of the load profile of a city [8]. The possibility to valley-filling with the recharging load of PHEV to avoid new peak is also reported [9] as well as the potentiality of dispatchable PHEV [10]. Moreover, the EVs could also be used as a distributed energy resource [11,12,13,14].

This study is focused on residential load profile, including electric transportation at a local level for a rural village located in the east of France. We emphasis the load curve analysis on the winter peak load (i.e. the coldest day of the year with the maximal electric demand) as also studied elsewhere [10]. The study is completed by the Medium Voltage network analysis facing the simulated winter load peak.
The effect of a fleet of EV and PHEV is presented with different recharging scenarios, on the long-term residential winter load peak and the impact on the DSO infrastructure (feeder, transformer) including previous evolution of the building stock (new construction and retrofitting) and new end-uses (especially heat pump).

METHODOLOGY

Residential load profile simulation

The general approach relies on a bottom-up methodology, with different segments of identical dwellings based on various parameters: vintage, individual vs. collective, energy and technology for space heating, number of appliances…
For this purpose we used a dedicated software, called EPURE[1] and developed at EDF-R&D. This software is based on a calculation core working with similar box modelling [15] for the heating space load and on average load curve for the other end-uses. EPURE software requires a residential household model in which each dwelling segment is characterised by 25 parameters describing:

- type of dwelling (weighting coefficient, level in the building).

[1] EPURE means “Assessment of Rational Use of Energy policy”.

- building envelope (thermal losses, floor area, windows area…).
- occupancy (number of person in the household).
- equipment (heating system, appliances…).
- weather (climate zone (location)).
- Individual housing on platform or crawlspace.
- Collective housing: ground, middle and upper floors.
  seasonal variation of heat pump's COP (coefficient of performance) simulated with a linear equation depending on external temperature.

The results are the dynamic calculation of load curve (8760 hourly loads) per end-uses at a national, regional or district level and provide assessment of a demand side management or energy saving policy on the load curve and energy consumption.

The electric space heating load curve is calculated using a thermal software. For the other end-uses, the simulation is based on average load curve provided by internal field test representing the consumption behaviour of the stock of end-uses.
Such approach of individual end-use load curve aggregation is slighter different from other long term studied based on aggregated load curve by type of customers [16] or based on top-down model with linear regression model or related one [17,18].

Electric vehicle load profile and scenarios

Both plug-in hybrid and pure electric vehicle, recharging patterns are considered as constant power with different time durations and intensities like other study [1,19] without other consideration of driving range assuming complete recharging when needed. The simulated recharging patterns are presented in Table 1.

In order to simulate the customer behaviour's diversity, the starting time of the recharging pattern were roughly shifted for:

- 50% at t time,
- 25% at t+1 h,
- 25% at t-1 h.

The recharging patterns are based on assumption coming from a national enquiry on transportation [20]. The number of EVs are forecasted in accordance with previous scenarios ("voluntarist scenario")[21] corresponding to a penetration of 24% of PHEV and 3.5% of EV in the household vehicle fleet in 2030.
Such level of penetration sounds reasonable compared to other studies showing potential penetration of PHEV from 40% to 75% in 2030 [3,22]. It also must be noticed that a French scenario for 2030 had proposed a 15% penetration of alternative vehicles [23].

Table 1: simulated recharging patterns for EV and PHEV.

Vehicle allocation	EV				PHEV			
	Normal load 3 kW		Reduced load 1.5 kW		Normal load 3 kW		Reduced load 0.5 kW	
	Start (t)	end	Start (t)	end	Start (t)	end	Start (t)	end
Scenario S1 "classical load"								
100%	19h00	23h00	-	-	19h00	21h00	-	-
Scenario S2 "soft load"								
50%	-	-	19h00	03h00	-	-	19h00	07h00
50%	-	-	12h00	20h00	-	-	08h00	20h00

Scenario S3 “mixed load”								
50%	19h00	23h00	-	-	-	-	19h00	07h00
50%	12h00	16h00	-	-	-	-	08h00	20h00

Building assumptions

The data source for the building stock is the 1999 national census from INSEE which provide a brief description of the 30 millions of French dwellings. Unfortunately, if the national census gives an exhaustive description of the 1999 building stock, there is no information about equipment inside the dwellings. Some hypothesis, based on other studies are needed to complete the whole description of the building stock.

The chosen village is located in the south of Alsace near large urban areas from 20 to 40 km without connection to any gas network. The weather chronicle used in this study is from Météo France and no climatic change has been considered from 1999 to 2030. However, in 2050 for the Alsace region, the estimated rise of temperature in January could be between +2.1 and +4.5°C [24].

A large refurbishment of the building stock has been simulated as previously decided in the French Law for the coming years [25]. This was translated as a reduction of heat losses by 30% from 1999 to 2020 and by extra 20% reduction from 2020 to 2030.

Table 2: description of the rural city located in Alsace and long-term scenario assumptions.

	1999	variation	2030
dwellings			
Households	621	2.18%/y	1210
Persons / household	2.4	-0.28%/y	2.2
Refurbishment of existing dwellings	-	Thermal losses (W/K)	-44%
appliances			
Appliances consumption Individual housing	730 kWh	+2%/y	1358 kWh
Appliances consumption collective housing	530 kWh	+2%/y	995 kWh
Lighting consumption (per dwelling)	394 kWh	-0.56%/y	331 kWh
And other appliances (per dwelling)	2585 kWh	+0.24%/y	2788 kWh
Space heating systems			
New buildings	Individual: 72%	Space heating system	80% heat pump 20% other
	Collective: 28%	Space heating system	76% direct heating 24% other
Heat pump	0%		52%
Direct electric heating	20.6%		18.2%
Wood boiler	20.6%		20.9%
Gas, fuel, LPG coal boilers	58.8%		8.9%
Electric & plug-in hybrid vehicles			
Plug-in Hybrid Vehicles	0%		24%
Electric vehicles	0%		3%

Distribution system analysis

The impact of the residential long-term loads on the distribution grid is done with a proprietary software (developed also at EDF R&D) called PRAO (Medium Voltage Electrical Network Computerized Planning) based on circuit modelling [26]. PRAO is a tool used for realizing the planning studies of MV electrical networks and allows to assess the load on the MV side. LV data are not detailed by Low Voltage (LV) feeder and by customer but aggregated at the MV/LV distribution substation. With PRAO, a planner is able to study electrical grid and conceive load evolutions as well as testing grid reliability and validating reinforcement solution. From the MV grid description (loads, topology…), PRAO is able to:

- give the grid statement for a dedicated year (voltage drops, losses, load flow),
- optimize the network,
- assess the grid quality (strength network, failure cost),
- make technical & economic calculations such as Energy Not-Served (ENS) and cost-benefit ratio.

RESULTS

Residential Load profile

In order to separate the impact of growth population and heat pumps from the impact of EVs in general, we have first studied simplified scenarios which are presented below. For all the scenarios, it has to be noticed that the other hypothesis stay the same (see Table 2).

Impact of the population growth

Forecast of population growth is based on observed data between the last two national census (i.e. 1999 and 2004)[27,28]. So, the average annual growth rate from 1999 to 2020 is of 2.26% per year with a slight decrease of 2.0% per year between 2020 and 2030.

Tableau 3: hypothesis for population forecast of the village.

	1999	variation	2030
population	1,511	2.29%/y	3,050
Households	621	2.18%/y	1210
Persons / household	2.43	0.13%/y	2.52

The evolution of the population shows that the evening peak load for the winter coldest day (3rd week of January) increases from 1,000 kW to 1,650 kW between 1999 and 2030 (Figure 1). This represents an increase of respectively 31% and 72% for the years 2020 and 2030. This is mainly due to new buildings (2 times increase).

In this case, the forecasted load curve could be represented as a merely translation of the 1999 situation based on the increase of building stock.

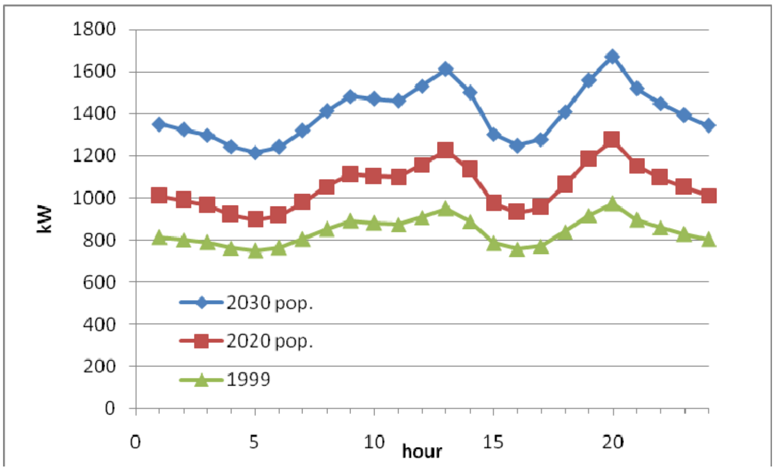

Figure 1: calculated load curves of the highest day load (January) for the years 1999, 2020 and 2030 showing the impact of solely population growth.

Impact of heat pumps

The second scenario presents the evolutions of the building stock (refurbishment and space heating system switch) including the hypothesis of the first scenario as previously described.
For the new buildings, the part of individual houses represents 72% mainly equipped with heat pumps (80%) and 20% with wood boilers. For the collective housing, the principal space heating system still remains direct electric heating (76%), the others are equipped with collective wood boilers.
The existing building stock is refurbished in accordance with the target of the French energy policy. In this study, we applied a global reduction of energy need for space heating by 44% which are compatible with extensive insulation (roof, walls, windows and floor).
Moreover, the space heating system are switching from fossil energies to wood boilers and heat pumps (see table 4). Consequently, the sanitary hot water is now largely produced by electricity (electric heating storage tank).

The consequences of this scenario show a large modification of the daily load curve:

- a global increase of the power from 1,500 kW to 2,100 kW between the simple evolution of the population (scenario 1) and the heat pump dissemination (scenario 2),
- a new load peak (see “a” on Figure 2) during the night due to the electrical sanitary hot water tank (ESHW) driven by the powerline communication (PLC[2]) signal from the DSO,
- an increase of the lunch time peak (see “c” on Figure 2) partly due to the electric sanitary hot water monitored with a specific tariff “low cost hours”,
- a secondary new load peak (see “b” on Figure 2) due to the wake-up activities of households,
- finally, the peak “d” which is at the moment the most important load peak of the day became 7% lower than the night load peak “a”.

[2] Called TCFM signal for centralized remote by musical frequency. Signal at 175 Hz used in France since 1958.

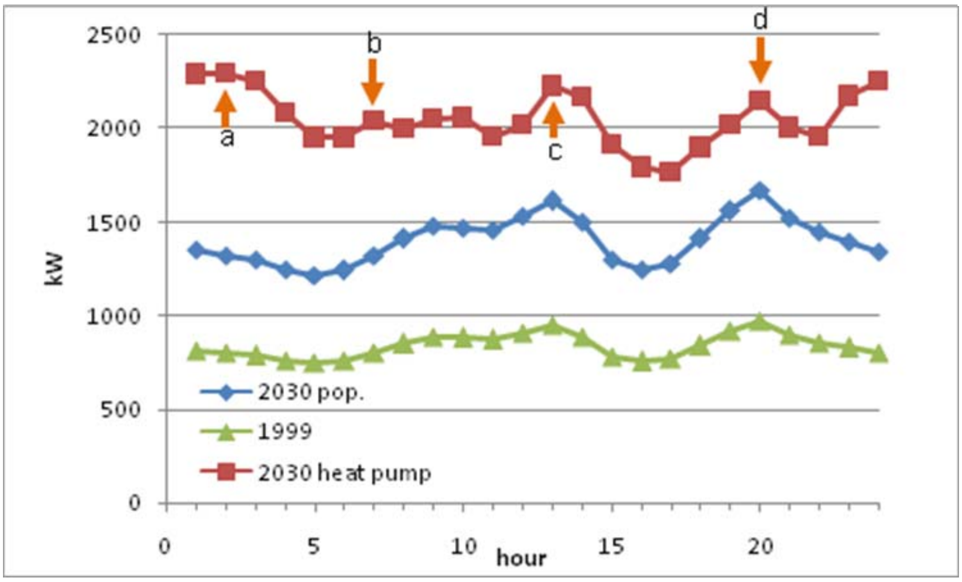

Figure 2: calculated load curves of the highest day load (January) for the years 1999 and 2030 on the basis of population growth (2030 pop) and spreading of heat pumps in the building stock (2030 heat pump).

Impact of EVs

Different recharging scenarios for EVs (see Table 1) were studied with huge different impacts on the load curve. For the scenario S1 called "classical load" (i.e. recharging EVs at 19h), the evening peak (20h) increase considerably from 2,144 kWh to 2,964 kWh (+38%). Without any adaptation, this is likely to be unbearable from an utility point of view insomuch that the load peak had already been largely increased due to population growth and heat pump stock (see below for the impact on the DSO grid). To explore alternative ways, or no so drastic recharging patterns, we simulate the scenarios S2 and S3 with soft load schedule (Table 1).

For the S2 scenario, the evening peak (20h) slightly increased (+4%) but the lunch peak (14h) increased more (+12%). In this case, the two peak growth are lower than the increase of the S1 scenario.

For the S3 scenario, the highest peak rise occurs at 20h but with a low value (+8%). Globally, the load curve increase at any time around an average value of +3% to +6%.

It is clear that the assumptions chosen for the recharging patterns, are of dramatic importance on the resulting load curve. The sums of the increase is respectively 145%, 159% and 113% for the S1, S2 and S3 scenarios. The S3 scenario appears to be the most valuable to reduce the load rise as it allows the scattering of the EVs recharge all day long.

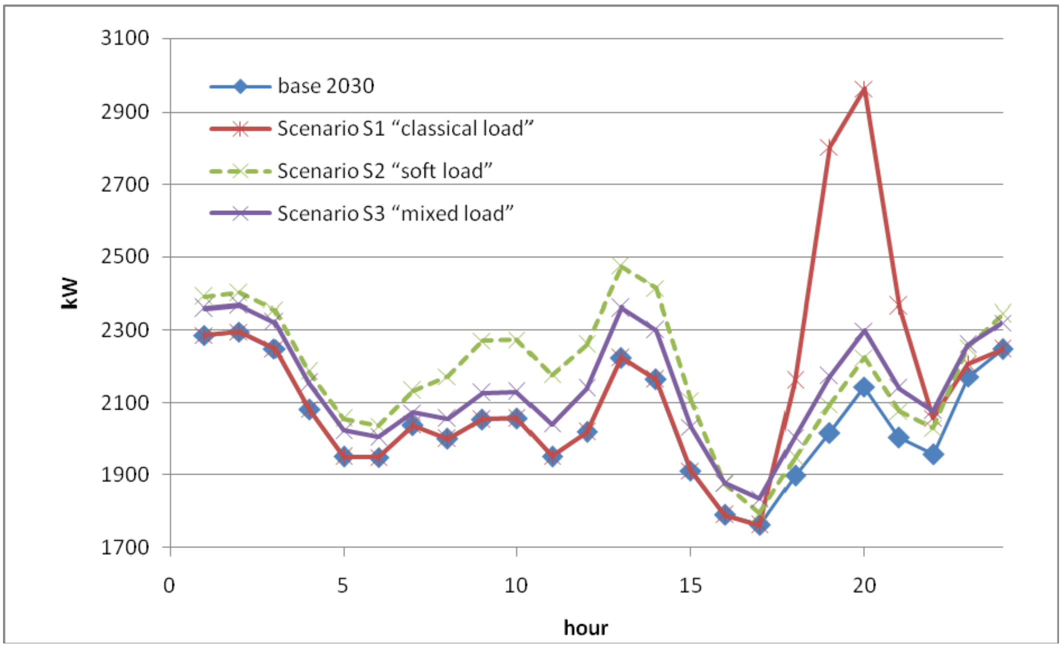

Figure 3: calculated load curves of the highest day load (January) for the year 2030 on the basis of various recharging EVs patterns. 2030 base: population growth and spreading of heat pump in the building stock and no EVs. Scenario S1, S2, S3: "2030 base" scenario assumptions with different EVs recharging patterns.

To compare with other study, we could referred to a RTE (french TSO) work done at a national level [29]. For an EVs stock of 2 millions in 2020, the evening peak increase is around 2000 MW for total load of 90,000 MW corresponding to a 2% rise. In our case, the relative peak increase is higher due to the local and only residential level of the analysis. However, the ratio of kW/EV is of the same order, respectively 1.8 and 1 kW/EV for this study and RTE one. This lead us to conclude that the impact at a local level (DSO) could be more important than at the national one (TSO).
Moreover, the evolutions of the future load curve simulated here are in accordance with the RTE studies showing, for year 2020, an increase of the night load and a decreased of the day peaks (morning and evening).

Impact of the EVs diversity

Even if the diversity of EVs recharge is roughly simulated in this study leading to overestimate the evening peak increase, we must admit that the load rise could occurred even though the assessed level should be argued. For that purpose, we have calculated the 20h load peak rise for various maximum level of recharging EVs from 50% to 20% with the same other assumptions than S1 scenario (Figure 4)(remaining EVs are recharged before or after 20h – from 17h to 24h see Figure 4). The effect on the evening peak could be roughly extrapolate by a linear equation:

$$y=0.605*x+0.086 \qquad R^2=0.992$$

with: x:proportion of EVs fleet recharging at 20h.
y: 20h peak increase (in % of the load peak without EVs).

showing that even with 5% of EVs recharging at 19h, the peak increase by 15%. Again, the importance of the load management is demonstrated to avoid a large amount of EVs recharging at the same time (i.e. in the evening after returning from job or other day activities).

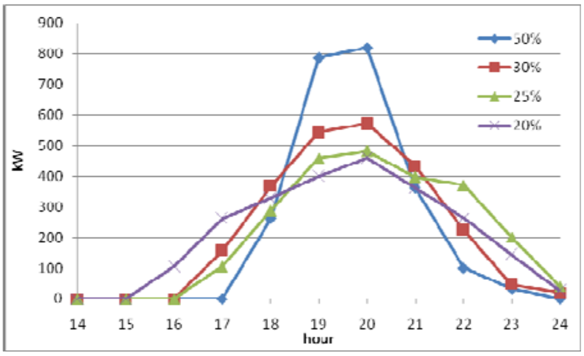

Figure 4: additional load (between 14h and 24h) due to EVs as a function of different schedule. Maximum proportion of EVs recharging at 20h: 20%, 25%, 30%, 50%; resulting 20h load peak rise is respectively: +21%, +23%, +27%, and +39%.

Distribution System

The impact of the three scenarios on the distribution grid was studied for the years 2009 to 2030 on the basis of a linear evolution. We know that such hypothesis is simplifying as the spreading of the EVs will certainly follow a logistic curve [3]. However, as we are more interested by the 2030 results such simplification doesn't change the figures but only bring forward the potential distribution grid problems.
The PRAO studies had been made following three scenarios (heat pump, S1 and S3) at different hours (1h, 8h, 13h, 17h, 20h, 24h). Here only the results at 20h, corresponding to the evening peak load, will be presented.

The village studied in this paper is served by 2 HV/MV substations which are also feeding others cities in the same grid. So, the same assumptions were applied to all these cities to extrapolate the impacts on the two substations. The village is deserved at the LV level by 15 power transformers (MV/LV substations).

Impact of heat pumps

Following the assumption of the "2030 heat pumps" scenario, the operation of the distribution grid was simulated showing an increased of the load and a drop in voltage around 10% Such a drop in level could be considered as worrying, if we considered that the acceptable limit is around 7% to 8% even if it is difficult to conclude. In-depth study should be conducted because the acceptable limit is depending on the nature of the LV network which is unknown.
We must noticed that the core losses (or iron losses) stay the same for each scenario with a value of 91 kW.

Tableau 4: impact of the load evolutions (2030) for the two HV/MV substations following the "2030 heat pump" scenario (i.e. no EVs) for the highest load day (January) at 20h.

	2009	2015	2020	2025	2030
Load (MVA)	11.354	12.943	14.500	16.304	18.394

Overload (kVA)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Copper losses (kW)	**367.50**	**474.00**	**592.70**	**738.90**	**938.50**
Drop in voltage (%)	**5.84**	**6.62**	**7.58**	**8.54**	**9.55**

Concerning solely the studied village, the results shows that, even without EVs, some transformers are overloaded (7 for 2030 and 2 for 2020) because the load is over the admissible level (>110%). About the drop in voltage, no problem is observed as the drop in stay below 8% (see table below).

Tableau 5: impact of the load evolutions (2030) for the 15 transformers following the "2030 heat pump" scenario (i.e. no EVs) for the winter peak (January) at 20h.

		2009	**2015**	**2020**	**2025**	**2030**
P0001	**Load (%)**	*75.72*	*90.36*	*104.70*	*121.31*	*140.57*
	Drop in voltage (%)	5.61	6.15	6.68	7.29	8.00
P0002	**Load (%)**	*18.07*	*21.57*	*24.99*	*28.96*	*33.56*
	Drop in voltage (%)	5.53	6.06	6.57	7.17	7.86
P0003	**Load (%)**	*66.46*	*79.31*	*91.90*	*106.48*	*123.38*
	Drop in voltage (%)	5.76	5.94	6.11	6.30	6.53
P0004	**Load (%)**	*32.04*	*38.24*	*44.31*	*51.34*	*59.49*
	Drop in voltage (%)	5.56	6.09	6.60	7.21	7.90
P0005	**Load (%)**	*42.45*	*50.65*	*58.69*	*68.01*	*78.80*
	Drop in voltage (%)	5.78	5.96	6.13	6.33	6.56
P0006	**Load (%)**	*12.32*	*14.71*	*17.04*	*19.75*	*22.88*
	Drop in voltage (%)	5.42	5.92	6.42	6.99	7.65
P0007	**Load (%)**	*81.10*	*96.78*	*112.14*	*129.94*	*150.57*
	Drop in voltage (%)	5.83	6.02	6.20	6.41	6.65
P0008	**Load (%)**	*78.10*	*93.20*	*107.99*	*125.13*	*144.99*
	Drop in voltage(%)	5.84	6.04	6.22	6.43	6.67
P0009	**Load (%)**	*29.58*	*35.30*	*40.90*	*47.39*	*54.91*
	Drop in voltage(%)	4.86	5.25	5.64	6.09	6.61
P0010	**Load (%)**	*57.61*	*68.74*	*79.65*	*92.30*	*106.94*
	Drop in voltage (%)	5.60	5.77	5.92	6.10	6.31
P0011	**Load (%)**	*75.58*	*90.20*	*104.52*	*121.10*	*140.32*
	Drop in voltage (%)	5.57	6.11	6.63	7.24	7.94
P0012	**Load (%)**	*92.02*	*109.81*	*127.24*	*147.43*	*170.83*
	Drop in voltage (%)	4.71	5.08	5.44	5.86	6.34
P0013	**Load (%)**	*69.90*	*83.41*	*96.65*	*111.99*	*129.77*
	Drop in voltage (%)	5.63	6.18	6.71	7.33	8.05
P0014	**Load (%)**	*65.97*	*78.73*	*91.22*	*105.70*	*122.48*
	Drop in voltage (%)	5.64	6.18	6.72	7.34	8.06
P0015	**Load (%)**	*19.71*	*23.52*	*27.25*	*31.57*	*36.59*
	Drop in voltage (%)	5.78	5.97	6.13	6.33	6.55

Impact of EVs

For the S1 scenario "classical load", the distribution grid is overloaded in 2030 (126 kVA) and the drop in voltage exceed 8%.

Tableau 6: impact of the load evolutions (2030) for the two HV/MV substations following the "2030 S1" scenario (classical EVs charge) for the winter peak (January) at 20h.

	2009	2015	2020	2025	2030
Load (MVA)	11.354	13.577	15.882	18.697	22.132
Overload (kVA)	0	0	0	0	126.1
Copper losses (kW)	367.5	520.6	701.6	969.4	1357.5
Drop in voltage (%)	5.84	7.01	8.33	9.69	11.35

For the transformers of the studied village, 9 are not sufficiently sized in 2030. Moreover, from 2015 a transformer has to be upgraded and 6 in 2020 but this latest point had to be taken cautiously.

Tableau 7: impact of the load evolutions (2030) for the 15 transformers following the "2030 S1" scenario (classical EVs charge) for the winter peak (January) at 20h.

		2009	2015	2020	2025	2030
P0001	**Load (%)**	*75.72*	96.19	117.43	143.35	175.00
	Drop in voltage (%)	5.61	6.36	7.15	8.11	9.27
P0002	**Load (%)**	18.07	22.96	28.03	34.22	41.77
	Drop in voltage (%)	5.53	6.27	7.03	7.96	9.10
P0003	**Load (%)**	66.46	84.43	103.07	125.82	153.60
	Drop in voltage (%)	5.76	6.00	6.25	6.55	6.92
P0004	**Load (%)**	32.04	40.71	49.69	60.66	74.05
	Drop in voltage (%)	5.56	6.30	7.07	8.00	9.15
P0005	**Load (%)**	42.45	53.92	65.83	80.36	98.10
	Drop in voltage (%)	5.78	6.02	6.27	6.58	6.96
P0006	**Load (%)**	12.32	15.66	19.11	23.33	28.48
	Drop in voltage (%)	5.42	6.13	6.86	7.75	8.84
P0007	**Load (%)**	81.10	103.04	125.78	153.55	187.44
	Drop in voltage (%)	5.83	6.09	6.35	6.67	7.07
P0008	**Load (%)**	78.10	99.22	121.12	147.86	180.51
	Drop in voltage (%)	5.84	6.10	6.37	6.70	7.10
P0009	**Load (%)**	29.58	37.58	45.87	56.00	68.36
	Drop in voltage (%)	4.86	5.41	5.98	6.68	7.53
P0010	**Load (%)**	57.61	73.18	89.34	109.06	133.14
	Drop in voltage (%)	5.60	5.82	6.05	6.33	6.68
P0011	**Load (%)**	75.58	96.03	117.22	143.10	174.69
	Drop in voltage (%)	5.57	6.32	7.10	8.04	9.19
P0012	**Load (%)**	92.02	116.90	142.71	174.21	212.67
	Drop in voltage (%)	4.71	5.23	5.76	6.41	7.21
P0013	**Load (%)**	69.90	88.80	108.41	132.34	161.55
	Drop in voltage (%)	5.63	6.40	7.19	8.15	9.33
P0014	**Load (%)**	65.97	83.81	102.32	124.90	152.48
	Drop in voltage (%)	5.64	6.40	7.20	8.16	9.34
P0015	**Load (%)**	19.71	25.04	30.56	37.31	45.55
	Drop in voltage (%)	5.78	6.02	6.27	6.57	6.94

The modification of the recharge patterns (soft load – S3 scenario) help to reduce the impact on the distribution system as no overload is observed. The drop in voltage is limited but still exceeding 8% and the load is reduced from 22 MVA to 19 MVA respectively for the S1 and S3 scenario.

Tableau 8: impact of the load evolutions (2030) for the two HV/MV substations following the "2030 S3" scenario (soft EVs charge) for the winter peak (January) at 20h.

	2009	2015	2020	2025	2030
Load (MVA)	11.354	13.052	14.733	16.699	18.997
Overload (kVA)	0	0	0	0	0
Copper losses (kW)	367.5	481.9	611.7	774.6	1000.6
Drop in voltage (%)	5.84	6.69	7.72	8.73	9.84

Concerning the 15 transformers, in 2030 like the S1 scenario results, 9 transformers had to be upgraded.

Tableau 9: impact of the load evolutions (2030) for the 15 transformers following the "2030 S1" scenario (classical EVs charge) for the winter peak (January) at 20h.

		2009	2015	2020	2025	2030
P0001	**Load (%)**	*75.72*	91.36	106.84	124.95	146.12
	Drop in voltage (%)	5.61	6.19	6.76	7.43	8.21
P0002	**Load (%)**	18.07	21.81	25.50	29.83	34.88
	Drop in voltage (%)	5.53	6.09	6.65	7.30	8.06
P0003	**Load (%)**	66.46	80.19	93.78	109.67	128.25
	Drop in voltage (%)	5.76	5.94	6.12	6.33	6.58
P0004	**Load (%)**	32.04	38.66	45.21	52.87	61.83
	Drop in voltage (%)	5.56	6.12	6.68	7.34	8.10
P0005	**Load (%)**	42.45	51.22	59.89	70.04	81.91
	Drop in voltage (%)	5.78	5.96	6.15	6.36	6.62
P0006	**Load (%)**	12.32	14.87	17.39	20.34	23.78
	Drop in voltage (%)	5.42	5.96	6.49	7.12	7.84
P0007	**Load (%)**	81.10	97.86	114.44	133.83	156.51
	Drop in voltage (%)	5.83	6.02	6.22	6.44	6.71
P0008	**Load (%)**	78.10	94.24	110.21	128.88	150.72
	Drop in voltage (%)	5.84	6.04	6.23	6.46	6.73
P0009	**Load (%)**	29.58	35.69	41.74	48.81	57.08
	Drop in voltage (%)	4.86	5.28	5.70	6.18	6.76
P0010	**Load (%)**	57.61	69.51	81.29	95.06	111.17
	Drop in voltage (%)	5.60	5.77	5.94	6.13	6.36
P0011	**Load (%)**	75.58	91.20	106.66	124.73	145.86
	Drop in voltage (%)	5.57	6.14	6.71	7.37	8.14
P0012	**Load (%)**	92.02	111.03	129.84	151.84	177.57
	Drop in voltage (%)	4.71	5.11	5.49	5.95	6.48
P0013	**Load (%)**	69.90	84.34	98.63	115.35	134.89
	Drop in voltage (%)	5.63	6.22	6.79	7.47	8.26
P0014	**Load (%)**	65.97	79.60	93.09	108.87	127.31
	Drop in voltage (%)	5.64	6.22	6.80	7.48	8.27
P0015	**Load (%)**	19.71	23.78	27.81	32.52	38.03
	Drop in voltage (%)	5.78	5.97	6.15	6.36	6.60

CONCLUSION

This paper presents the forecasted impacts of a large spreading of EVs on the distribution systems in 2030 with concomitant evolutions of the building stock (new buildings, refurbishment and heat pumps). We must noticed that the assumptions chosen here could be considered as a worst realistic scenario but were selected to assess a maximal rise of the load curve.

As expected, the EVs recharging load, without no power management, is piled up on the increased load curve of household end-uses leading to a large rise of the winter evening load peak. The distribution grid at the HV/MV level (sub-stations) became overloaded and the drop in voltage exceed 10%. For the MV/LV level (transformers) 60% have to be upgraded. A management of the recharge of EVs, called soft load, could reduce the overload and the drop in voltage. Unfortunately, although the transformer loads are reduced, the transformers still have to be replaced.

The simulated load curves argue for a load management of the EVs recharge at the risk of trouble in the DSO even if such approach is not solving all problems. Obviously, even if the results presented in this paper are preliminaries and needs further and more precise investigations, the signal is clear.

BIBLIOGRAPHY

1 Jay K. Lindly et al., Impact of electric vehicles on electric power generation and global environmental change, Advances in Environmental Research 6 (2002) 29-302

2 K. Nansai, Effects of electric vehicles (EV) on environmental loads with consideration of regional differences of electric power generation and charging characteristic of EV users in Japan, Applied Energy 71 (2002) 111–125

3 W. J. Smith, Plug-in hybrid electric vehicles—A low-carbon solution for Ireland?, Energy Policy 38 (2010) 1485–1499

4 K.Funk, A. Rabl, Electric versus conventional vehicles: social costs and benefits in France, Transportation Research Part D 4 (1999) 397-411

5 S.J.Skerlos, J.J.Winebrake, Targeting plug-in hybrid electric vehicle policies toincrease social benefits, Energy Policy 38 (2010) 705–708

6 R.Webster, Can the electricity distribution network cope with an influx of electric vehicles?, Journal of Power Sources, 80 (1999) 217–225

7 F. Albuyeh, Grid of the future – Are we ready to transition to a smart grid, IEEE Power & Energy Magazine march-april 2009, 52-62

8 T.Doöscher et al., Evaluation of technical Intergration of electric mobility into the grid, EVSA24 International Battery, Hybrid and fuel Cell Electric Vehicle Symposium, Stavanger Norway, may 13-16 2009, 10p

9 M. Kintner-Meyer et al., Impact assessment of plug-in hybrid vehicles on the electric utilities and regional U.S. power grids. Part 1: technical analysis

10 K.Clement et al., Analysis of the impact of plug-in hybrid electric vehicles on the residential distribution grids by using quadratic and dynamic programming, EVSA24 International Battery, Hybrid and fuel Cell Electric Vehicle Symposium, Stavanger Norway, may 13-16 2009, 10p

11 C.Guille et al. A conceptual framework for the vehicle-to-grid (V2G) implementation, Energy Policy 37 (2009) 4379-4390

12 B.K.Sovacool , R.F.Hirsh, Beyond batteries:An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition, Energy Policy 37 (2009) 1095–1103

13 P.H.Andersen, J.A.Mathews, M.Rask, Integrating private transport into renewable energy policy:The strategy of creating intelligent recharging grids for electric vehicles, Energy Policy 37 (2009) 2481–2486

14 W.Kempton, J.Tomi, Vehicle-to-grid power implementation: From stabilizing thegrid to supporting large-scale renewable energy, Journal of Power Sources 144 (2005) 280–294

15 F. Deque, F. Ollivier, A. Poblador, Grey boxes used to represent buildings with a minimum number of geometric and thermal parameters, Energy and Buildings 31 (2000) 29–35

16 A.Hainoun, Construction of the hourly load curves and detecting the annual peak load of future syrian electric power demand using bottom-up approach, Electrical Power and Energy Systems 31 (2009) 1-12

17 J. Thatcher, Modelling change to electricity demand load duration curves as a consequence of predicted climate change for Australia, Energy 32 (2007) 1647-1659

18 M.Manera et al., Modelling the load curve of aggregate electricty consumption using principal components, Environmental Modelling & Software 20 (2005) 1389-1400

19 A.Maitra et al., Evaluation of PEV loading characteristics on hydro-Quebec's distribution system operations, EVSA24 International Battery, Hybrid and fuel Cell Electric Vehicle Symposium, Stavanger Norway, may 13-16 2009, 11p
20 INSEE ,SoES, INREST, transports et déplacements 2007-2008.
21 Centre d'Analyse Stratégique, Perspectives énergétiques pour la France à l'horizon 2020-2050, Rapport de la commission Énergie présidée par Jean Syrota, n°12 -2008, volume 1, 327p
22 M.A. Kromer, A.Bandivadekar, C.Evans; Long-term greenhouse gas emission and petroleum reduction goals: Evolutionary pathways for the light-duty vehicle sector, Energy 35 (2010) 387–397
23 Carburants alternatifs, les cahiers du CLIP, n°14, Octobre 2001, 35-46
24 Météo France, Simulateur climatique, http://climat.meteofrance.com/chgt_climat/simulateur/simclim
25 French National Assembly (2008), Law's project related to the implementation of the environment round table [Projet de loi de programme relatif à la mise en œuvre du Grenelle de l'environnement], 13 octobre 2008, 11p
26 P.Veyret, Découpage fonctionnel de l'outil PRAO et autres outils d'études HTA et BT, EDF-R&D, HR-49/05/008/A, 34p
27 INSEE, Détail...Logements – France métropolitaine, (2001) CD-ROM
28 INSEE, 2004 Annual census [*Enquête annuelle de recensement 2004*], june 2007
29 RTE, Groupe de travail « Gestion de la pointe électrique ». Atelier n°1: Caractérisation précise de la pointe, 16 novembre 2009